Essays on Macroeconomic Policies in Developing Countries

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Contents

Introduction

"You could not step twice into the same river."

— Heraclitus (535 BC – 475 BC)

The river of time flows fast. The world has experienced dramatic economic changes over the past decades. While the largest developing country, China, presented an unprecedented economic miracle, some other countries bogged down in the mire of development with low growth rate and large volatility.

Trying to understand the stories in developing countries requires great effort. The huge inter-country heterogeneity makes it difficult to distinguish the net effect of a macroeconomic policy from the influence of other factors like political institution, culture, and natural environment. Moreover, since the data for developing countries is often incomplete or with a low quality, it is hard to test the macroeconomic theory or summarize the regularity from the observed phenomena. In consequence, though it is frequently found that a helpful policy in developed countries may work unsatisfactorily or cause unexpected negative byproducts in developing economies, it is extremely controversial about the underlying reason. This thesis consists of three explorations on macroeconomic policies in developing countries. The first essay evaluates the desirability of public capital investment, taking China as the study subject. The second paper investigates the impact of international financial liberalization on the public debt across a set of developing countries. The third research attempts to understand whether domestic financial development affects the aggregate output volatility. In order to provide a glance over my findings, the main contents of these three papers are summarized as below.

The first paper works on the debate about the existence of infrastructure overinvestment in China. In order to evaluate the optimal allocation between infrastructure and non-infrastructure capital, much literature compares their marginal products by implicitly assuming that the optimality holds when the marginal products are equal. We show in an endogenous growth model that this criterion is misused as long as the investment efficiencies and depreciation rates of different capitals differ. We derive a simple benchmark criterion, linking capital marginal product, investment efficiency and depreciation rate together, for policy evaluation. Empirically, this paper employs a semiparametric varying coefficient model to calculate the marginal products of infrastructure capital and private capital in a panel of 30 Chinese provinces during 2004-2015. Based on our policy evaluation criterion, it is found that generally there is still an underinvestment of infrastructure in Chinese provinces. We find even in the western provinces, which had relatively high infrastructure capital ratio and were believed to have "too much infrastructure" according to some previous studies, the optimal match between infrastructure and non-infrastructure capital was roughly maintained after 2008.

The second paper provides both empirical evidence and theoretical explanation that, international financial liberalization was linked to the decrease of external public debt in developing countries since the 1990s. It is often thought that financial globalization facilitates the international borrowing of governments. However since the 1990s we have seen a significantly negative comovement between increased financial globalization and decreased external public debt to GDP ratio in developing countries. Using a panel dataset for 46 developing economies during 1990-2007, this paper empirically confirms that financial liberalization in the home country was correlated with the retirement of external public debt. The estimated coefficient for financial openness in other countries is not sufficiently robust. We rely on cointegrating regression methods of FMOLS and DOLS because of the nonstationarity (and cointegration) of the relevant macroeconomic variables, which is often (incorrectly) ignored in previous empirical works. Our estimation is robust as we carefully check different data sources, possible reverse causality and omitted variable. We also provide a plausible theoretical argument why financial liberalization can help reduce external public debt ratio. The main mechanism is that financial globalization shrinks the interest rate differential between developing and advanced countries, which reduces the government's domestic financing cost and dampens its incentive to borrow externally.

Is financial development positively, negatively, or not linked to the aggregate output volatility? Very controversial debates exist in both empirical and theoretical literature. The third paper argues that financial development can either exacerbate or dampen output volatility, depending on the type of industry whose credit access is expanded. Using a two-sector real business cycle model augmented with the collateral constraint à la Kiyotaki and Moore (1997), we show that if the borrowing constraint is relaxed in the consumption goods sector, macroeconomic volatility will rise. On the contrary, if the financial friction is lessened in the capital goods sector, output volatility may decline or be roughly unchanged. The underlying intuition is that the sensitivity of output to economic shocks crucially depends on the intensity of firms to adjust their production inputs, which relies on the marginal products of capital and labor. Financial development increases the labor marginal product, but alters the overall capital marginal product through two opposite effects on the capital allocation dynamics. Credit expansion mainly causes an *inter-industry capital reallocation* if it occurs only in consumption industry, while the reallocation effect is dominated by the *economy-wide capital expansion* if the financial development occurs in capital industry. In the latter case the overall marginal product of capital decreases, but in the former case no substantial change is induced. Therefore, the industrial heterogeneity and the associated capital allocation are crucial, in order to analyze the effect of financial development on aggregate output volatility.

Chapter 1

Does China invest too much in infrastructure?

This paper works on the debate about the existence of infrastructure overinvestment in China. In order to evaluate the optimal allocation between infrastructure and non-infrastructure capital, much literature compares their marginal products by implicitly assuming that the optimality holds when the marginal products are equal. We show in an endogenous growth model that this criterion is misused as long as the investment efficiencies and depreciation rates of different capitals differ. We derive a simple benchmark criterion, linking capital marginal product, investment efficiency and depreciation rate together, for policy evaluation. Empirically, this paper employs a semiparametric varying coefficient model to calculate the marginal products of infrastructure capital and private capital in a panel of 30 Chinese provinces during 2004-2015. Based on our policy evaluation criterion, it is found that generally there is still an underinvestment of infrastructure in Chinese provinces. We find even in the western provinces, which had relatively high infrastructure capital ratio and were believed to have "too much infrastructure" according to some previous studies, the optimal match between infrastructure and non-infrastructure capital was roughly maintained after 2008.

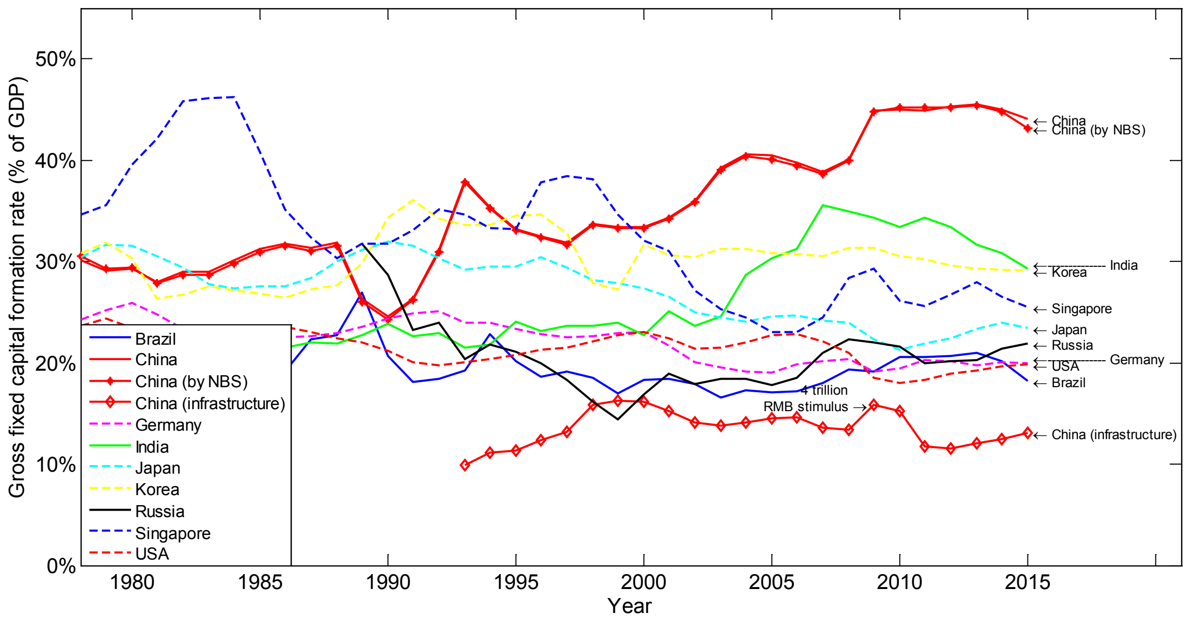
Keywords: infrastructure, public capital, marginal product, overinvestment, China

JEL Classification: H54, O11, O18, O25

1.1 Introduction

The accumulation of infrastructure played an important role in China's rapid economic development over the past decades. However nowadays an overinvestment of infrastructure may exist and be detrimental in China, according to the concerns of some economists and policy makers.[1] Figure 1.1 shows the gross fixed capital formation rates as percentage of output in 9 countries during 1978-2015.[2]

Figure 1.1: **Gross fixed capital formation rates (% of GDP) in 9 countries, 1978-2015**



Compared to other countries, it is obvious that the investment rate in China is unusually high. In recent years, its fixed capital formation rate reached a level of around 45%. In the past three decades, only Singapore in the early 1980s has ever reached this level. A great part of China's capital investment was distributed into infrastructure industries. Since the 1990s, the ratio of infrastructure investment which is indicated by the curve "China (infrastructure)" was relatively stable and fluctuated between 10% and 15% of annual GDP. This ratio of infrastructure investment is even close to the gross fixed capital formation rates over all sectors

[1]Typical arguments to evaluate the existence of overinvestment of public capital or gross capital as a whole in China can be grouped into 7 types. Unfortunately they are all not competent to answer our research question. Section 1.2.1 provides a brief summary on these arguments.

[2]Data source: "China (by NBS)" is the "*Gross Fixed Capital Formation*" divided by "*Gross Domestic Product by Expenditure Approach*" reported by the National Bureau of Statistics (NBS) of China. "China (infrastructure)", whose original data is also reported by the NBS, refers to the ratio of only infrastructure-relevant industrial investment based on author's calculation as the sum of investment across 4 industrial sectors: (i) production and supply of electricity, gas and water, (ii) transport, storage and post, (iii) information transmission, computer services and software, (iv) management of water conservancy, environment and public facilities. Other data is directly from the World Development Indicators (WDI). The gross fixed capital formation rate of China reported by the NBS is slightly different from the data by WDI. But the difference is small and never larger than 1%.

in Russia, Germany, America and Brazil. This phenomenon induces a natural question: Does China really need so much infrastructure? In November 2008, the Chinese central government started an unprecedented 4 trillion RMB (586 billion US$) fiscal stimulus package to deal with the global financial crisis. The money was mainly invested into infrastructure. The warning about a possible overinvestment of infrastructure became especially important in recent years, when people found that the public debt of some local governments, which is often related to radical infrastructure construction, had risen to a frightful level. But how much infrastructure is too much, and how to evaluate the proper level of the infrastructure capital stock in an aggregate economy? The existing literature is not sufficient to answer these questions, neither theoretically nor empirically.

The list of literature on the benefits and functioning of infrastructure (or similarly, public capital or government capital) is very long, but there is not much consensus to be found. Since it is extremely complicated to determine an "optimal" level of infrastructure (which involves the exact knowledge about the utility function, production technique, financing channels, household wealth distribution, demographic and geographic situation and so forth), we focus instead on the efficient allocation between infrastructure and non-infrastructure investment within a country. We proceed as follows. (i) We first employ a theoretical endogenous growth model to derive a criterion for evaluating whether there is overinvestment or underinvestment in infrastructure capital. (ii) Then we empirically estimate the effects of public and private capital on Chinese provincial output. (iii) By comparing our estimation result with the criterion from theoretical model, we are able to answer the question whether China invests too much in infrastructure. In this paper we focus on the spending aspect of government investment with respect to aggregate production and hence, some other issues like financing the infrastructure construction and the poverty reduction effect of infrastructure development are not our concern. Throughout our paper, we use the terms "public capital" and "infrastructure" interchangeably. Likewise, "private capital" and "non-infrastructure" refer to the same thing in this paper.

The analysis in our paper has two main implications. First, the theoretical model of infrastructure investment shows that the investment efficiency and depreciation rate gap of different types of capital should be considered in determining the optimal allocation between them. Second, the econometric estimation indicates a room for investing more in infrastructure in most Chinese provinces, even though the infrastructure stock has already increased grossly in recent decades.

Our paper contributes to the literature not only by providing a policy analysis on the desirability of infrastructure investment in China, but also by shrinking the gap between the theoretical and empirical studies on public capital topic. There are a lot of growth models incorporating public capital. However the connection between theoretical model and empirical work is often weak. Theoretical research has already studied many interactive aspects of public infrastructure, such as the network effect, congestion, capital adjustment cost, investment efficiency, endogenous depreciation, capital quality and composition. But the empirical studies still prefer measuring the output effects of public capital and then advocating that public capital should be invested more (less) when its estimated productivity is high (low), or when it does (does not) positively affect economic growth. One possible reason why the empirical research substantially neglects the fruits of the theoretical literature is the lack of macroeconomic data for the theoretical elements. Our framework relies on a comparison between the output effect of infrastructure and its opportunity cost i.e. non-infrastructure capital. This produces a simple policy assessment criterion requiring only three components: the capital marginal product, investment efficiency and depreciation rate.

The rest of the paper proceeds as follows. Section 1.2 presents a brief literature review. Section 1.3 employs an endogenous growth model to derive the optimality condition for infrastructure policy analysis, and presents our theoretical finding of a simple policy evaluation criterion in a first-best case. Section 1.4 describes the details of our semiparametric varying coefficient econometric model employed to estimate the capital marginal product. The issues regarding our data and capital stock estimates are in Section 1.5. Section 1.6 displays our regression results and the corresponding policy implications. Conclusion is given in Section 1.7.

1.2 Literature review

In this section we present a brief literature review. We first take a glance at several different approaches in the literature that may be used to evaluate the existence of public capital overinvestment, and discuss why none of them is sufficient to answer our research question. Then we summarize the main findings from the recent public capital literature, which is the basis for our theoretical and empirical analysis. Afterwards we talk about three main difficulties for our research topic of evaluating whether an overinvestment exists in an aggregate economy. These three difficulties are frequently confronted in literature. An understanding of them makes it clear why our paper has to spend much space analyzing a growth model, constructing a regression equation, and investigating the official statistical data.

1.2.1 Evaluating the (in)existence of public capital overinvestment

In the literature there are several typical approaches to evaluate whether an overinvestment of public capital exists. The arguments can be grouped into seven types. (1) The first approach relies on some neoclassical aggregate indicators such as the capital-to-output ratio as in Gros (2015), the difference between Gross Capital Income/GDP and Gross Investment/GDP ratios as in He, Zhang and Shek (2007), or the (GDP-Investment)/GDP ratio as in Lee, Syed and Liu (2013). But this approach depends on many strong assumptions and is perhaps not applicable in a transition economy like China. (2) The second is to predict some "reasonable" investment rate by estimated coefficients from regressions based on the data of "comparable" countries, as done in Lee, Syed and Liu (2012). But ignoring the heterogeneity of the Chinese economy can make the estimated "good" investment rate misleading. (3) The third approach measures the crowding-in and crowding-out effects of public investment on private investment, as in Cavallo and Daude (2011), Xu and Yan (2014). This approach provides some hints regarding whether the overinvestment exists. But not only the amount but also the productivity of investment matter for economic growth. Thus, the investigation of a crowding-out effect of public investment alone cannot generate a clear answer for our research question. (4) The fourth calculates the rates of return in industries, as in Ding, Guariglia and Knight (2012). This is probably not really useful since the rate of return of a certain industry in the market often differs from its social rate of return, especially for public-goods-relevant industries. (5) Another approach employs frontier production function techniques such as data envelopment analysis. This approach, including Qin and Song (2009), Wu (2008) etc., generally finds that investment efficiency in the western and inland provinces of China is lower than that in the eastern coastal areas. But the strict assumptions underlying this approach limit its reliability for policy analysis, and the estimated efficiencies of different capitals are not comparable. (6) Another type of argument directly compares the domestic physical availability of facilities (e.g. the transportation network density, proportion of population with access to the Internet) with the international counterparts. This, while supplying information about the future development potential of capital in the country, does not take account of the contemporary interaction with other economic sectors. (7) The last one is using micro-level evidence or impressions, such as the phenomenon of "ghost towns" in some regions or the high-speed train without many passengers. This is often discussed in nonacademic media and influential in shaping public awareness. However, the fact that some places are rich of investment can occur at the same time while investment is sparse elsewhere, even within the same city or same town. From an aggregate perspective we need some "average" conclusion across different areas and industries.

Ding, Guariglia and Knight (2012) and Lee, Syed and Liu (2012, 2013) present brief literature reviews on the macro- and micro-data-based research for China grounded on (some of) the 7 approaches aforementioned.

1.2.2 Findings from the recent literature

Our study is primarily linked to the theoretical and empirical literature on public capital's output effect. The existing literature is huge – we can easily find at least hundreds of research papers discussing how infrastructure affects the economic growth and output. In order to summarize what we have learned from the previous studies, here we present a short review mainly based on some literature review papers since the 2000s.

The theoretical research mostly uses the framework of Ramsey–Cass–Koopmans model, either with the decentralized economy solution or the social planner problem. The frequently cited work of Barro (1990) devised a fundamental endogenous growth model with public capital. Irmen and Kuehnel (2009) and Dissou and Didic (2013) provide helpful literature reviews for the theoretical development since 1990s. In these two review papers, different growth models from literature are incorporated into one consistent framework which evolves according to the change of underlying assumptions. In order to obtain an explicit expression of solution to offer comprehensive perspective, the model has to be subject to some specific function forms. Leduc and Wilson (2012) provide a novel DSGE model to study both the short-run and long-run effect of infrastructure investment, which can be employed to compare with the estimation results from the "fiscal multiplier" literature. The findings from the theoretical literature can be roughly summarized as follows. (1) The conclusions and policy recommendations often hinge on the specific assumptions in the growth model, such as the form of production function, degree of congestion effect, and the public investment financing instruments. (2) The theoretical findings are not tightly linked to the practical policy evaluation. Particularly, some important elements in theoretical model are often simply ignored in reality because of the difficulty to measure or lack of reliable data.

In the domain of empirical research four approaches are usually relied on: estimating the production function, estimating the cost function, using vector autoregression model, or working on cross-section regression. Romp and de Haan (2007) is often cited because of their comprehensive review on the previous empirical research. Bom and Ligthart (2014), Dissou and Didic (2013), Duran-Fernandez and Santos (2014), Elburz, Nijkamp and Pels (2017), Ligthart and Suárez (2011) as well as Núñez-Serrano and Velázquez (2017) also give the discussions of the empirical literature. The findings from the previous empirical studies can be roughly summarized into two points. (1) So far, most empirical studies have provided evidences for the importance of public capital on economic activity. For example, averagely speaking the estimated output elasticity of infrastructure is significantly positive (but not too large, e.g. around 0.1-0.2). (2) However much more effort of offering refined data and robust methodology is called for, since the documented magnitude and charateristics of public capital's impact vary greatly and depend critically on the data, econometric model and technique used.

1.2.3 Three main difficulties in our research topic

There are three main difficulties in our research. The first is the lack of an explicit criterion to evaluate the appropriate level of infrastructure capital. Second, there is no official data of the capital stock for empirical research. Third, there exists a series of econometric difficulties to measure the output effects of public capital. We have to overcome all these obstacles. We hereby briefly discuss these three issues.

Theoretical studies have found that the proper level of infrastructure capital depends on the specific macroeconomic conditions such as the production function property of infrastructure and the government's tax rate. Despite of the fruits of theoretical research, many empirical studies are keen on estimating the output effect of infrastructure and advocating to invest more if the estimated effect is large. This opinion has the obvious problem that it only considers the benefit of public capital without taking into account its cost. A more careful consideration as in some empirical works explicitly concerns the tradeoffs among investing in public capital and other sectors, which is essentially a benefit-cost analysis. Since the direct cost of raising funds for infrastructure is difficult to be measured, the most obvious opportunity cost of infrastructure – investing in private capital – is more often compared with. A lot of empirical works cannot proceed farther beyond reporting the output elasticities of infrastructure and non-infrastructure capitals, often because many of them use physical index of infrastructure which is uncomparable to the currency measure of non-infrastructure. Some literature argues to invest more infrastructure because the estimated elasticity is positive. This is questionable since it is the marginal product rather than elasticity who really matters. A few of studies, including Peterson (1994), Canning (1999) and Shi and Huang (2014), explicitly compare the marginal products of public and private capitals. This public-private capital tradeoff approach typically resorts to the formula $F_k = F_g$ by implicitly assuming that the optimality holds when the marginal product of public capital F_g equates that of private capital F_k. However, as we will show later the static equality $F_k = F_g$ only holds in a macroeconomic environment without a lot of elements such as capital depreciation, infrastructure congestion, and investment efficiency.[3] On the other hand, while theoretical models produce fruitful insights into the real world, we currently still lack a sufficiently simple but powerful criterion to evaluate the desirability and tradeoff of infrastructure stock, without resorting to estimating many parameters,. The misused formula $F_k = F_g$ is so intuitive, at least in a micro-static partial equilibrium. Will a macroeconomic model provide a different equation, or just add something on it? We will show in a Ramsey model that it is particularly important not to ignore the investment efficiency and depreciation of capital. We will derive a simple evaluation criterion linking capital marginal product, investment efficiency and depreciation together.

An explicit dataset for aggregate capital stocks in developing countries is scarce. This is also true for China. Zhang, Wu and Zhang (2004) and Zhang (2008) estimate China's provincial gross capital stock during 1952-2000 and 1952-2004, respectively, by the Perpetual Inventory Method (PIM). Most recent studies estimating the capital stock in China use methods analogous to their work. For our research topic, we should go further to estimate both infrastructure and non-infrastructure capital stocks separately. Jin (2012, 2016), Hu, Fan and Xu (2016), and Shi and Huang (2014) recently estimated China's infrastructure capital stocks at provincial level. However, their works are not without shortcomings and we have to construct the capital stock series from the first step, while the data we can rely on is quite limited.

[3]Recently, cointegrated panel (e.g. Canning and Pedroni, 2008) or vector error correction model (e.g. Egert, Koźluk and Sutherland, 2009) is employed to escape from calculating marginal products. By construction, the estimated long-run effect coefficient of infrastructure capital variable should be (smaller/larger than) zero if the infrasctructure is (over-/under-) optimally invested. But in this paper we do not rely on these methods because we do not want the explicit economic dynamics of variables to be hidden by the numerical equations.

Following the seminal work of Aschauer (1989), a great amount of empirical research attempts to quantify the output effects of public capital. However this is econometrically difficult. The spurious regression and reverse causality issues are two of the most severe obstacles but unfortunately we do not have a perfect way to deal with them. Moreover, since China has very large inter-district heterogeneities and speedy institutional and economic transitions, we have more difficulties to select a sufficiently robust regression method. We select the semiparametric varying smooth coefficient model to allow for the inter-district heterogeneity of estimated parameters, while maintaining the variation meaningful in economics.

1.3 Theoretical model

In this section, we utilize an endogenous growth model with public capital to derive an optimization criterion for infrastructure investment evaluation. The criterion should have two crucial features: (1) it should base only on aggregate variables and parameters that are easily measurable; (2) it should be robust to varieties of the model setup and economic environment. The first feature is indispensable because a reliable microeconomic dataset covering Chinese provinces and industries is scarce, which makes agent-level theoretical criteria inapplicable. The second feature is necessary because a well-defined economic model for a fast-growing transition country like China is lacking.

1.3.1 Two approaches: a dilemma

The literature mostly uses the framework of Ramsey–Cass–Koopmans model, either with the decentralized economy solution or the social planner solution. The pros and cons of both decentralized economy analysis and central planner solution are so substantial that we in fact bog down a dilemma of model selection.

In a decentralized economy, the government is limited to setting several policy variables like the tax rate and public expenditure. Given these policies, the households and firms behave autonomously. This kind of "second-best" situation is clearly more realistic and prevalent in literature. However, it can hardly be used in Chinese context because of three major disadvantages. (1) The associated analysis works well only when the economy is in or close to the steady state – for instance we can describe the economy's dynamics in (and only in) the neighborhood of steady state using a linear differential equation system. But we know little about the steady state of China's economic development. (2) In order to obtain closed form solutions, the model has to impose specific forms of utility function, production function, and/or some strong assumptions such as constant return to scale in production. These assumptions may not suit China. (3) It is required to measure some key parameters (e.g. the preference parameter of elasticity of substitution in consumption), which are unavailable empirically.

The solution for social planner problem, in which the versatile benevolent government optimizes all variables, supplies a "first-best" case. This is clearly not realistic but useful in our policy analysis. (1) As shown below, a clear and simple optimal relation between marginal products of infrastructure and non-infrastructure capital can be derived for the first-best situation. Thus we only need to measure a small number of variables, which greatly facilitates our econometric regression. (2) It is no longer necessary to limit the economy to be close to the steady state. Instead, we are able to analyze the whole transition dynamics. This is especially powerful in Chinese context. Therefore, we make our theoretical model stuck to the first-best situation with some loss of modeling reality. In Appendix 1.B we give two decentralized economy examples to demonstrate that the central planner solution indeed provides a good benchmark.

1.3.2 Theoretical model

We construct a social planner problem to derive the optimality conditions, in a first-optimal situation, which generate a convenient equation regarding the tradeoff between private capital and public capital investment. Our social planner model incorporates several key elements developed in the recent literature, including the congestion cost of public capital (Dioikitopoulos and Kalyvitis, 2008; Fisher and Turnovsky, 1998; Ott and Turnovsky, 2006; Turnovsky, 1997), and the inefficiency of private and public investment (Pritchett, 2000; Gupta et al., 2014).[4] We assume that there are two types of agents in a closed economy – households as consumer-producers, and the government which taxes and provides public service. There is no intermediary financial sector in this economy. Thus the allocation of private investment and public investment is conducted through taxation.[5] Here, following the tradition of growth model in continuous time we omit the time index subscript of each variable.

1.3.2.1 Model setup

The social planner maximizes the social welfare, defined as the discounted sum of households' utilities, in the form:

[4] We do not model the maintenance in public capital which decreases the public capital's depreciation rate (Dioikitopoulos and Kalyvitis, 2008; Kalaitzidakis and Kalyvitis, 2004; Rioja, 2003), because the existence of public capital maintenance will change the size of depreciation rate gap in our policy evaluation criterion but not the format of the criterion. Thus, introducing the maintenance spending into the model would not provide essentially different insight.

Moreover, we do not consider the possible implementation lag of government investment (Leeper, Walker and Yang, 2010), because it can be shown that as long as the implementation delay for building public capital and impatience of household are not too severe, the effects of implementation lag are almost negligible.

[5] Absence of financial friction disables us to model the interaction of private and public investment via financial channels, which is important if we concern the crowding-in or crowding-out effects of public investment. The end of Section 1.6.2 briefly discusses some relevant issues.

$$\int_0^\infty e^{-\rho t} U(C, L, C_g) dt$$

where ρ is time preference rate; C is aggregate private consumption; L is aggregate labor; C_g is the public consumption good provided by the government which benefits households directly. Households are consumer-producers, who accumulate private capital and produce by a concave production function satisfying the Inada conditions. The production function is:

$$Y = \mathscr{F}(K, K_g^s, L) = F(K, K_g, L)$$

where K is aggregate private capital stock and K_g^s is the service provided to each household by aggregate public capital K_g. We set $K_g^s = \psi K_g$ where $\psi = \left(\frac{k}{K}\right)^{\xi}$ measures the the congestion effect in public capital. Here k is the private capital stock of each production unit in the economy and $0 \leqslant \xi \leqslant 1$ is a congestion effect parameter. K_g becomes a pure public good when $\xi = 0$ and a private good when $\xi = 1$. Since all producers are assumed homogeneous, from the perspective of social planner $\psi = \left(\frac{k}{K}\right)^{\xi}$ can be regarded as a fixed parameter $\psi = N^{-\xi}$ where $N = \frac{K}{k}$ is the total amount of production units. Note that we directly model the aggregate economy as a whole. In fact in such a social planner problem, if we as usual first write down the representative agent's equations and then aggregate to obtain the economy-wide ones, we will just get to the aggregate model here.

Households allocate after-tax income between consumption and private capital investment. Abstracting from fiscal risk, the government is assumed to keep a balanced budget in every period. The stock of private capital K and public capital K_g evolve according to the transition equations:

$$\dot{K} = \phi_k[(1-\tau)Y - S - C] - \delta_k K$$

$$\dot{K}_g = \phi_g(1-\mu)(\tau Y + S) - \delta_g K_g$$

where $\phi_k, \phi_g \in [0,1]$ measure the efficiency of private and public capital investment, respectively. In order to keep model tractable, we simply assume ϕ_k and ϕ_g are constant parameters.[6] Accordingly, the value of $(1-\phi_k)$ and $(1-\phi_g)$ can be interpreted as the size of capital adjustment costs of private and public investment, which may be important in countries without well established institutions and project management. Moreover, the existence of ϕ_k and ϕ_g indicates that public capital and private capital stocks are generally not one-to-one convertible.

[6]Literature shows that the (nearly) constant capital investment efficiency is likely in practice, at least in some developing countries. Arestoff and Hurlin (2006), Hurlin and Arestoff (2010) investigate the efficiency of public capital investment in Colombia and Mexico. They find that the new capital created can be well approximated by a simple linear function of investment: $f(I_t) = \alpha I_t$ where the efficiency parameter α is constant and below 0.5. This is also confirmed by Gupta et al. (2014), from which we find the average "normalized Public Investment Management Indices (PIMI)" for 40 low income and 31 middle income countries are quite similar in the 1990s and 2000s.

Parameter δ_k is the fixed depreciation rate of K. δ_g is the depreciation rate of K_g. Variable τ gives the rate of income tax and S is the amount of lump-sum tax. So the government's tax income is $\tau Y + S$.[7] The variable μ indicates the proportion of tax revenue used for providing public consumption goods C_g. The flow of public consumption goods C_g is:

$$C_g = \mu(\tau Y + S)$$

Since $K_g^s = \psi K_g$, the equation of $\dot{K}_g$ can be equivalently written in terms of K_g^s as:

$$\dot{K}_g^s = \psi\phi_g(1-\mu)(\tau Y + S) - \delta_g K_g^s$$

1.3.2.2 Equilibrium optimality conditions

To get the first order optimality conditions, we have the usual (present value) Hamilton function:

$$\begin{aligned}\mathscr{H} &= e^{-\rho t}U(C,L,C_g) + \lambda_1\{\phi_k[(1-\tau)Y - S - C] - \delta_k K\} \\ &\quad +\lambda_2\left\{\psi\phi_g(1-\mu)(\tau Y + S) - \delta_g K_g^s\right\} \\ &\quad +\lambda_3\left\{\mu(\tau Y + S) - C_g\right\}\end{aligned}$$

in which the control variables are $\{C, L, C_g, \tau, \mu, S\}$ and the state variables are K and K_g^s (or equivalently K_g). The combination of first order conditions $\frac{\partial \mathscr{H}}{\partial C} = 0$, $\frac{\partial \mathscr{H}}{\partial L} = 0$, $\frac{\partial \mathscr{H}}{\partial C_g} = 0$, $\frac{\partial \mathscr{H}}{\partial \tau} = 0$, $\frac{\partial \mathscr{H}}{\partial \mu} = 0$, $\frac{\partial \mathscr{H}}{\partial S} = 0$, $\frac{\partial \mathscr{H}}{\partial K} = -\dot{\lambda}_1$, $\frac{\partial \mathscr{H}}{\partial K_g^s} = -\dot{\lambda}_2$ (with the proper transversality conditions) gives us several important relations with clear economic meanings:

$$U_c = U_{cg}$$

$$-U_l = U_c F_l$$

$$\phi_k\lambda_1 = \psi\phi_g\lambda_2 = \lambda_3$$

$$\phi_k F_k = \phi_g F_g + (\delta_k - \delta_g)$$

where U_c, U_{cg}, U_l are the marginal utilities of C, C_g, L; and F_l, F_k, F_g are the marginal products of L, K, K_g. The congestion effect on public capital does not matter in any of these equations since the social planner can fully handle this externality. The meanings of these four equa-

[7] If consumption tax or government bond is additionally introduced into the model, (just as expected in a social planner economy) the basic conclusions of our model would not be changed at all.

tions above are explicit. The first equation indicates the equality between the marginal utility of private consumption and public consumption good; the second equation demonstrates the tradeoff between leisure and working more for more consumption; the third equation means that at optimality the "effective" shadow values of constraints should be equal.

Among these equations, we want to focus on the last one. It indicates the tradeoff between infrastructure capital and non-infrastructure capital. Generally, the optimal ratio of the marginal products of infrastructure and non-infrastrucutre capital depends on investment efficiency and the corresponding depreciation rates. The equation $\phi_k F_k = \phi_g F_g + (\delta_k - \delta_g)$ can be equivalently written as $(\phi_g F_g - \delta_g) = (\phi_k F_k - \delta_k)$, which can be interpreted as that the social rates of return to infrastructure and non-infrastructure capital should be equal. It is notable that Canning and Bennathan (2000) obtain a similar criterion. But they derive it mainly from an accounting perspective and explain marginal product minus depreciation rate as the internal rate of return to investment project. They omit the possibility of nonzero investment adjustment cost and unequal depreciation rates.

1.3.3 Implication for policy analysis

The implication for policy analysis of the formula $(\phi_g F_g - \delta_g) = (\phi_k F_k - \delta_k)$ is clear. That is, at optimality the society should allocate capital resource in a way that each marginal unit of capital should have the same contribution everywhere, taking into account two aspects: (1) the existence of capital adjustment cost and investment inefficiency, and (2) the dynamic effects of private and public investment that in order to sustain economic growth the capital decays in the following periods should be compensated. Hence the capital sector whose investment efficiency is lower or depreciation rate is larger should be invested less until its marginal productivity is large enough to offset these disadvantages. In the policy evaluation practice, we need to measure the data of three items: the capital investment efficiency ϕ_g and ϕ_k, depreciation rate δ_g and δ_k, marginal product F_g and F_k. Then we can compare $(\phi_g F_g - \delta_g)$ versus $(\phi_k F_k - \delta_k)$ to decide whether the infrastucture has an overinvestment or underinvestment.[8]

It is widely believed that in developing countries the coefficients of capital investment efficiency ϕ_g and ϕ_k are significantly below one. Arestoff and Hurlin (2006), Gupta et al. (2014), Hurlin and Arestoff (2010) and Pritchett (1996) estimate that only roughly "half of the money invested in investment projects will have a positive impact on the public capital stocks in the developing countries". The investment efficiency term ϕ_g and ϕ_k play two roles in our policy

[8] In some early literature, either the depreciation of capital was not considered (e.g. Barro, 1990; Futagami, Morita and Shibata, 1993; Turnovsky, 1997; Aschauer, 2000; or by modeling public services as flow) or it was assumed that there is no difference between δ_k and δ_g (e.g. Bajo-Rubio and Díaz-Roldán, 2005). Accordingly the condition $F_k = F_g$ was stated. Our result shows that, even in a most tractable social planner problem the relation $F_k = F_g$ does not hold in general, as long as we consider a little bit more realistic economic environment. Hence, in empirical work before we compare the marginal products of public and private capital from aggregate production function, we should care that between F_k and F_g there should exist a wedge which depends on the parameters (and probably also policy variables).

assessment criterion. (1) First, they serve as weights to change the relative importance of F_g versus F_k. At optimality, *ceteris paribus*, the type of capital with lower investment efficiency is required to have higher marginal product. (2) Second, since the values of ϕ_g and ϕ_k are both below one, they raise the importance of the depreciation difference $(\delta_k - \delta_g)$. In an extreme case, if the investment efficiency is sufficiently small, the depreciation difference may even dominate.

The magnitude of depreciation rate difference $(\delta_k - \delta_g)$ is not negligible. The difference of depreciation rates is the result of distinct physical composition of infrastructure and non-infrastructure capital. The infrastructure mostly consists of structure (Rioja, 2003), which depreciates at a relatively low rate. In contrast, the equipment, machine and some other materials with faster depreciation rates make up a large proportion of the non-infrastructure capital. Bai, Hsieh and Qian (2006) assume a depreciation rate of 8% for structures and 24% for machinery in China. Zhang, Wu and Zhang (2004) assume that the depreciation rate is 6.9% for building, 14.9% for equipment, and 12.1% for other capitals. At this moment let us assume that infrastructure is made up completely of structures (Hu, Fan and Xu, 2016; Shi and Huang, 2014), and non-infrastructure consists half of structures and half of machines (Shi and Huang, 2014). Using the depreciation rates from Zhang, Wu and Zhang (2004), the depreciation difference $(\delta_k - \delta_g)$ would be 4%. In Shi and Huang (2014) (which actually use the value from Bai, Hsieh and Qian, 2006), Huang and Shi (2014), the depreciation difference $(\delta_k - \delta_g)$ is 8% and 7% respectively. From the literature, e.g. Kamps (2006), Arslanalp et al. (2010), Arestoff and Hurlin (2006), we can also make an international comparison of depreciation rates as well as the difference between infrastructure and non-infrastructure capital. Table 1.1 lists the values of capital depreciation rate and the difference $(\delta_k, \delta_g, \delta_k - \delta_g)$ in some empirical literature.

Table 1.1: **Values of capital depreciation rate in some empirical literature**

Literature	δ_k	δ_g	$\delta_k - \delta_g$	**Sample Country and Period**
based on Zhang, Wu and Zhang (2004)	10.9%	6.9%	4%	China, 1952-2000
based on Bai, Hsieh and Qian (2006)	16%	8%	8%	China, 1978-2005
Huang and Shi (2014)	14%	7%	7%	China, 1995-2011
Kamps (2006)	8.5%	4%	4.5%	22 OECD countries, 2001
Arslanalp et al. (2010)	8.5%	4%	4.5%	22 OECD countries, 2001
	7%	3.25%	3.75%	13 middle-income non-OECD countries, 2001
Arestoff and Hurlin (2006)	-	2.5%	-	26 developing countries, 1998

Note: "based on" means the paper does not directly provide the estimated values of δ_k and δ_g. We calculate them by assuming that infrastructure (non-infrastructure) is made up completely of buildings (half buildings and half machines).

We learn two points from these studies. First, infrastructure has a significantly lower depreciation rate than private capital. Second, we find that the magnitude of $(\delta_k - \delta_g)$ is comparable to that of δ_g. In literature the typical estimated magnitude of F_k or F_g roughly ranges from 0.2 to 0.4.[9] Thus, the depreciation difference documented in Table 1.1 roughly counts for 10%-40% of the estimated marginal product of capital.[10] Obviously, neglecting the depreciation difference could significantly misguide the policy making on resource allocation between private and public investment, especially when F_k and F_g are close to each other. Moreover, if the capital adjustment cost is substantial or investment efficiency is low, the importance of the depreciation rate difference even increases.

1.4 Empirical model

According to the previous theoretical analysis, we can evaluate the desirability of infrastructure investment based on the criterion $\phi_k F_k = \phi_g F_g + (\delta_k - \delta_g)$. In this formula, the investment efficiency ϕ_k, ϕ_g and depreciation rate δ_k, δ_k are structural parameters that we can obtain by analyzing the statistical data (which will be discussed in Section 1.5). What we need to estimate using econometric method are the marginal products F_k and F_g. We will first estimate the output elasticity of capital, and then calculate the marginal product based on the estimated elasticity. Regardless of some drawbacks of the aggregate production function approach (discussed in e.g. Haughwout, 1998, 2002), the estimation of aggregate production function has become the dominant method. Our empirical model also relies on it. Since the empirical part of our paper is analogous to that in Shi and Huang (2014) (henceforth SH for short), we now move to a short discussion on their paper and then lay out our econometric model after that.

[9] The estimated marginal product of capital varies depending on the method and data used. Here we list some examples of the estimated capital returns in China. (Although the capital return does not necessarily equate the marginal product of capital in aggregate production sense, it should be an indicator of the size.) The pre-tax return on capital is roughly 21% in 2005 in Bai, Hsieh and Qian (2006), 15% in 2013 in Bai and Zhang (2014), and 18% in 2013 in Thomas (2013). The median value of the marginal revenue product of capital is 32% in 2007 in Ding, Guariglia and Knight (2012).

[10] We can use a simple numerical example with Cobb–Douglas production function to illustrate the importance of $(\delta_k - \delta_g)$, while temporarily omitting the existence of investment inefficiency. The details of this exercise are in Appendix 1.A. Figure 1.7 in Appendix 1.A.1 displays the capital resource misallocation within one single period if a depreciation gap $(\delta_k - \delta_g)$=0.06 is not taken into account. The resulting capital misallocation is serious. By setting the depreciation difference to 0.04, 0.06, 0.08 respectively and calculating the allocation of K_g and K based on equation $F_k = F_g$ and equation $F_k = F_g + (\delta_k - \delta_g)$, it is found that if the social planner incorrectly uses the equation $F_k = F_g$, on average as much as 4.79%, 7.36% and 10.1% of stock K would be misallocated from public capital into the private sector. Even worse, in a long-run perspective, neglecting the depreciation rate difference causes a severe deviation from the optimal convergence path toward the steady state. Clearly, the consequence is a grave welfare loss. In our policy experiment demonstrated in Figure 1.8 of Appendix 1.A.2, where the economy starts with half steady state capital stocks with depreciation rates $(\delta_k, \delta_g, \delta_k - \delta_g)$=(0.12, 0.06, 0.06), a welfare loss as large as 5.54% permanent consumption reduction would occur. The loss is 2.40% and 10.3% in the case of $(\delta_k, \delta_g, \delta_k - \delta_g)$=(0.11, 0.07, 0.04) and (0.13, 0.05, 0.08), respectively. The numerical instances provide important lessons for developing countries. Especially for low-income countries far behind the steady state and with high depreciation rates, if the planners do not consider the depreciation difference seriously, the associated welfare loss may even climb to 20%, 30% or more.

SH use a semiparametric aggregate production function to estimate the marginal products of infrastructure and non-infrastructure capital in 28 Chinese provinces during 1997-2011. Based on their estimation result, they propose that, after 2008, most western (eastern and central) provinces exhibited an oversupply (undersupply) of infrastructure relative to private capital since the marginal product of infrastructure in the region is lower (higher). According to our findings from the theoretical model, their policy suggestion needs more inspection because they do not consider the wedge of investment efficiency and depreciation rate. However the main merits of their work are obvious. First, they recalculate the provincial capital stock series in China by especially noting that the price of infrastructure may be different from that of private capital. Also, they depreciate the two types of capitals by different rates. Thus, their estimated capital stock data is perhaps more reliable than some previous works. Second, they use the recently developed semiparametric varying coefficient method to estimate the output elasticities of capital. By allowing the coefficients to vary with economic circumstance, they are able to better model the nonlinear interaction between public capital, private capital and production. Third, they carefully deal with several severe problems prevalent in aggregate production regression, especially the issues of spurious correlation and reverse causality.

1.4.1 Model specification

A lot of econometric challenges stand in front of us when we try to identify the marginal products of aggregate production factors. Now we start to discuss these econometric difficulties one by one and write down our regression model accordingly. The organization of this section is analogous to that in SH since our framework is admittedly revised from theirs. In each model equation below we simply save the subscript index for district in each variable, as it is apparent that we are talking about a panel data set.

1.4.1.1 Misspecification of functional form

Previous literature has often used a Cobb-Douglas or translog production function. But it is considerably suspect whether these functional forms correctly specify the nonlinearity between production input and output. Nonparametric or semiparametric models can help us go beyond these imposed functional forms. Theoretically, by some proper nonparametric techniques we can directly estimate the aggregate production function of the form:

$$\ln Y_t = f(\ln K_{g,t}, \ln K_t, \ln L_t) + \ln A_t$$

where $K_{g,t}$, K_t and L_t are the stock of infrastructure, non-infrastructure capital and labor amount, respectively; Y_t is the aggregate output; A_t is the TFP. However pure nonparametric estimation can hardly be interpreted in economic terms. For the topic of production functions, a semiparametric varying coefficient model is especially powerful, since it allows the output elasticities of input factor to vary with economic environment while keeping the ways of variation nonarbitrary.

Classical microeconomic theory shows that the marginal product of one production factor could be influenced by other input factors. Concerning the private and public capital investment at macroeconomic level, it is natural to believe that a good match of public and non-public capitals is crucial for the productivities of both capitals.[11] Hence, we set out our model in a way that allows the elasticities of capital (and labor) to change over time, as a function of infrastructure to non-infrastructure capital stock ratio $z_t = K_{g,t}/K_t$. In other words, the output elasticities of infrastructure and non-infrastructure capital can be written as $\beta_{g,t} = \beta_g(z_t)$ and $\beta_{k,t} = \beta_k(z_t)$, respectively. This setup is adopted by SH. Of course we may also consider the coefficients to vary with respect to other variables. In the estimation robustness check part in Section 1.6.3, we study other possibilities.

Furthermore, we write the production function in per capita form without argument L_t. This is because of three reasons. (1) First, we follow the constant returns to scale assumption, which is widely used in the literature estimating aggregate production functions. (2) Second, the labor in one province is not really a variable input here. Because there is no data on the working hour of Chinese workers, the constructed variable L_t is based on the demographic information rather than dynamic labor input. (3) Third, we find that output and capital stocks are clearly at least $I(1)$ in logarithmic terms, but labor supply is not necessarily that. As documented by the panel unit root test results in Table 1.6 at Appendix 1.D, all the regression variables are $I(1)$ in our baseline sample of 2004-2015 data. However the property of $\ln L_t$ series is actually found sensitive to the selection of sample period. Directly using population as the definition of L_t is clearly not suitable since the labor proportion in population is substantially heterogeneous across provinces. If we use the amount of labor defined as people aged 15-64 to represent L_t, we will find $\ln L_t$ in some provinces is nearly $I(0)$ because the population slightly increases while labor to population ratio slightly decreases. This makes the econometric model questionable. If we (ultimately) use L_t of skill-adjusted labor amount (which is discussed in detail in Section 1.5), it is found that the variation of $\ln L_t$ could be almost constant in some provinces. This renders efficiently estimating parameters difficult. Therefore, as a result of these three abovementioned reasons we consider the aggregate production function in intensive form:

$$\ln y_t = f(\ln k_{g,t}, \ln k_t) + \ln A_t$$

[11] For example, we can consider a CES (constant elasticity of substitution) production function: $Y_t = \left\{\beta\left(K_t^{\alpha} K_{g,t}^{1-\alpha}\right)^{\gamma} + (1-\beta)L_t^{\gamma}\right\}^{\frac{1}{\gamma}}$. The output elasticities with respect to infrastructure and non-infrastructure are $\varepsilon_{yg,t} = (1-\alpha)\beta\left(\frac{K_{g,t}}{K_t}\right)^{-\alpha\gamma}\left(\frac{K_{g,t}}{Y_t}\right)^{\gamma}$ and $\varepsilon_{yk,t} = \alpha\beta\left(\frac{K_{g,t}}{K_t}\right)^{(1-\alpha)\gamma}\left(\frac{K_t}{Y_t}\right)^{\gamma}$, respectively. In this case, $\varepsilon_{yg,t}$ and $\varepsilon_{yk,t}$ depend on the values of structural parameters, infrastructure to non-infrastructure capital ratio, and capital stock to output ratio.

where the variables in lower case letter are variables per skill-adjusted labor.

1.4.1.2 Spurious correlation

Along with the high speed development in China, the variables of output and capital stock are definitely nonstationary. Thus the problem of spurious correlation arises. In literature, there are three major ways to deal with spurious regression issue.

(i) Detrending There are several detrending methods including first (or higher order) differencing, linear detrending (e.g. Hassler, 1999), stochastic detrending (e.g. Ferson, Sarkissian and Simin, 2010), HP filter and so on. A comparison of detrending methods can be found in Burnside (1998) and Canova (1998a,b). The typical literature with aggregate production function framework uses the first differencing. While first differencing removes the spurious correlation, it has defects. It "destroys any long run relationship that may exist amongst the levels of variables of interest" (Abdih and Joutz, 2008), but this does not matter in our model as we focus on the marginal effect within one period rather than the "long run relationship". On the other hand, the other detrending methods do not work since they demand relatively strong assumption underlying the data generating process which we lack here. (Actually we tried the linear detrending, stochastic detrending and HP filter but did not obtain any meaningful result.) Thereby, we choose the first differencing to detrend the data.

(ii) Cointegration The cointegration method is popular, conditional on the existence of a cointegration relationship. Abdih and Joutz (2008) give an example of using cointegration analysis to investigate the impact of public capital on American private sector output. But we do not employ cointegration technique because (1) we do not find an easy way to incorporate varying coefficient model into cointegration analysis; (2) more importantly, for our data sample the existence of conintegration relationship is uncertain. We find the relation is sensitive to the selection of sample period. In some cases the relevant variables are integrated of different orders – this feature violates the precondition of cointegration analysis.

(iii) Error correction model The error correction model (ECM) can estimate both the short term effects and long term effects of explanatory variables. However, the typical ECM suits the case that dependent variable gradually returns to its long run equilibrium after a change in independent variables. But in our aggregate production function framework, we actually assume that the dependent variable of output reaches the new equilibrium level within one period. This rules out the employment of ECM.

Therefore, we resort to the first differencing method and get:

$$\Delta \ln y_t = \Delta f(\ln k_{g,t}, \ln k_t) + \Delta \ln A_t$$

where the symbol Δ refers to the first differencing operator. Next we express the equation using $\Delta \ln k_{g,t}$ and $\Delta \ln k_t$, based on the mean value theorem. For a continuous function $g(x)$, mean value theorem tells that $g(x_2) - g(x_1) = \frac{\partial g}{\partial x}(cx_1 + (1-c)x_2) \cdot (x_2 - x_1)$ where $\frac{\partial g}{\partial x}$ is the gradient, x could be a vector and $c \in (0,1)$. Thus we have $\Delta f(\ln k_{g,t}, \ln k_t) = \beta_{g,\tilde{t}} \Delta \ln k_{g,t} + \beta_{k,\tilde{t}} \Delta \ln k_t$ where $\beta_{g,\tilde{t}}$ and $\beta_{k,\tilde{t}}$ measure the marginal output contributions of infrastructue and non-infrastructure capital at one specific (unknown) time point $\tilde{t}$ between period t and $t-1$. As mentioned previously, it is not unreasonable to assume that the output elasticities of capitals vary along with the ratio of $z_{\tilde{t}} = K_{g,\tilde{t}}/K_{\tilde{t}}$. Built on this assumption, the model now becomes:

$$\Delta \ln y_t = \beta_g(z_{\tilde{t}}) \Delta \ln k_{g,t} + \beta_k(z_{\tilde{t}}) \Delta \ln k_t + \Delta \ln A_t$$

Since $z_{\tilde{t}} = K_{g,\tilde{t}}/K_{\tilde{t}}$ measures the ratio of capital stocks which can only vary gradually, we can use z_t to reasonably approximate it. Therefore, the model can be expressed by:

$$\Delta \ln y_t = \beta_g(z_t) \Delta \ln k_{g,t} + \beta_k(z_t) \Delta \ln k_t + \Delta \ln A_t$$

1.4.1.3 Reverse causality

The reverse causality issue arises because an increase of capital stock could be just a result of capital accumulation in an environment of output increase. In econometrics, this mainly turns out to be the endogeneity problem of capital stock variables. Reverse causality problem is often mitigated by IV or GMM regression. But as (1) IV or GMM method cannot be incorporated with varying coefficient model smoothly and (2) our sample's short time dimension critically hinders their powers, we deal with reverse causality from three other aspects. We rely on the start-of-the-year capital stock as explanatory variable, add time fixed effects dummies, and introduce a proxy variable for TFP shock in the regression equation.

In the regression, the capital stock $k_{g,t}$ and k_t are defined as the stocks at the start of year t. Since the dependent variable y_t is produced during year t, it naturally has not much impact backward on the past capital stocks, unless one year ago the agents already had strong anticipation on the future output dynamics. In order to control for this potential "anticipation", we further decompose the TFP term.

The TFP term can be written as $\Delta \ln A_t = \sigma_t + \Delta \varepsilon_t$ where σ_t is the time fixed effect common to all provinces and ε_t is the residual which is the TFP shock. Reverse causality arises when the term $\ln k_{g,t}$ or $\ln k_t$ is correlated to ε_t. This is possible since the government (or firm, household) may adjust the factor input when they perceive (anticipate or observe) the TFP shock. For instance, the government can invest more infrastructure as discretionary policy to stimulate the economy when negative TFP shock comes or is anticipated to come. The existence of reverse causality makes the estimation biased.

The TFP shock $\Delta \varepsilon_t$ can be divided into two components $\Delta \varepsilon_t = \Delta \omega_t + \Delta \mu_t$ where ω_t is the component that can be perceived by the agents and hence correlated to $\ln k_{g,t}$ and $\ln k_t$, while μ_t

is the uncorrelated error term that cannot be perceived. So it is important to find a valid proxy variable for ω_t. SH propose to use the approach from Ackerberg, Caves and Frazer (2006, 2015) (ACF) to address the reverse causality problem. But, because of the assumptions of ACF do not hold in our context of aggregate production function, ACF approach is in fact not suitable for us. Appendix 1.E states why we think SH misuse the ACF approach. However the underlying idea of ACF approach – using proxy variables to control for unobservables when estimating productivity – indeed works. As pointed out in SH, two conditions for proxy variable should hold: (i) the proxy is not an input factor for the output, (ii) it is monotonic with ω_t. We use the HP-filtered consumption to GDP ratio to proxy the conceived TFP shocks. The reason is as follows: based on economic theory, the private consumption should be smooth over time, which indicates that the fluctuations in consumption ratio should be the result of some "shocks".

This proxy variable obviously satisfies condition (i), since consumption to GDP ratio is definitely not a production input. Regarding condition (ii), we can test it after regression. After we estimate the model, we can obtain the estimated value of ω_t. Then we can test the monotonic relationship between proxy variable and the perceived TFP shock. Appendix 1.H gives us the result. We find that the monotonicity indeed well holds.

Denoting $proxy_t$ as the proxy variable for the perceived TFP shock, we write that $\Delta proxy_t = \phi(\Delta\omega_t)$ where $\phi(\cdot)$ is a monotonic function of $\Delta\omega_t$. Then we have $\Delta\omega_t = \phi^{-1}(\Delta proxy_t)$. For simplicity, we use the semiparametric varying coefficient form to approximate the function $\phi^{-1}(\cdot)$. We write as:

$$\Delta\omega_t = \phi^{-1}(\Delta proxy_t) = \varphi_t \Delta proxy_t = \varphi(z_t)\Delta proxy_t$$

(In the robustness check in Section 1.6.3 we also check the case of using a third order polynomial to proxy $\Delta\omega_t$.) Thus we now have:

$$\Delta \ln y_t = \beta_g(z_t)\Delta \ln k_{g,t} + \beta_k(z_t)\Delta \ln k_t + \varphi(z_t)\Delta proxy_t + \sigma_t + \Delta\mu_t$$

1.4.1.4 Spillover effects from neighboring regions

We follow SH's setting of spatial spillover effects of infrastructure and non-infrastructure capital but simply assume that there is no spatial autocorrelation of shocks. Now we get our final complete regression model:

$$\begin{aligned}\Delta \ln y_t &= \beta_g(z_t)\Delta \ln k_{g,t} + \beta_k(z_t)\Delta \ln k_t + \varphi(z_t)\Delta proxy_t \\ &\quad + \theta_g * W * \Delta \ln \tilde{k}_{g,t} + \theta_k * W * \Delta \ln \tilde{k}_t + \sigma_t + \Delta\mu_t\end{aligned}$$

where $\tilde{k}_{g,t}$ and $\tilde{k}_t$ denote the vector of capital stocks in other provinces, and W is a known spatial weight matrix. We use the relative economic size of one province among all the adjacent provinces as weight, with the geometric mean of 2003-2015 real GDP as indicator of economic size. No geographically adjacent provinces only have zero weights. Table 1.2 gives the definitions of all variables in our econometric model. The data sources of the variables are discussed in Section 1.5.

Table 1.2: **Definitions of variables in econometric model**

Variable	Definition
y_t	GDP per skill-adjusted labor
z_t	ratio of infrastructure to non-infrastructure capital stock
$k_{g,t}$	infrastructure capital stock per skill-adjusted labor
k_t	non-infrastructure capital stock per skill-adjusted labor
$proxy_t$	proxy variable for TFP shock; we use the HP-filtered consumption to GDP ratio
W	spatial weight matrix; we use the relative economic size of one province among all the adjacent provinces as weight
$\tilde{k}_{g,t}$	vector of infrastructure capital stocks in other provinces
$\tilde{k}_t$	vector of non-infrastructure capital stocks in other provinces
σ_t	time fixed effect common to all provinces
μ_t	error term

1.4.2 Estimation

The varying coefficient model can be estimated by the local constant least-squares method as described in Li and Racine (2007). For a regression model $Y_i = X_i^{'}\beta(Z_i) + \varepsilon_i$ the general form of the estimator is:

$$\hat{\beta}(z) = \left[\sum_{j=1}^{n} X_j X_j^{'} K\left(\frac{Z_j - z}{h}\right)\right]^{-1} \sum_{j=1}^{n} X_j Y_j K\left(\frac{Z_j - z}{h}\right)$$

For $K(\cdot)$, we choose the Gaussian kernel function. The bandwidth h is selected by least-squares cross-validation. The coefficients for time fixed effects and spillover effects can be estimated by the three steps procedure suggested in Li and Racine (2007) for the "partially linear varying coefficient model". We use the residual based wild bootstrap method suggested by Mammen (1993) to estimate the standard errors of estimated coefficients.

1.5 Data

This section provides the details on our data. We first discuss the data source and sample. Then we outline our procedures of estimating capital stock by the Perpetual Inventory Method. Afterwards we demonstrate the estimated capital stock and investment efficiency in China.

1.5.1 Data source and sample

We rely on the official statistics documented in different kinds of statistical yearbooks published by the National Bureau of Statistics (NBS) of China. The data on the GDP and price level are from *China Statistical Yearbook 1994-2016*. The data sources for the capital and labor are relatively complicated. We put the details in Appendix 1.F. Most of the after-2003 data in *China Statistical Yearbook* are also readily downloadable from NBS' website.

We define infrastructure as the sum of 4 industrial sectors: (i) production and supply of electricity, gas and water, (ii) transport, storage and post, (iii) information, transmission, computer service and software, (iv) management of water conservancy, environment, and public facilities.[12] Accordingly, non-infrastructure is defined as all other industries in the economy except the abovementioned four infrastructure industries. Labor input is calculated by the labor amount adjusted by the average years of schooling.

We classify the 31 provinces in mainland China into eastern, central and western parts, according to the official classification of NBS. Therefore we have 11 eastern provinces: Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin, Zhejiang; 8 central provinces: Anhui, Heilongjiang, Henan, Hubei, Hunan, Jiangxi, Jilin, Shanxi; and 12 western provinces: Chongqing, Gansu, Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Tibet, Xinjiang and Yunnan. We find that Tibet is indeed an outlier since it (i) has a very high infrastructure ratio, (ii) has a great proportion of data missing, and (iii) is with a very small economy size. Hence we do not include Tibet in our regression. So we have a panel of 30 Chinese provinces. The data for Chongqing before 1997 is calculated from Sichuan data, as Chongqing was a part of Sichuan previously.

We mainly focus on the data during 2003-2015. On the one hand, NBS changed the statistical system in 2003, which makes the data before 2003 actually uncomparable. On the other hand, as we start our estimation of capital stocks from 1993, we think that the influence of estimate errors for base year capital stock should sufficiently vanish 10 years later i.e. 2003. In the robustness check section, we also look at the regression result based on 2000-2015 data.

[12]If the concept of "infrastructure" is more widely defined as in some literature, the "infrastructure" in this present paper is just "economic infrastructure" which is "a direct input to economic activity". And the fixed capital for social services (such as school, hospital) should be sorted into another part of the concept – "social infrastructure". Moreover, not all capitals in the 4 infrastructural industries necessarily work as the "infrastructure". But the data at hand does not allow us to distinguish the different capital components within the industries. Hence, it is important to take into account the possibly distinct definitions of "infrastructure" when comparing our results with other papers.

1.5.2 Estimating capital stock by Perpetual Inventory Method

Without a dataset for the capital stocks, as a tradition, the stocks of both infrastructure and non-infrastructure capitals can be estimated by the Perpetual Inventory Method (PIM). Thus, we have

$$K_t = (1 - \delta_{t-1})K_{t-1} + I_{t-1}$$

where K_t denotes the capital stock at the beginning of period t; δ_{t-1} is the depreciation rate; and I_{t-1} is the efficiency-adjusted investment flow.[13] PIM requires the data of 4 elements: initial (base period) capital stock, capital investment time series, capital price, and capital depreciation profile. We select the year 1993 as the base year to calculate the capital stock at constant price. Starting from an initialized stock at the beginning of 1993, the capital stock series in the subsequent years can be calculated from the investment data. (1) The initial capital stock in 1993 can be estimated in several ways. We calculate it using the capital investment growth rate and depreciation rate in the subsequent four years, assuming that they were the same in all years before 1993. In formula, we have $K_{1993} = I_{1993}/(gr + \delta)$ where K_{1993} is the capital stock in 1993, I_{1993} is the capital investment in 1993, gr is the assumed growth rate of capital investment before 1993 (for which we use the country-wide average 1993-1997 growth rate 24.96% for infrastructure and 13.75% for non-infrastructure), and δ is the corresponding depreciation rate. (2) Regarding the investment-efficiency-adjusted capital investment flow data, we follow Jin (2016) and Wang and Szirmai (2012) to use the item of "*Newly Increased Fixed Assets*" in Chinese statistical system, as its definition is more consistent with what we need compared to other investment series data.[14] (3) We use the "*Price Index for Investment in Fixed Assets*" to deflate the price for both infrastructure and non-infrastructure capitals. (4) The selection for capital depreciation rate is quite controversial. We make a compromise among the existing studies and choose 8% and 9.5% as the depreciation rate for infrastructure and non-infrastructure, respectively.

[13] It is important to explicitly distinguish the two timing notations of K_t in literature where K_t could be defined as the stock at the beginning or end of period t. Unexpectedly, we find some literature confuses this and is actually in mistake.

[14] Here we cite the definition of "*Newly Increased Fixed Assets*" from *China Statistical Yearbook* as below. "Newly Increased Fixed Assets refers to the value of fixed assets that has completed the construction and purchase, and has been delivered to the production or owner units, including investment in projects that have been completed and put into operation in current year and the investment in equipment, tools and appliance that meet the standard of fixed assets and fees that should be apportioned. This is an indicator that demonstrates the results of investment in fixed assets in monetary terms, and an important indicator to reflect the speed of construction and to calculate the efficiency of investment."

Figure 1.2: **Average K/Y and K_g/Y ratios in eastern, central and western provinces, 1993-2015**

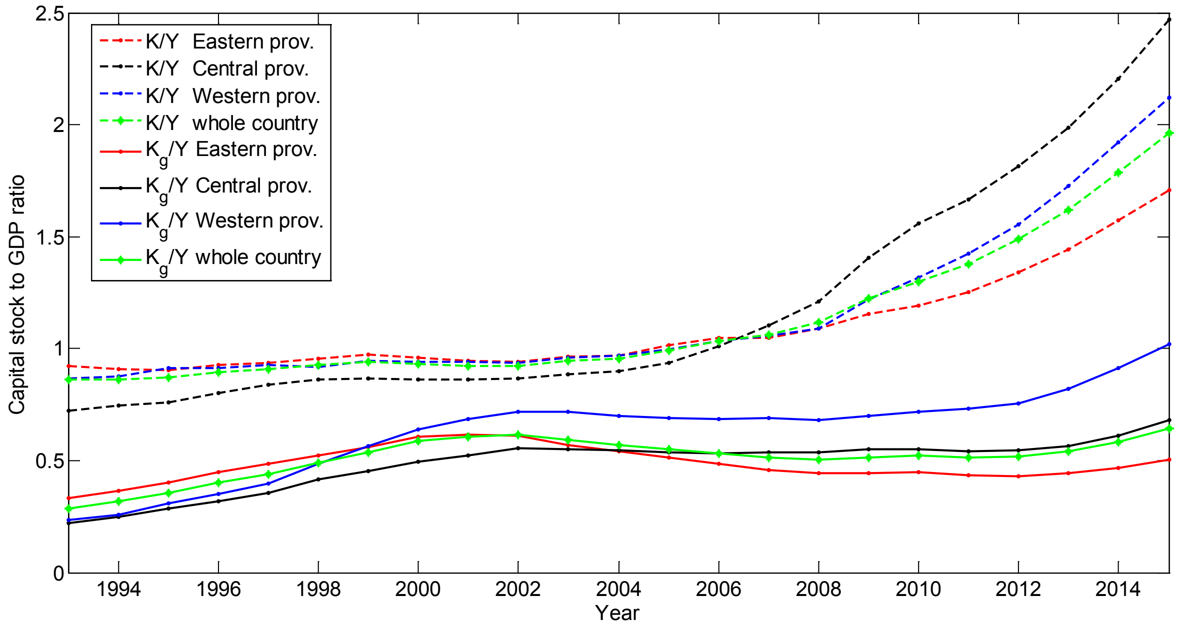
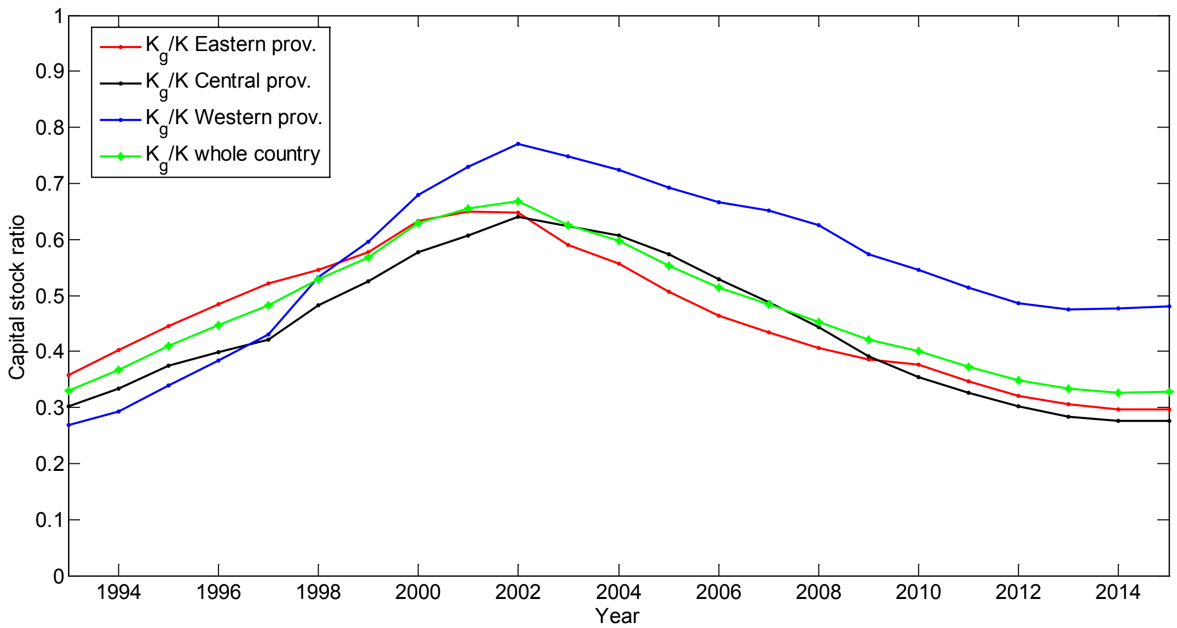


Figure 1.3: **Average K_g/K ratios in eastern, central and western provinces, 1993-2015**



Employing the method and data abovementioned, we are able to estimate the infrastructure and non-infrastructure capital stocks for 31 provinces in mainland China. According to Gupta et al. (2014)'s estimation for the public capital stocks in a group of countries, the mean (non-efficiency-adjusted) public capital stock in middle-income countries during 2000-2009 is 93.2% of GDP. Adjusting the capital stock by efficiency will halve the value. This number is not very far from our estimation. Figure 1.2 and Figure 1.3 show the average K/Y, K_g/Y and K_g/K ratios in the eastern, central, western regions and the country as a whole during 1993-2015. We know from the graph that K/Y rates were relatively stable before 2006 and obviously rose after then. K_g/Y ratios smoothly increased in the three regions before 2002, remained stable during 2003-2012, and rose after 2013. The gaps of capital to GDP ratios among three regions aggravated after the 1990s. K_g/K ratios climbed up in the first decade of the sample period and went down after the peaks around 2002.

Figure 1.10 in Appendix 1.G additionally shows the evolution of K, K_g and Y shares (as the fraction of country-wide sum) of the three districts. It is obvious that the output shares were stable for all the three regions, while the shares of infrastructure and non-infrastructure capital stocks demonstrated some variations especially after 2006. The most notable phenomenon is the large decline of the share of K_g in the eastern area accompanied with a large increase in the western area during the whole sample period. In 1993, the share of K_g was around 65% in the eastern district and 15% in the western disctrict. The numbers become 45% and 30% in 2015. In contrast, the GDP share was maintained around 60% and 20% in the eastern and western zones, respectively. One may guess this fact implies that the infrastructure in the western region was less productive since an increase of K_g's proportion did not go with an increase of Y's. However, we in fact observe that the share of non-infrastructure K increased as well in recent years. Hence, we need a rigorous comparison about the relative contributions of K and K_g to output. The next section presents our regression results.

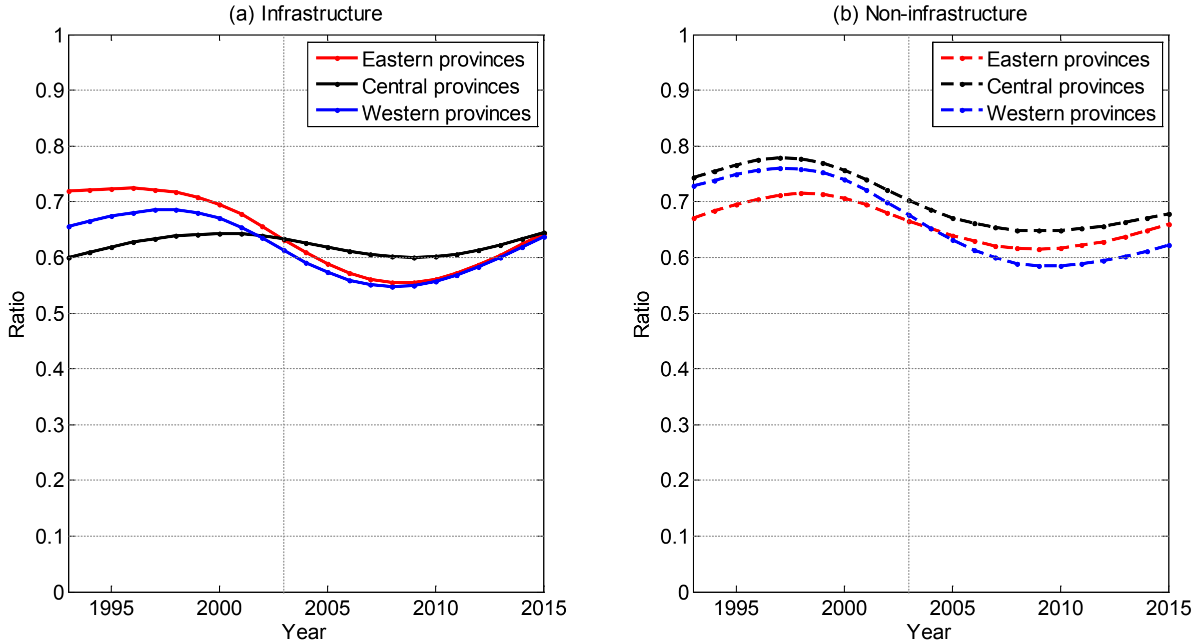
1.5.3 Estimated investment efficiency

Investment efficiency is measured by the ratio of "*Newly Increased Fixed Assets*" to "*Total Investment in Fixed Assets*". This ratio is equal to the item "*Rate of Projects of Fixed Assets Completed and Put into Operation*" in Chinese statistical system.[15] We use HP filter to obtain a smooth trend of the ratio, in order to get rid of the business cycle fluctuations.

Figure 1.4 demonstrates the estimated average efficiency of non-infrastructure and infrastructure investment in the eastern, central and western areas during 1993-2015. We see that in recent years (1) the investment efficiency of infrastructure was around 60%, and the efficiency of non-infrastructure was slightly higher; (2) the investment efficiency was highest in the central provinces and lowest in the western area, though the difference was not huge.

[15]Here we cite the definition of "*Rate of Projects of Fixed Assets Completed and Put into Operation*" from *China Statistical Yearbook* as below. "Rate of Projects of Fixed Assets Completed and Put into Operation refers to the ratio of the newly increased fixed assets to the total investment made in the same period. This a comprehensive indicator reflecting the speed of the employment of fixed assets and the investment efficiency at the macro-level. As the newly increased fixed assets is the result of a long period while the investment is completed in the current year, this indicator is expected to be used to reflect the employment of fixed assets over a long period of time."

Figure 1.4: **Average investment efficiency of infrastructure and non-infrastructure in eastern, central and western provinces, 1993-2015**



1.6 Empirical result

This section presents our regression results and the corresponding policy implications. We will first document the estimated output elasticities. Then we compare the marginal products of infrastructure and non-infrastructure. By applying the policy evaluation criterion derived in the previous theoretical section, we find that there is still a space of investing more infrastructure in most Chinese provinces. The robustness of our result is inspected at the end of this section.

1.6.1 Output elasticity

We summarize our estimation of coefficients in Table 1.3. For comparison, we also report the results from one-way fixed effects model, and median values of estimation from varying coefficient model without TFP proxy and spillover effects. For the complete varying coefficient model with TFP proxy and spillover effects, we report the values of 5%, 25%, 50%, 75% and 95% quantile over the entire data panel.[16] The significance level of estimated coefficients is evaluated by the corresponding estimation standard errors which can be obtained by residual based wild bootstrap method. Result for a monotonicity test for proxy variable with respect to perceived TFP shock can be found in Appendix 1.H.

The estimated coefficients are located within the range in line with literature. The coefficients for infrastructure, non-infrastructure capital and TFP shock proxy variable are significant in almost all cases. The spillover effect is generally insignificant. This is not surprising since we are working on the data of Chinese provinces with usually very wide area, in which most capitals are located far from the provincial boundary and thus have little connection to other provinces. We check the cross-section correlation, auto-correlation (by Box-Pierce and Ljung-Box tests), normality (by Shapiro-Wilk test) and heteroscedasticity of the residuals. The residuals typically well behave and should not bias our estimation.

[16] In Table 1.3 the quantile of each coefficient is reported separately. Thus, for instance, a data point with β_g at 25% quantile is not necessarily with β_k at 25% quantile. That is also the case in Table 1.4.

Table 1.3: **Estimated output elasticities of infrastructure and non-infrastructure capital**

Coef.	**Estimated Value**							
		Semiparametric Varying Coefficient Model						
	One-Way Fixed Effects Model	**without Spillover and TFP Proxy**	**without Spillover**	**Complete Model**				
		Median	**Median**	**5% Quantile**	**25% Quantile**	**Median**	**75% Quantile**	**95% Quantile**
β_g	0.130***	0.096***	0.096***	0.106***	0.106***	0.109***	0.120***	0.127***
	[0.023]	*[0.028]*	*[0.028]*	*[0.029]*	*[0.027]*	*[0.027]*	*[0.024]*	*[0.032]*
β_k	0.233***	0.228***	0.230***	0.227***	0.231***	0.238***	0.246***	0.305***
	[0.022]	*[0.029]*	*[0.026]*	*[0.025]*	*[0.024]*	*[0.029]*	*[0.029]*	*[0.044]*
φ	-0.255***	-	-0.264**	-0.301***	-0.297***	-0.283***	-0.229**	-0.107
	[0.092]		*[0.115]*	*[0.116]*	*[0.121]*	*[0.117]*	*[0.117]*	*[0.129]*
θ_g	-0.036*	-	-			-0.031		
	[0.020]					*[0.020]*		
θ_k	0.012	-	-			0.005		
	[0.014]					*[0.014]*		
σ_t	Yes	Yes	Yes			Yes		
R^2	0.584	0.553	0.551			0.578		
Obs.	360	360	360			360		

Note: * p<0.1, ** p<0.05, *** p<0.01; bootstrapped standard errors in brackets for the varying coefficient model.

1.6.2 Marginal product

With the estimated output elasticity, ratio of capital to output and price level, we can calculate the marginal products of infrastructure and non-infrastructure capital. Table 1.4 shows the results.

The median marginal products of infrastructure and non-infrastructure are 22.4% and 21.9%, respectively. The magnitude is consistent with the estimated Chinese capital return rate in the literature. For example, the estimated pre-tax return on capital is roughly 21% in 2005 in Bai, Hsieh and Qian (2006), 15% in 2013 in Bai and Zhang (2014), and 18% in 2013 in Thomas (2013). The median value of the marginal revenue product of capital is 32% in 2007 in Ding, Guariglia and Knight (2012).

The median marginal product of infrastructure is very close to that of non-infrastructure, which results in a median value of F_g/F_k around one. Taking into account the investment efficiency and depreciation rate, the adjusted ratio $[\phi_g F_g + (\delta_k - \delta_g)]/\phi_k F_k$ is increased compared to the unadjusted ratio F_g/F_k. In order to check whether it is desirable to invest more infrastructure, we can inspect the value of $MPdiff = \phi_g F_g + (\delta_k - \delta_g) - \phi_k F_k$ (which we call it "dynamic marginal product difference"). As documented in the last row of Table 1.4, the difference of

F_g and F_k adjusted by investment efficiency and depreciation rate is positive averagely. This indicates an underinvestment of public capital.

Table 1.4: **Estimated marginal products of capital**

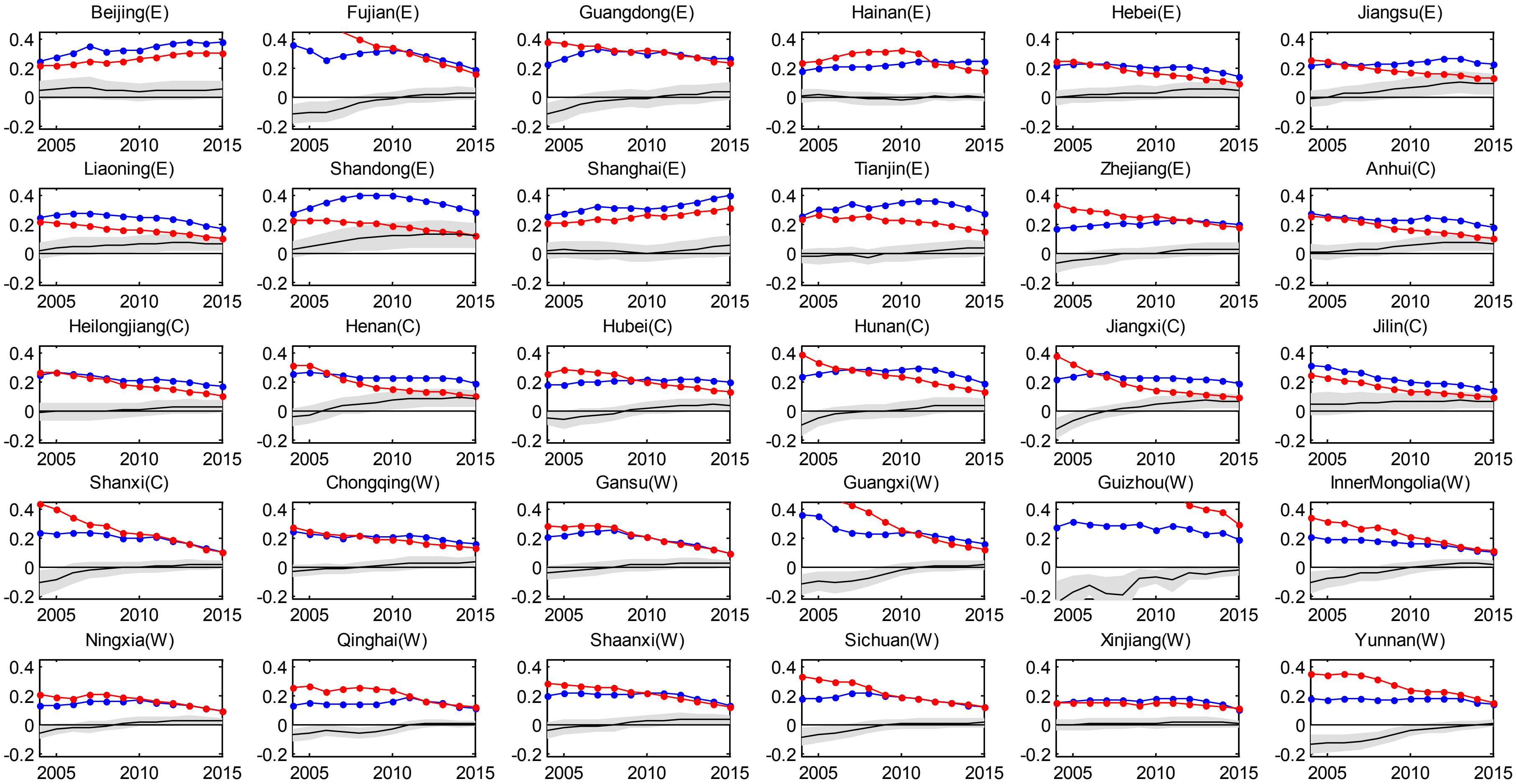
Variable	**Estimated Value**				
	5% Quantile	**25% Quantile**	**Median**	**75% Quantile**	**95% Quantile**
F_g	0.138	0.186	0.224	0.267	0.355
F_k	0.117	0.160	0.219	0.275	0.415
$F_{(g+k)}$	0.124	0.171	0.221	0.264	0.350
F_g/F_k	0.557	0.812	1.060	1.310	1.790
$[\phi_g F_g + (\delta_k - \delta_g)]/\phi_k F_k$	0.598	0.887	1.110	1.330	1.920
$\phi_g F_g + (\delta_k - \delta_g) - \phi_k F_k$	-0.101	-0.018	0.012	0.038	0.081

Note: $F_{(g+k)}$ is the marginal product of capital as a mix of public and private capital with current capital ratio maintained.

Figure 1.5 shows the marginal products of infrastructure and non-infrastructure capital, as well as the difference of marginal products net of investment efficiency and depreciation rates, for 30 provinces during 2004-2015. Figure 1.6 demonstrates the average dynamic marginal product difference in the eastern, central and western regions, taking the capital investment volumes at each year as weights. These two figures enable us to obtain the main findings of our paper.

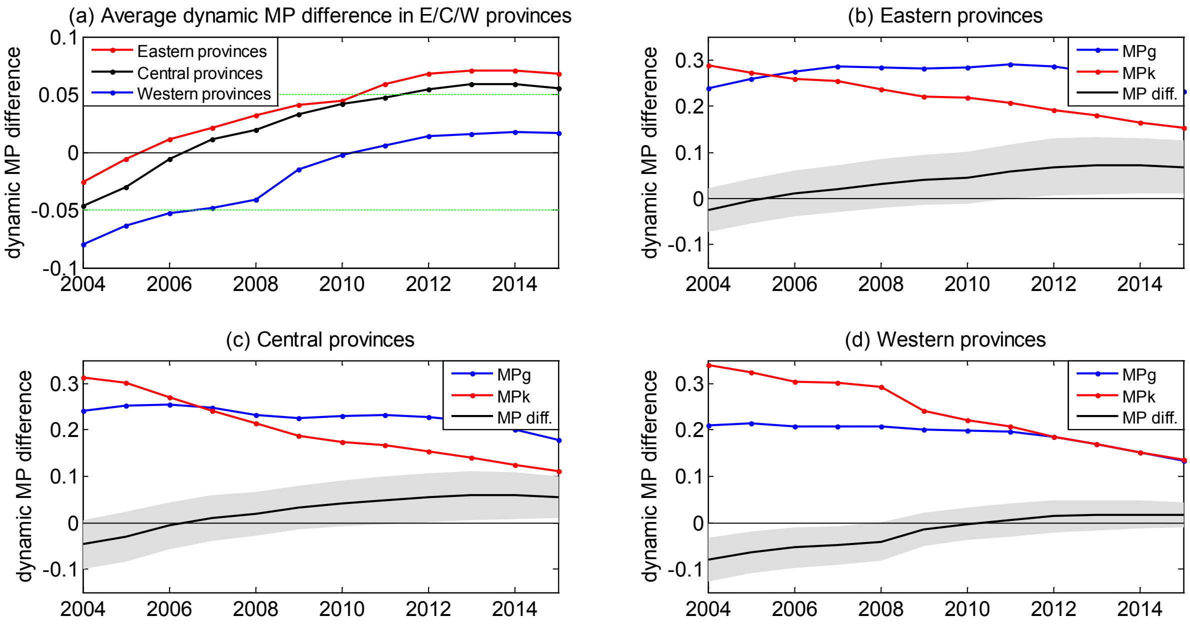
The main findings can be summarized as two points. (1) The dynamic marginal product difference $MPdiff$ has experienced an overall increase during the sample period. By investigating its components, we see that (i) the investment efficiencies of infrastructure and non-infrastructure were relatively stable with similar variation trends (see Figure 1.4 in Section 1.5.3); (ii) the depreciation rates were constant (by assumption); (iii) the infrastructure marginal product was stable but the non-infrastructure marginal product declined in most provinces. (2) In the early years of the sample period, the dynamic marginal product difference was around zero or slightly negative in most areas. This implied no need to expand the infrastructure construction. However, recently the level of $MPdiff$ was significantly above zero. This indicated that the benefit of investing more infrastructure exceeded that of private capital.

Figure 1.5: **Estimated marginal products of infrastructure and non-infrastructure capital in 30 provinces, 2004-2015**



Note: Blue curve is F_g; red curve is F_k; gray shaded area is $\phi_g F_g - \phi_k F_k + (\delta_k - \delta_g)$ with its 90% confidence interval. After the name of each province, the letters E, C, W refer to the eastern, central, and western region, respectively.

Figure 1.6: **Evolution of estimated average dynamic marginal product difference $\phi_g F_g - \phi_k F_k + (\delta_k - \delta_g)$ in eastern, central and western provinces, 2004-2015**



Note: The gray shaded area is $\phi_g F_g - \phi_k F_k + (\delta_k - \delta_g)$ with its 90% confidence interval.

Next we discuss in more detail the situations in each province and the eastern, central and western areas. As shown in Figure 1.5, in most eastern provinces the efficiency-adjusted marginal product of infrastructure net of depreciation was above that of non-infrastructure. This was a signal of infrastructure lack. Exceptions are Hainan, Shanghai, Tianjin, some early years for Fujian, Guangdong, Zhejiang, where the dynamic marginal product difference was approximately zero or negative. However, since the negative value was still close to zero, we can regard these provinces as holding a roughly balanced allocation of infrastructure and non-infrastructure capitals. Subfigure 1.6(b) tells us that the average marginal product difference in the eastern provinces was significantly positive after 2011. Thus, an underinvestment of infrastructure clearly existed in the east. Although we categorize these provinces into one group, the great inter-province heterogeneity should not be neglected. For instance, in Beijing, Liaoning, Shandong, Shanghai, and Tianjin, F_g was always higher than F_k. But in other eastern provinces F_g was often close to F_k, in which case the investment efficiency and depreciation rate difference were quite important.

Some studies (such as SH) argue that there was already too much infrastructure in the western provinces. As demonstrated by Figure 1.6(d), our estimation supports this opinion for the sample period before 2008. After that period, however, our estimation demonstrates no evidence of significant overinvestment of infrastructure in most western provinces. For Chongqing, Gansu, Ningxia, Shaanxi, and Xinjiang, $MPdiff$ was close to zero for the whole period. That is to say, a good match of infrastructure and non-infrastructure capital was roughly maintained. For several other provinces like Guangxi, Guizhou, Inner Mongolia, Qinghai, Sichuan, Yunnan, though the infrastructure was overinvested in the early years when private capital's productivity was high, the value of $MPdiff$ converged to zero after 2008. Overall, we think that the current infrastructure investment policy in the west did not result in an overstock of infrastructure.

The situation of the central provinces is similar to that in the east, and we do not analyze in detail here. We see from Figure 1.6(c) that the average marginal product difference in the central region was near zero in the early years and significantly positive recently. This indicates a space for more infrastructure investment.

In Appendix 1.I we discuss some supplementary support for our argument that it is still desirable to invest more in infrastructure in China. The first is regarding the crowding-in effect of infrastructure investment. The second is about the high return of capital in infrastructure-relevant firms. (1) A drawback of our analysis framework is that by considering infrastructure and non-infrastructure as two separate production inputs, we fail to explicitly test whether infrastructure stimulates or impedes non-infrastructure investment. Particularly, if infrastructure investment crowds out the private capital, the output enhancement effect of infrastructure may be offset. But the literature provides empirical evidences that public investment crowds in private investment in China. Appendix 1.I.1 presents the details on this aspect. This supports our argument that it is beneficial to invest more in infrastructure. (2) Considering that most infrastructure in China is invested by government or state-owned enterprises (SOEs), our estimation result may be challenged by the opinion that the efficiency of government and SOEs is probably low. However there exist firm-level empirical evidences that the infrastructure-relevant firms indeed have high capital return rates. The information is discussed in Appendix 1.I.2.

1.6.3 Robustness analysis

Nonparametric models are usually very flexible. We check the robustness of the estimated coefficients in different model setups and by different samples, and find no crucial change of the result. We describe our exercises briefly as below.

Our econometric model uses proxy variable to control for TFP shock. (1) Previously we only use the first order polynomial of proxy variable $\varphi(z_t)\Delta proxy_t$ to get $\Delta\omega_t$. Column (1) in Table 1.5 presents the result of using the third order polynomial $\varphi(z_t) * \Delta proxy_t + \varphi_2(z_t) * (\Delta proxy_t)^2 + \varphi_3(z_t) * (\Delta proxy_t)^3$, whose difference is negligible. (2) In the baseline model we use the HP-filtered cyclical component of private consumption to GDP ratio as proxy variable. We may also try other possible proxy variables such as the government spending to GDP ratio or capital formation rate. These alternative choices do not make the estimates for β_g and β_k largely changed. The results are not reported here.

In our baseline model, we assume that the estimated capital elasticity coefficients β_g and β_k are both functions of variable z_t. It is possible that they are functions of several variables. Then we consider to add more variables in the part of z_t. For instance we can assume β_g and

β_k are functions of $(z_t, K_t/Y_t)$. Here K_t/Y_t is the ratio of non-infrastructure capital to GDP. We report the results in column (2) of Table 1.5. Expanding the content of z_t variable improves the R^2 value but introduces a "sparse sample" problem. Since we only have 360 observations (12 years times 30 provinces), the sample points are sparsely distributed in the two dimensional space of $(z_t, K_t/Y_t)$. This severely damages the power of our kernel function and results in very volatile estimates for some points close to the boundary of sample space. But for most sample points our baseline estimate is robust.

There are several alternative ways to estimate the capital stock, depending the assumptions underlying the estimation. (1) First, we may change the depreciation rate. We check the result of setting (δ_g, δ_k)=(0.095, 0.095). The column (3) of Table 1.5 displays the result, which is close to the baseline estimation. (2) We may define the non-infrastructure as excluding the household residential capital, compared to our baseline case with residential capital. The estimation result is just analogous. (3) We also change the base year by which we calculate the constant price capital stock. We choose the year to 2003, 2013 and find no much difference.

In our baseline estimation we exclude the data before 2003, because of the uncomparability of pre- and post-2003 data as a consequence of statistical system change. Here we test whether our result is sensitive to the sample period. For example, we change our sample period to year 2000-2015. We report the result in column (4) in Table 1.5. The estimated coefficients are close to our baseline values.

It is possible that the location can have some fixed effects on the aggregate production function. Even though first differencing should eliminate the section fixed effects, there are possibly some location features that vary constantly and slightly in each year and still appear in our first differenced equation. We try to add the dummy variables for location, either for the 30 provinces or 8 economic regions (Northeast, North Coastal, Eastern Coastal, South Coastal, the Middle Yellow River, Middle Reaches of the Yangtze River, Southwest, and Big Northwest regions) according the official categorization of NBS. We find that the results do not have essential change. Thus we do not report the results here.

Table 1.5: **Robustness analysis for the estimated coefficients in varying coefficient model**

Coefficient	Estimated (Median) Value				
	(0)	(1)	(2)	(3)	(4)
	baseline model	$proxy^{123}$	$(z, \frac{K}{Y})$	δ_g**=0.095** δ_k**=0.095**	**2000-2015**
β_g	0.109***	0.119***	0.108***	0.097***	0.083***
β_k	0.238***	0.237***	0.248***	0.242***	0.262***
φ	-0.283***	-0.338***	-0.188*	-0.280***	-0.150**
θ_g	-0.031	-0.029	-0.007	-0.026	-0.037***
θ_k	0.005	0.005	-0.007	0.003	0.010
σ_t	Yes	Yes	Yes	Yes	Yes
R^2	0.578	0.594	0.628	0.573	0.569
Obs.	360	360	360	360	480

Note: * p<0.1, ** p<0.05, *** p<0.01. All the reported values for varying coefficients are in the median.

1.7 Conclusion

Our analysis has two main implications. First, the theoretical model of infrastructure investment shows that the investment efficiency and depreciation rate gap of different types of capital should be considered in determining the optimal allocation between capital types. The investment efficiency and depreciation rate are widely ignored in literature. But they can be crucial if the marginal products of capitals are low or close to each other. Our theoretical analysis confirms the effort of estimating efficiency-adjusted public capital stocks across countries by Gupta et al. (2014). All in all, more elements of the economy and further analysis can build on our simple growth model and investigate the wedge between marginal products of public capital and private capital.

Second, focusing on the objective of regional economic growth, the econometric estimation indicates a space for investing more in infrastructure in most Chinese provinces, even though the infrastructure stock has already increased grossly in recent decades. This proposes one path for structural reform of improving capital product and towards internal rebalancing. When recently it became difficult to maintain an economic growth rate above 7%, some began to consider whether something is wrong with the government-led high investment rate. However, our empirical finding supports the idea that the key issue facing China is the distribution of capital and how it is used (Purdy and Qiu, 2014). Using a global computable general equilibrium (CGE) model, Freestone and Horton (2014) show that even assuming in the future 10 years the investment ratio decreases by 10%, if the rise in productivity can be sufficiently large, the growth rate of real GDP can still be around 6%. We think a more efficient allocation between infrastructure and non-infrastructure investment would greatly facilitate the favored improvement of productivity.

Our paper has several shortcomings, which we cannot overcome at this stage but would like to deal with in the future. The first is the short period of available time series sample. Since the NBS reformed its statistical system in 2003, we currently can only work on the consistent data series of about one decade. Considering that we intend to study the 30 (or 31) provinces in mainland China, the sample period is clearly short. However this data limit seems insuperable. What we can do in the future is inspecting the currently available data seriously and improving the utilization of it.

Second, we failed to consider the region-specific rates of depreciation. The depreciation rate is crucial for us, both in the empirical estimation of capital stocks and the theoretical criterion of evaluating the tradeoff between infrastructure and non-infrastructure capitals. Wu (2009) estimates the different depreciation rates in 31 provinces for 3 sectors (agriculture, manufacturing, and services). But his result is not really helpful for us because we divide the production into two sectors – infrastructure and non-infrastructure. Jia and Zhang (2014), and Wu (2009) find that in general the depreciation rate is "high in the more developed regions and low in the less developed regions". For us, it is important to investigate the depreciation differences $(\delta_k - \delta_g)$ across different provinces. Also, in the long run we may also need to consider the time-varying depreciation rates. We should do that if we can find a satisfactory way with sufficient data.

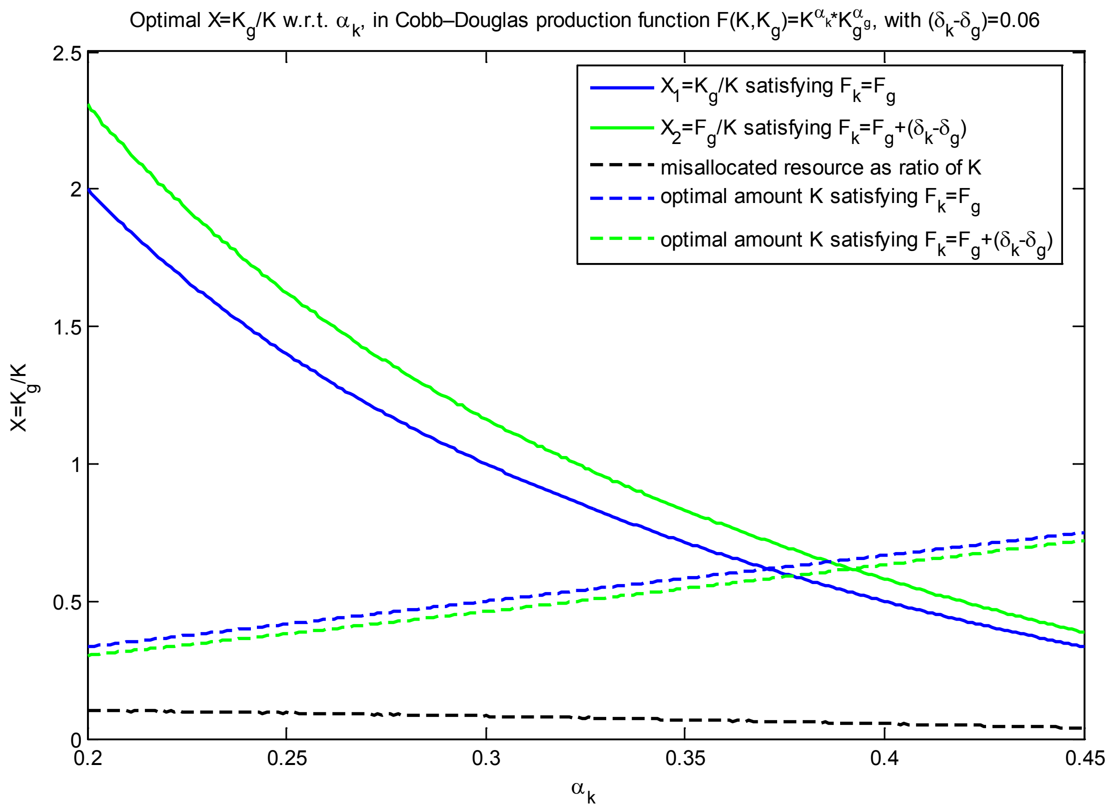
Appendix

Appendix 1.A. Illustrating the importance of depreciation difference by a numerical example with Cobb-Douglas production function

Here we use a simple numerical example to illustrate the importance of $(\delta_k - \delta_g)$, while neglecting the existence of investment inefficiency. We assume a Cobb-Douglas aggregate production function $Y = K^{\alpha_k} K_g^{\alpha_g} L^{1-\alpha_k-\alpha_g}$. We set fixed labor input $L = 1$, and $1 - \alpha_k - \alpha_g = 0.4$ since the estimated labor share in China is roughly 40%. Hence, the production function can be simply written as $Y = F(K, K_g) = K^{\alpha_k} K_g^{\alpha_g}$ with $\alpha_k + \alpha_g = 0.6$.

1.A.1. Capital resource misallocation within one period

Figure 1.7: **Capital resource misallocation in one period, with depreciation difference** $(\delta_k - \delta_g) = 0.06$



First, we look at a one-period example to see how capital resource would be allocated. Suppose that at the beginning of the period, the economy as a whole is endowed with 1 unit of resource which can be allocated between private and public capital i.e. $K + K_g = 1$. Obviously, using $F_k = F_g$ will generate $\frac{K_g}{K} = \frac{\alpha_g}{\alpha_k}$. Also we numerically find the solution (K, K_g) for $F_k = F_g + (\delta_k - \delta_g)$ satisfying the resource constraint. Figure 1.7 displays the results in the case of $(\delta_k - \delta_g)$=0.06 for parameter $\alpha_k \in [0.2, 0.45]$. Particularly we find that misusing the formula $F_k = F_g$

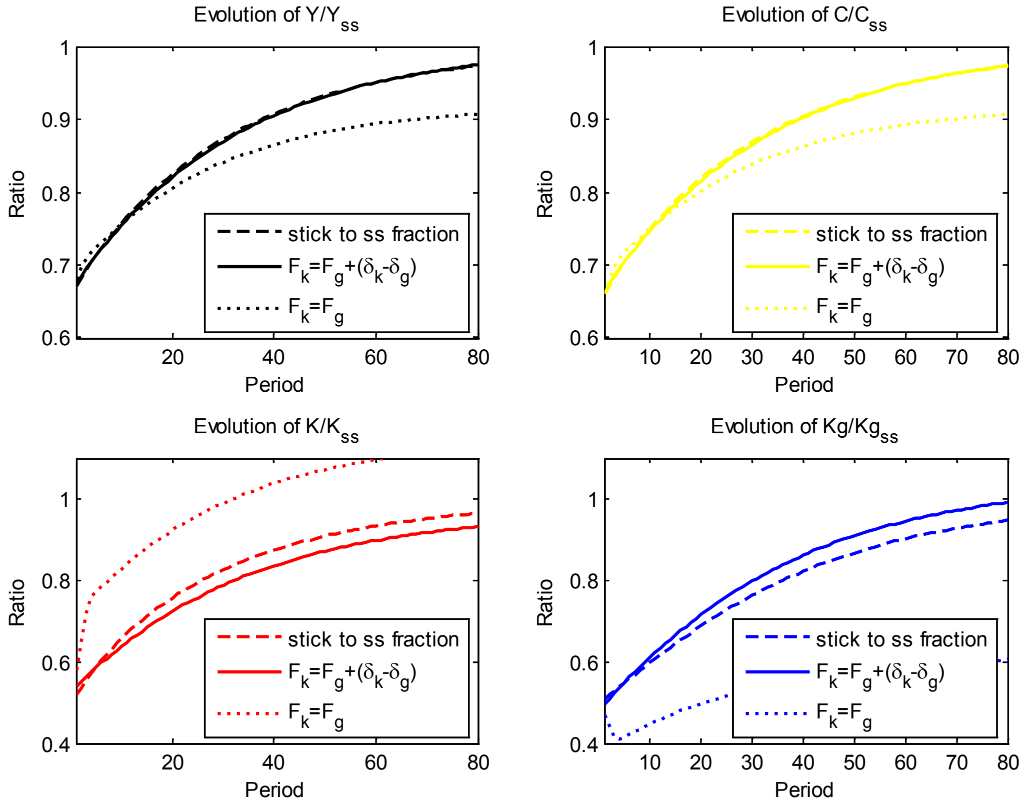
results in a misallocation of average 7.36% of capital stock K. The misallocation would be 4.79% and 10.1% if the depreciation gap is 0.04 and 0.08.

1.A.2. Long-run dynamics and welfare loss

Now we turn to investigate the long-run dynamics of convergence toward the steady state. Since if we use criterion $F_k = F_g$ the balanced growth path (BGP) is not sustainable under $(\delta_k - \delta_g) \neq 0$, we look at the situation before the economy reaches its BGP. Specifically, we let the economy start at $(0.5\bar{K}, 0.5\bar{K}_g)$ where $\bar{K}$ and $\bar{K}_g$ are the steady state capital stocks. Just for illustrative convenience, we currently use a discrete-time version of endogenous growth model in which the social welfare is $\sum_{t=0}^{\infty} \beta^t U(C_t)$. We set quarterly discount rate $\beta = 0.99$ and log-utility $U(C_t) = \ln(C_t)$. The capital stocks are accumulated according to $K_{t+1} = \omega_{k,t} Y_t + (1-\delta_k) K_t$ and $K_{g,t+1} = \omega_{g,t} Y_t + (1-\delta_g) K_{g,t}$. Here $\omega_{k,t}$ and $\omega_{g,t}$ are the fractions of output used for private and public capital accumulation, respectively. Definitely, the proportion for consumption is $\omega_{c,t} = 1 - \omega_{k,t} - \omega_{g,t}$ i.e. $C_t = \omega_{c,t} Y_t$. It is not difficult to calculate that the welfare maximizing steady state private capital stock is $K^* = \left[\frac{(1+\theta)\delta_k}{(\alpha_k+\alpha_g)\Theta^{\alpha_g}}\right]^{\frac{1}{\alpha_k+\alpha_g-1}}$ where $\Theta = \frac{\alpha_g}{\alpha_k} \frac{\frac{1}{\beta}-(1-\delta_k)}{\frac{1}{\beta}-(1-\delta_g)}$ and $\theta = \frac{\delta_g}{\delta_k}\Theta$. Accordingly, $K_g^* = \Theta K^*$ and $Y^* = \Theta^{\alpha_g} (K^*)^{\alpha_k+\alpha_g}$. The steady state fraction $\omega_k = \delta_k \Theta^{-\alpha_g} (K^*)^{1-\alpha_k-\alpha_g}$ and $\omega_g = \theta \omega_k$.

Now we would like to see how the economy gradually converges to the steady state from the start point $(0.5\bar{K}, 0.5\bar{K}_g)$. We consider three types of policy rules for resource allocation: (i) always stick to $\omega_{k,t} = \omega_k$ and $\omega_{g,t} = \omega_g$; (ii) ensure $F_{k,t+1} = F_{g,t+1} + (\delta_k - \delta_g)$; (iii) target $F_{k,t+1} = F_{g,t+1}$. In order to maintain the comparability of consumption process, we let $\omega_{c,t} = \omega_c$ under all three scenarios. We plot the first 80 periods (i.e. 20 years) of the economic evolution in Figure 1.8. In the graph, we set $\alpha_k = 0.33$ and $\alpha_g = 0.27$ and the variables (Y, C, K, K_g) are expressed in terms of the proportion of the steady state values.

Figure 1.8: **Evolution of** (Y, C, K, K_g) **as proportion of the steady state values, with** $(\delta_k, \delta_g, \delta_k - \delta_g) = (0.12, 0.06, 0.06)$



From the figure, we see that the policy (i) and (ii) are almost overlapped while policy (iii) results in a severe deviation from the optimal convergence path. As expected, the policy (iii) results in a large welfare loss. We experiment on different values of $(\delta_k, \delta_g, \delta_k - \delta_g)$ at (0.11, 0.07, 0.04), (0.12, 0.06, 0.06), or (0.13, 0.05, 0.08). Under these parameterizations, the welfare loss of policy (iii) is equivalent to 2.40%, 5.54%, 10.3% permanent consumption reduction, respectively. And the welfare difference between rule (i) and (ii) are completely negligible.

Appendix 1.B. Two illustrative decentralized economy models

In Section 1.3.2, we already showed that in centrally planned economy the social welfare maximization requires $\phi_k F_k = \phi_g F_g + (\delta_k - \delta_g)$. A further question is: does this criterion change in a decentralized economy? Unfortunately a closed form solution for the corresponding criterion is generally infeasible, especially when $\delta_g = \delta_k = 0$ does not hold, unless a set of strict assumptions are imposed into the decentralized model. On the other hand, (as mentioned at Section 1.3.1) several disadvantages of decentralized economy modeling tend to make the effort of finding decentralized solution meaningless in Chinese context. Therefore, in this section we merely use two artificially simplified models to illustrate the form of criterion in a decentralized economy.

Using the two illustrative models, we want to show that $F_k = F_g + (\delta_k - \delta_g)$ can be a convenient good benchmark for empirical policy analysis. We focus the macroeconomic dynamics along the balanced growth path (BGP) (which indeed exists in our simple examples) in which the consumption, capital stock and output grow at the same rate $\gamma = \frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{K_g}}{K_g} = \frac{\dot{Y}}{Y}$.[17] We investigate one example of welfare-maximizing, and another of growth-maximizing tax policy. These two models do not incorporate capital investment efficiency, since this feature complicates the calculation while merely providing essentially analogous insights.

1.B.1. Example with welfare-maximizing tax policy

We look at a situation under welfare-maximizing tax policy through the len of a model with basic setup from Fisher and Turnovsky (1998). The model is actually a simplified decentralized counterpart of our socially planned economy model in Section 1.3.2.

Model setup

The representative private agent maximizes the life-time utility:

$$\int_0^\infty e^{-\rho t} u(c,l)dt$$

subject to the flow budget constraint:

$$\dot{k} = (1-\tau)f(k, K_g^s, l) - s - c - \delta_k k$$

where τ is the distortionary income tax rate and s the amount of lump-sum tax. Following a set of literature (e.g. Turnovsky, 1997; Fisher and Turnovsky, 1998; Gómez, 2004; Dioikitopoulos and Kalyvitis, 2008) we assume the public service $K_g^s = K_g(\frac{k}{K})^\xi$. The individual production function is $y = f(k, K_g^s, l) = f(k, K_g(\frac{k}{K})^\xi, l)$. With homogeneous consumer-producers, in equi-

[17] The growth rate γ can be zero or strictly positive, depending on the specific model functional form and parameterization. But we would not distinguish these two cases intentionally, since the value of γ is not really important for our purpose in theoretical analysis.

librium the aggregate and individual private capital stocks are related by $K = Nk$. With $\psi = N^{-\xi}$ we get the aggregate production $Y = Ny = Nf(k, K_g^s, l) = Nf(\frac{K}{N}, K_g^s, \frac{L}{N}) = F(K, K_g^s, L) = F(K, \psi K_g, L)$. The properties of the assumed individual and aggregate production functions imply the following relationships:

$$F_k = f_k; \quad F_{g^s} = Nf_{g^s}; \quad F_g = \psi F_{g^s}; \quad F_l = f_l$$

where F_k, F_{g^s}, F_g, F_l are the marginal products of Y with respect to the aggregate variables K, K_g^s, K_g, L, respectively. And f_k, f_{g^s}, f_g, f_l are the marginal products of y associated with k, K_g^s, K_g, l. The government finances the public investment by either distortionary or lump-sum tax. Considering the optimization behavior of agents in a decentralized economy, the government intends to maximize the social welfare as the sum of all consumers' utilities by setting the policy instrument – taxation. Government's budget constraint is:

$$\dot{K}_g = \tau F(K, \psi K_g, L) + S - \delta_g K_g$$

Equilibrium optimality conditions

Household's optimization solves the Hamilton function:

$$\mathscr{H} = e^{-\rho t} u(c, l) + \lambda \left[(1-\tau) f(k, K_g (\frac{k}{K})^{\xi}, l) - s - c - \delta_k k \right]$$

taking the policy variables τ, s and aggregate variables K, K_g as given. Two of the first order conditions are:

$$e^{-\rho t} u_c = \lambda$$

$$(1-\tau) \left[f_k + \xi \left(\frac{k}{K} \right)^{\xi - 1} \frac{K_g}{K} f_{g^s} \right] - \delta_k = -\frac{\dot{\lambda}}{\lambda}$$

Plugging the relationships $F_k = f_k$, $F_{g^s} = Nf_{g^s}$ and $F_g = \psi F_{g^s}$, we get an equation in aggregate variables:

$$(1-\tau) \left[F_k + \xi \frac{K_g}{K} F_g \right] - \delta_k = -\frac{\dot{\lambda}}{\lambda}$$

The government flow budget constraint is just another way of writing the transition equation for public capital:

$$\frac{\dot{K}_g}{K_g} = \frac{\tau Y + S}{K_g} - \delta_g$$

Noting that in equilibrium $\frac{\dot{C}}{C} = \frac{\dot{c}}{c}$, obviously imposing several often used assumptions would facilitate us to obtain some simple equations in the macroeconomic dynamic equilibrium.

[Assumption 1] We do not consider the variation of labor input by setting fixed $l = \bar{l}$.

[Assumption 2] We assume consumer has logarithm utility function $u(c) = \ln c$. These result in $\frac{\dot{C}}{C} + \rho = \frac{\dot{c}}{c} + \rho = -\frac{\dot{\lambda}}{\lambda}$. **[Assumption 3]** We restrict that government only levies income tax τY but no lump-sum tax. **[Assumption 4]** A Cobb-Douglas individual production function $f(k, K_g^s) = k^{\alpha_k}(K_g^s)^{\alpha_g}$ is imposed. Therefore, the aggregate production is $F(K, K_g) = Nf(k, K_g^s) = N^{(1-\alpha_k)-\xi\alpha_g} K^{\alpha_k}(K_g)^{\alpha_g}$ which gives $F_k = \alpha_k \frac{Y}{K}$ and $F_g = \alpha_g \frac{Y}{K_g}$. By combining all these four assumptions (i.e. fixed labor input, log-utility, no lump-sum tax, and Cobb-Douglas production function) and noting that $\frac{\dot{C}}{C} = \frac{\dot{K}_g}{K_g}$ along the BGP, we immediately reach an equality $(1-\tau)\left[F_k + \xi \frac{\alpha_g}{\alpha_k} F_k\right] - \delta_k - \rho = \frac{\tau}{\alpha_g} F_g - \delta_g$. Rearranging it produces the simple formula:

$$F_k = F_g + (\delta_k - \delta_g) + \left\{\rho + (\frac{\tau}{\alpha_g} - 1)F_g + \left[\tau - (1-\tau)\xi\frac{\alpha_g}{\alpha_k}\right] F_k\right\}$$

which can be further simplified if the tax rate τ is known.

It is well known that (e.g. Barro, 1990) under the key assumptions of full congestion $\xi = 1$ and $\alpha_k + \alpha_g = 1$, the welfare-maximizing tax rate is $\tau^* = \alpha_g$. In this case, we readily get:

$$F_k = F_g + (\delta_k - \delta_g) + \rho$$

As discussed in Appendix 1.C.1, in fact both the property of setup $K_g^s = K_g(\frac{k}{K})^{\xi}$ and empirical evidence guarantee the reasonability to restrict ξ to be sufficiently close to value 1. Since, fixing other parameters, τ would be a continuous function of ξ, the simple formula $F_k = F_g + (\delta_k - \delta_g) + \rho$ would be a good approximation for situation of ξ around 1.[18] In the next step we further simplify the model to exemplify what could happen when $\xi < 1$.

Under partial congestion, the public capital is no longer shared completely privately and hence the government is able to use a tax rate $\tau < \alpha_g$ to finance public service. In order to obtain a clear solution, we impose one additional assumption onto the previous four. **[Assumption 5]** $\alpha_k + \alpha_g = 1$ in the production function. (Hereby, after adding these five assumptions our model is analogous to that in Dioikitopoulos and Kalyvitis, 2008). Equalizing the growth rate of aggregate consumption γ_c in decentralized economy and γ_c^{SP} in social planner problem, a necessary condition of welfare-maximizing income tax is attained: $\tau^* = \frac{\alpha_g\xi}{\alpha_g\xi + \alpha_k}$. In consequence the simple formula can be written as $F_k = F_g + (\delta_k - \delta_g) + \left[\rho - \frac{\alpha_k(1-\xi)}{\alpha_g\xi + \alpha_k} F_g\right]$. As long as ξ is sufficiently close to 1 (e.g. $\xi = 0.95$), the term ρ is already large enough to offset the negative term $-\frac{\alpha_k(1-\xi)}{\alpha_g\xi + \alpha_k} F_g$. Accordingly we see again that the criterion $F_k = F_g + (\delta_k - \delta_g)$ derived from the central planner solution serves as a good benchmark. (Admittedly, if we suppose that ξ is indeed not enough close to 1 by some reasons, we may get $F_k = F_g + (\delta_k - \delta_g) + NT$ with NT negative. Anyhow, we find the existence of a wedge between F_k and F_g disavows the

[18] Typically the value of time preference rate ρ is quite small, such as 0.02 in Barro (1990). For example, with logarithm utility we have the relationship between ρ and steady state real interest rate $\bar{r}$ that $\bar{r} = \rho + \bar{gr}$ where $\bar{gr}$ is the steady state economic growth rate. Let us assume $\bar{r} = 4\%$ and $\bar{gr} = 2\%$. We accordingly have $\rho = 2\%$. The Section 2 of Weitzman (2010) gives some normative justifications for setting $\rho = 0$.

relationship of $F_k = F_g$.)

We already see that the degree of congestion impacts on the magnitude of wedge $F_k - F_g$, notwithstanding the impact is small when ξ is close to 1. In different places and for different public capital types, the degree of congestion could be dissimilar. Thus the empirical work can be strengthened if we are able to measure the congestion parameter and determine the exact size of optimal wedge. Howbeit this is a difficult work and is important for our empirical research topic only when ξ is far from 1 which case is believed by us to be not. Moreover, it will be promising if we can analyze a more elaborate congestion model beyond setting $K_g^s = K_g(\frac{k}{K})^{\xi}$. However, this likely renders the wedge to depend on the calibration of much more parameters and make empirical research messy. Also, it is highly suspect whether a closed form solution is available (while noting that we need five strict assumptions to get the abovementioned simple formula for $\xi < 1$). Therefore we leave these aspects for work in the future.

1.B.2. Example with growth-maximizing tax policy

Economic growth is usually the main measurable merit of the government's economic intervention. And in China, the GDP growth rate is one of the crucial indicators determining the political promotion chance of local officials. Hence it is useful to analyze the situation with growth-maximizing tax policy. The intuition to answer what would happen is simple. (As usual, we suppose that the government in a decentralized economy aims to maximize the economic growth and needs to levy distortionary tax to finance its policy.) The distortions associated with taxation discourage the accumulation of private capital. As a result the public to private capital ratio z^{max} for growth maximization in decentralized economy is higher than (or in some special case, equal to) the ratio z^{SP} in the first-best social planner situation. Here $z = K_g/K$. Note that the first-best ratio z^{SP} is implicitly restricted by the criterion $F_k = F_g + (\delta_k - \delta_g)$ with usual concave production function. Thus $z^{max} > z^{SP}$ combining with the properties of concave production function implies that the corresponding growth maximization criterion in a decentralized economy would be $F_k = F_g + (\delta_k - \delta_g) + PT$ where PT is some positive term(s).

Following the argument in Dioikitopoulos and Kalyvitis (2008), using the model in Appendix 1.B.1 with the abovementioned five assumptions it can be shown that $\tau^{max} = \alpha_g$ and

$$F_k = F_g + (\delta_k - \delta_g) + [\rho + \alpha_g(1-\xi)F_k]$$

accordingly. Clearly the term $\rho + \alpha_g(1-\xi)F_k$ is positive. In fact, as in the welfare-maximizing case, an explicit simple criterion under growth-maximizing tax policy is (perhaps more) seldom available. But after we check several models it seems that the formula $F_k = F_g + (\delta_k - \delta_g)$ really serves well as the baseline. Here we would like to present another straightforward model for illustrative purpose. A generalized research on growth-maximizing criterion may be done in the future.

The model is revised from Kamps (2005). We addtionally introduce the depreciations δ_g and δ_k into the model. This model intentionally introduces government debt because this makes the derivation of criterion very easy.

Model setup

The representative household maximizes the life-time utility

$$\int_0^{\infty} e^{-\rho t}\frac{c^{1-\sigma}}{1-\sigma}dt$$

subjest to the budget constraint

$$\dot{k}+\dot{d}+c=(1-\tau)y+rd-\delta_k k$$

with individual production function $y=k^{\alpha_k}k_g^{\alpha_g}$ with $\alpha_k+\alpha_g=1$. This model is abstract from the labor input choice and assumes full congestion of public capital. The household takes the tax rate τ, and market interest rate r as given. Since government raises risk-free public debt d at fair interest rate, household is willing to lend any amount of d to government (subject to resource constraint, of course). Hence d is actually decided by government, not household.

Equilibrium optimality conditions

Household's first order optimality conditions can be derived from the Hamiltion function:

$$\mathscr{H}=e^{-\rho t}\frac{c^{1-\sigma}}{1-\sigma}+\lambda\left\{(1-\tau)y+rd-\delta_k k-c\right\}$$

Combining $\frac{\partial\mathscr{H}}{\partial c}=0$ and $\frac{\partial\mathscr{H}}{\partial k}=-\dot{\lambda}$ generates $(1-\tau)f_k-\delta_k=\sigma\frac{\dot{c}}{c}-\rho$. Here f_k is the marginal product of y with respect to k. Along the balanced growth path (BGP) (which indeed exists in this present simple model), the consumption, capital stock and output grow at the same rate $\gamma=\frac{\dot{c}}{c}=\frac{\dot{k}}{k}=\frac{\dot{k}_g}{k_g}=\frac{\dot{y}}{y}$. Thus:

$$\gamma=\frac{1}{\sigma}[(1-\tau)f_k-\delta_k-\rho]$$

In the competitive equilibrium, it must be that:

$$r=(1-\tau)f_k-\delta_k$$

(If $r<(1-\tau)f_k-\delta_k$, household would not lend to government. If $r>(1-\tau)f_k-\delta_k$, government has no incentive to pay such a high interest rate since the interest payment comes from distortionary tax revenue.)

Government's flow budget constraint is:

$$\dot{D}=rD+\dot{K}_g-\tau Y+\delta_g K_g$$

It is assumed that the tax τY in each period is completely used to pay government debt interest payment rD and compensate the public capital depreciation $\delta_g K_g$ i.e. $\tau Y = rD + \delta_g K_g$. Hence, the net accumulation of public capital $\dot{K}_g$ is fully financed by $\dot{D}$ i.e. $\dot{D} = \dot{K}_g$. This means $D = K_g$. The government is assumed to maintain a particular public to private capital ratio z and maximize economic growth γ. Tax and debt are used to serve this purpose. It is obvious that with identical agents under full congestion of public capital, we have $Y = Ny = K^{\alpha_k} K_g^{\alpha_g}$ and thus $F_k = f_k$. The equality $\tau Y = rD + \delta_g K_g$ and $D = K_g$ give:

$$\tau = \frac{(r+\delta_g)K_g}{Y} = (r+\delta_g)z^{\alpha_k}$$

and

$$r = \tau z^{-\alpha_k} - \delta_g = \frac{\tau}{\alpha_g} F_g - \delta_g$$

Now we nearly find the aimed criterion. On the one side, we get $r = \frac{\tau}{\alpha_g} F_g - \delta_g$ from government budget constraint. On the other side, we have $r = (1-\tau) f_k - \delta_k = (1-\tau)F_k - \delta_k$ by household's optimization. Thus clearly:

$$(1-\tau)F_k - \delta_k = \frac{\tau}{\alpha_g} F_g - \delta_g$$

But in this equation the tax rate τ is still unknown. In this illustrative example we focus on the case of maximized growth rate γ^{max} along the BGP. Appendix 1.C.2 documents the steps to find the value of growth maximizing τ^{max} which is α_g.

Now we ultimately get the optimality condition assuming $\alpha_k + \alpha_g = 1$ in a decentralized economy: $(1-\alpha_g)F_k - \delta_k = F_g - \delta_g$ i.e.

$$F_k = F_g + (\delta_k - \delta_g) + \alpha_g F_k$$

Comparing this with the first-best case criterion $F_k = F_g + (\delta_k - \delta_g)$, we find the depreciation wedge is increased in the decentralized economy. This is consistent with our intuition $F_k = F_g + (\delta_k - \delta_g) + PT$ with PT positive. This model presented above is extremely simplified and only for illustrative purpose. Especially, the constant return to scale assumption $\alpha_k + \alpha_g = 1$ is very helpful to get the simple criterion. In a more elaborate and realistic model, it is in general very difficult to get the explicit expression of the PT term. We may, again, resort to simple intuition to get some insights.

We consider two possible ways to extend the model – incorporating (i) the congestion of public capital i.e. the negative externality of private capital accumulation, and (ii) maintenance expenditure to reduce depreciation of public capital. In the decentralized economy, the growth-maximizing tax rate will be positively related to the degree of public service congestion in the economy because of the desirability of tax to mitigate the intensity of private capital's negative externality. The growth-maximizing tax rate will be higher in the existence of public capital maintenance, which needs to be financed to sustain the high usage or lower the depreciation of public capital. So in both cases the growth maximization tax rate is likely higher. In consequence the ratio z^{max} is probably larger; and the depreciation rate wedge between F_k and F_g may increase. Admittedly, this intuition may not be correct in some circumstances. For example, in the model of Dioikitopoulos and Kalyvitis (2008) in which congestion and public capital maintenance are present together, they find the interaction of them may make the overall effect of congestion on the growth-maximizing tax rate ambiguous, depending on the initialization of congestion level and structural parameters. A detailed analysis is complicated and not our concern here.

Although a detailed theoretical analysis based on a generalized decentralized economy model would be beneficial, that is far beyond the scope of our current paper. Now we summarize our finding from theoretical model briefly: the optimization in a centralized or decentralized economy would always require a wedge between F_k and F_g as long as the condition $\delta_g = \delta_k = 0$ does not hold; and the formula $F_k = F_g + (\delta_k - \delta_g)$ is found to be a good benchmark criterion for policy analysis.

Appendix 1.C. Supplement for Appendix 1.B

1.C.1. Argument for (nearly) full congestion (i.e. ξ close to 1) setup of public capital

(1) Property of of setup $K_g^s = K_g(\frac{k}{K})^{\xi}$

Following a set of literature we assume the public service $K_g^s = K_g(\frac{k}{K})^{\xi}$. For simplicity, we focus on the Cobb-Douglas individual production function $y = k^{\alpha_k}(K_g^s)^{\alpha_g}$. In equilibrium, the aggregate and individual private capital stocks are related by $K = Nk$. Thus we have the aggregate production $Y = Ny = N^{(1-\alpha_k)-\xi\alpha_g}K^{\alpha_k}K_g^{\alpha_g}$. As an example we restrict that $\alpha_k + \alpha_g = 1$. Then we get $Y = K^{\alpha_k}K_g^{\alpha_g}N^{(1-\xi)\alpha_g}$ and accordingly $\frac{Y}{K} = N^{(1-\xi)\alpha_g}\left(\frac{K_g}{K}\right)^{\alpha_k}$. Usually in real economy, the value of N (i.e. the amount of economic units e.g. population) is very large. Hence the term $N^{(1-\xi)\alpha_g}$ is large when ξ is not sufficiently close to 1. On the other hand, we know if we count Y, K and K_g in the real world by monetary value, we should observe that $\frac{Y}{K} = \mathscr{O}(1)$ and $\frac{K_g}{K} = \mathscr{O}(1)$. This fact contradicts the situation that $\frac{Y}{K} = N^{(1-\xi)\alpha_g}\left(\frac{K_g}{K}\right)^{\alpha_k}$ when $N^{(1-\xi)\alpha_g}$ is very large (compared to value 1). In other words, the setup of $K_g^s = K_g(\frac{k}{K})^{\xi}$ naturally only allows the parameterization that ξ is sufficiently close to 1 i.e. (nearly) full congestion.

In order to eliminate the scale effect related to large N, Dioikitopoulos and Kalyvitis (2008) set up that $y = k^{\alpha_k}\left(\frac{K_g^s}{N^{1-\xi}}\right)^{\alpha_g}$. In this case, we get a very convenient aggregate production function $Y = K^{\alpha_k}K_g^{\alpha_g}$. But now the individual production itself is problematic. In equilibrium of $K = Nk$, we have $y = k^{\alpha_k}\left(\frac{K_g N^{-\xi}}{N^{1-\xi}}\right)^{\alpha_g} = k^{\alpha_k}\left(\frac{K_g}{N}\right)^{\alpha_g}$. The aggregate public capital stock is equally divided by all N agents and each agent only takes the $\frac{K_g}{N}$ piece of government capital into account. This turns out to be the full congestion circumstance regardless of the value of ξ, which denies our attempt of using parameter $0 \leqslant \xi < 1$ to model non-full congestion situation. So, whether eliminating the scale effect or not, we see that letting ξ to be close to 1 is the reasonable setup of congestion model.

(2) Empirical evidence

Full congestion of public capital means that the public service enjoyed by a production unit is proportional to its relative economic scale among all firms. In order to ensure the level of public service available to the individual firm to remain fixed, when individual private capital stock k is unchanged the aggregate public capital K_g should increase in proportion to the aggregate private capital stock K. Those infrastructures such as transportation, energy used directly in private production and input-output distribution may have this full congestion characteristic. Also, in population dense area such as big cities the high degree of public service congestion is often observed. Craig (1987) and Edwards (1990) discuss some evidences that the local public goods could be quite congested. Recently, Breunig and Rocaboy (2008) use French data to estimate the effect of municipality size on per capita public expenditure. They find the very large population is associated with a severe congestion of public goods. This finding would be quite probably applicable to China.

Furthermore, the local governments often pay much attention and is willing to incline public policy toward the large firms located in the domain because of their crucial roles of taxpayer, GDP creator and employer. In some developing countries without transparent politics, the economic scale may be one-to-one or even one-to-more convertible to political influence. This generates economic rent and enables the public capital congestion parameter ξ close or even over 1.

1.C.2. Derivation of $\tau^{max} = \alpha_g$ in the illustrative decentralized economy growth-maximizing tax policy example

Plugging $\tau = (r+\delta_g)z^{\alpha_k}$ into $r = (1-\tau)F_k - \delta_k = (1-\tau)\alpha_k z^{\alpha_g} - \delta_k$, after arrangement we express r in terms of z: $r = \frac{\alpha_k z^{\alpha_g} - \alpha_k \delta_g z - \delta_k}{1+\alpha_k z}$. Since we already have $\gamma = \frac{1}{\sigma}[(1-\tau)f_k - \delta_k - \rho] = \frac{1}{\sigma}[r-\rho]$, we now get γ as a function of z: $\gamma = \frac{1}{\sigma}\left[\frac{\alpha_k z^{\alpha_g} - \alpha_k \delta_g z - \delta_k}{1+\alpha_k z} - \rho\right]$. Along the BGP, γ is maximized with respect to z. Thus z^{max} is the solution to $\frac{\partial \gamma}{\partial z} = 0$ which is equivalent to

$$\alpha_k^2 z^{max} - (\delta_k - \delta_g)(z^{max})^{\alpha_k} - \alpha_g = 0$$

This equation has no general closed form solution. Howbeit it is sufficient to help us obtain growth maximization tax rate τ^{max}.

We can write τ in terms of z. Plugging $r = \frac{\alpha_k z^{\alpha_g} - \alpha_k \delta_g z - \delta_k}{1+\alpha_k z}$ into $\tau = (r+\delta_g)z^{\alpha_k}$ we have $\tau = \frac{\alpha_k z - (\delta_k - \delta_g)z^{\alpha_k}}{1+\alpha_k z}$. Rearranging this generates

$$(1-\tau)\alpha_k z - (\delta_k - \delta_g)z^{\alpha_k} - \tau = 0$$

This apparently means that $\tau^{max} = \alpha_g$ gives the desirable z^{max}.

Appendix 1.D. Panel unit root tests for regression variables

Table 1.6 presents the panel unit root test result for variables of output, capital stock and skill-adjusted labor amount. The sample period is 2004-2015. In the table we report 5 test statistics: the LLC (Levin, Lin and Chu) t-, Breitung t-, IPS (Im, Pesaran and Shin) W-, ADF-Fisher χ^2- and PP-Fisher χ^2-Statistic. Intentionally, the Hadri test is not relied on because it is not informative for our sample, as it always rejects the stationarity null hypothesis for all variables.

Table 1.6: **Panel unit root tests for regression variables**

Variable	**Test Statistics**					**Whether It is Stationary?**	
	LLC	**Breitung**	**IPS**	**Fisher-ADF**	**Fisher-PP**	**based on 5 tests**	**based on Fisher-ADF**
Levels							
$\ln Y$	4.455	5.043	8.931	16.503	2.312	No	No
$\ln y$	1.059	-2.597***	5.205	28.856	29.490	No	No
$\ln K_g$	-1.211	5.668	2.517	59.411	75.518*	No	No
$\ln k_g$	-0.679	9.318	2.365	63.627	73.656	No	No
$\ln K$	-6.717***	0.376	0.730	63.602	72.540	No	No
$\ln k$	-4.167***	2.302	1.432	57.213	46.498	No	No
$\ln L$	-2.592***	0.406	2.793	48.557	40.224	No	No
First Differences							
$\Delta \ln Y$	-8.400***	1.007	-1.608*	86.703**	118.421***	Yes	Yes
$\Delta \ln y$	-16.483***	-3.649***	-5.389***	155.089***	223.077***	Yes	Yes
$\Delta \ln K_g$	-11.269***	-1.066	-4.405***	124.412***	171.421***	Yes	Yes
$\Delta \ln k_g$	-10.932***	1.062	-4.405***	136.349***	217.059***	Yes	Yes
$\Delta \ln K$	-12.500***	1.834	-3.165***	102.298***	132.064***	Yes	Yes
$\Delta \ln k$	-10.150***	-0.853	-3.006***	108.901***	132.651***	Yes	Yes
$\Delta \ln L$	-19.740***	-2.584***	-7.606***	187.351***	301.163***	Yes	Yes

Note: (1) */**/*** indicate the rejection of the null hypothesis of unit root at the 10%/5%/1% significance level, respectively. (2) An individual intercept and trend are contained in test equation. Lag length is selected automatically based on Schwarz information criterion.

Furthermore, we report whether the variables are stationary based on the test statistics at 10% significance level. Considering that sometimes different tests indicate distinct consequences, the column "based on 5 tests" refers to the judgement depending on whether at least 3 tests reject/unreject unit root hypothesis. We also report the judgement using the Fisher-ADF statistic in the column "based on Fisher-ADF", as this test is most often used in literature. A reading of Table 1.6 finds that all variables are $I(1)$. This justifies our employment of first difference to make variables stationary.

Appendix 1.E. Misusage of ACF approach in Shi and Huang (2014)

First let us recall how SH use the ACF approach (by using the notation in SH paper and suppressing the first difference operator without loss of generality). It is assumed that the TFP shock ε_{st} can be decomposed into two components: $\varepsilon_{st} = \varpi_{st} + \mu_{st}$ where "ϖ_{st} **is the part of the TFP shock anticipated in advance**" (by capital investors but unobservable to econometrician) which affects $\ln k_{i,st}$ and $\ln k_{p,st}$, and μ_{st} is the part of the TFP shock unanticipated in advance which is uncorrelated with $\ln k_{i,st}$ and $\ln k_{p,st}$. Then SH argue that the observable private consumption per working resident $\ln c_{st}$ increases monotonically with the variable ϖ_{st}. Thus for given $(\ln k_{i,st}, \ln k_{p,st})$, $\ln c_{st}$ is a monotonic function of ϖ_{st}: $\ln c_{st} = \phi(\varpi_{st}, \ln k_{i,st}, \ln k_{p,st})$ which gives $\varpi_{st} = \phi^{-1}(\ln c_{st}, \ln k_{i,st}, \ln k_{p,st})$. "**Assuming that ϖ_{st} follows a first-order Markov process**", ϖ_{st} can be rewritten as $\varpi_{st} = \rho(\varpi_{st-1}) = \rho\left[\phi^{-1}(\ln c_{st-1}, \ln k_{i,st-1}, \ln k_{p,st-1})\right] = \varphi(\ln c_{st-1}, \ln k_{i,st-1}, \ln k_{p,st-1})$ where the function ρ governs the first-order Markov process of ϖ_{st} and function φ is the composition of ρ and ϕ^{-1}. Ultimately in the regression model the coefficients for $\ln k_{i,st}$ and $\ln k_{p,st}$ can be identified because the correlated term ϖ_{st} is proxied by $\varphi(\ln c_{st-1}, \ln k_{i,st-1}, \ln k_{p,st-1})$.

Below we show that SH's application of ACF approach is quite implausible from both the aspects regarding "timing" and "Markov" assumptions (which are both crucial in ACF approach). The original idea of ACF method refers to Ackerberg, Caves and Frazer (2006). Ornaghi and Van Beveren (2011) compares several relevant approaches, including ACF, of using observable proxy variables to control for unobservables when estimating productivity.

1.E.1. Regarding "timing" assumption

In SH, ϖ_{st} is the part of the TFP shock anticipated in advance. Let us use another notation to indicate the nature of "anticipation" and write it as $E(\omega_{st}|I_{t-1})$ where I_{t-1} is the information set at the start of period t. We use p_{st} to refer to the selected proxy variable which is $\ln c_{st}$ in SH. Under these notations we have $p_{st} = \phi_t(E(\omega_{st}|I_{t-1}), k_{i,st}, k_{p,st})$. Without loss of generality we assume the private capital stock $k_{p,st}$ has the timing analogous to infrastructure stock $k_{i,st}$. In period t, the infrastructure and non-infrastructure stock are not predetermined and correlated to the anticipated TFP shock $E(\omega_{st}|I_{t-1})$. Without loss of generality we can express that $k_{i,st} = g_i(E(\omega_{st}|I_{t-1}), Plan_{i,st})$ and $k_{p,st} = g_p(E(\omega_{st}|I_{t-1}), Plan_{p,st})$ where $Plan$ refers to some predetermined investment and production plans. In this way we actually have $p_{st} = \phi_t(E(\omega_{st}|I_{t-1}), Plan_{i,st}, Plan_{p,st})$. Since $k_{i,st}$ and $k_{p,st}$ is not predetermined, merely from $p_{st} = \phi_t(E(\omega_{st}|I_{t-1}), k_{i,st}, k_{p,st})$ and based on historical data of $p_{st}, k_{i,st}, k_{p,st}$ we can never know *a priori* whether the proxy p_{st} is really monotonic to $E(\omega_{st}|I_{t-1})$. Since we do not have the knowledge about $g_i(\cdot)$ and $g_p(\cdot)$, we cannot infer the details of $Plan_{i,st}$ and $Plan_{p,st}$ and hence cannot test *a posteriori* whether p_{st} is a monotonic function of $E(\omega_{st}|I_{t-1})$.

Therefore, in SH we in fact can never assure that the selected proxy $\ln c_{st}$ is monotonic to ϖ_{st}.

1.E.2. Regarding "Markov" assumption

Even though we assume that p_{st} is a monotonic function of $E(\omega_{st}|I_{t-1})$ and hence $E(\omega_{st}|I_{t-1}) = \phi_t^{-1}(p_{st}, k_{i,st}, k_{p,st})$ holds, we still have the following problems. Under SH's assumption that $\varpi_{st} = \rho(\varpi_{st-1})$ we have $E(\omega_{st}|I_{t-1}) = \rho\left[E(\omega_{st-1}|I_{t-2})\right]$ in our notation. This means the agents only form $E(\cdot|I_t)$ based on $E(\cdot|I_{t-1})$ i.e. $E(\cdot|I_t) = \rho\left[E(\cdot|I_{t-1})\right]$ and never adjust the expectation based on the realization of innovation in TFP observed in the last period. This is clearly not a reasonable assumption.

Hence, it can hardly be true that $\varpi_{st} = \rho(\varpi_{st-1})$ as in SH.

1.E.3. Regarding "timing" assumption

Regardless of the reasonableness of $\varpi_{st} = \rho(\varpi_{st-1})$ assumption, we now check the timing of the variables' sequence in SH which is:

Period $t-1$	Period t	Period $t+1$
... $\Rightarrow y_{st-1}$	$\Rightarrow E(\omega_{st}|I_{t-1})$ $\Rightarrow (k_{i,st}, k_{p,st})$ $\Rightarrow p_{st}$ $\Rightarrow \omega_{st}$ $\Rightarrow y_{st}$	$\Rightarrow E(\omega_{st+1}|I_t)$ ...

Under SH's timing assumption, the TFP shock ω_{st} realizes at last, after all other variables except output (otherwise the proxy variable $\ln c_{st}$ should be a function of realized ω_{st} rather than the anticipated $E(\omega_{st}|I_{t-1})$). This timing structure is obviously implausible.

1.E.4. Regarding "Markov" assumption

Perhaps when SH express "... ϖ_{st} is the part of the TFP shock anticipated in advance", they actually want to refer to ω_{st} rather than $E(\omega_{st}|I_{t-1})$. However, using ω_{st} does not improve the plausibility of SH's application of the ACF approach. Generally, in macroeconomic models with the assumption that TFP shock ω_{st} follows a first-order Markov process, we cannot write $\omega_{st} = \rho(\omega_{st-1})$. In contrast, the true formulation of the process is $\omega_{st} = E(\omega_{st}|I_{t-1}) + \xi_{st} = \tilde{\rho}(\omega_{st-1}) + \xi_{st}$ (by noting that with Markov property the information set I_{t-1} is ω_{st-1}) where ξ_{st} is the innovation to TFP, which is uncorrelated to $(k_{i,st}, k_{p,st}, p_{st})$.

In order to make SH's argument working, it is required that $\omega_{st} = \rho(\omega_{st-1})$ for some certain function $\rho(\cdot)$. But undoubtedly $\omega_{st} \neq \tilde{\rho}(\omega_{st-1})$ unless $\xi_{st} = 0\ \forall t$ (or likewise, ξ_{st} is a known nonrandom function of some known variables) i.e. the whole TFP process is not stochastic. This case is definitely not realistic. Even though we accept that the TFP process can be wholly deterministic, we can never accept what is implied from this determinism. In the deterministic case that $\xi_{st} = 0\ \forall t$, we have $\omega_{st} = E(\omega_{st}|I_{t-1}) = \rho(\omega_{st-1}) = \rho\left[\rho(\omega_{st-2})\right] = ... = \rho^t(\omega_{s0})$. Thus, (since the form of function $\rho(\cdot)$ can be estimated by some, for example nonparametric, method) the whole path of TFP shock can be known as long as the initial value ω_{s0} or the value ω_{st-n} in a specific period is exactly measured. In this nonrandom circumstance, there is no reason why the econometrician cannot measure ω_{s0} or ω_{st-n} and then get ω_{st} directly (while the government and private sector know it and adjust capital investment as a response).

Thereupon using the realized TFP shock ω_{st} instead of $E(\omega_{st}|I_{t-1})$ in SH's argument does not help it work.

1.E.5. Short summary

Although we have not strictly proven the infeasibility of the application of ACF approach in SH, we have shown logically that it stood on a set of unconvincing assumptions that should be ruled out. The key problem is that in order to mitigate the endogeneity bias and estimate the coefficients for $(\ln k_{i,st}, \ln k_{p,st})$ directly, SH attempt to introduce the last period variables $(\ln c_{st-1}, \ln k_{i,st-1}, \ln k_{p,st-1})$ to replace ϖ_{st} by assuming $\varpi_{st} = \rho(\varpi_{st-1})$ – but $\varpi_{st} = \rho(\varpi_{st-1})$ does not depict the Markov process of TFP shock in a correct manner. (Even though assuming that SH's approach is without problem, we will face a difficulty to explain the regression result since the time $t-1$ capitals appear in the time t regression model. Thus, by construction the capitals have one period lag impacts on production which make the definition of marginal product ambiguous.)

In fact, if we tightly follow ACF's original two-stage regression procedure (rather than SH's revised approach), it is still possible to get a relatively good estimator. However, we do not do that because of the intrinsic charateristics of aggregate production function on which we disscuss below. ACF (and several other relevant) approach was devised initially for firm-level analysis. Since in firm-level production the inputs are often lumpy, it is much easier to find clear timing structure and select suitable proxy. But in an aggregate economy the things differ. (1) At macroeconomic level the input, output, investment and consumption happen every day. While GDP measures a flow during a period interval, aggregate capitals which vary frequently are only available in stock data at specific time points. So, using the start-of-the-year capital stock K_t may underestimate the (average) input really utilized while using the end of year capital stock K_{t+1} (which is used in SH) may overestimate the real (average) input. A weighted average of K_t and K_{t+1} perhaps approximates the amount of input well but we do not know the proper weight. (2) More importantly, the timing assumption of ACF approach requires that the selected proxy variable should occur after the capital inputs were determined. There exist no such an aggregate variable at all – the capital inputs actually vary all the year round. Thus, applying AFC method restricts us to think the world in an unjustified way: aggregate capital stock is determined in one specific moment and the proxy variable is produced after that. (3) Furthermore, we select to use first differenced data to avoid spurious regression. The timing structure is disordered after first differencing. Considering the reluctance of employing the method in aggregate production model, we in practice do not fully rely on proxy variable to control for unobservable TFP shock. We rely on the start-of-the-year capital stock as explanatory variable, and add time fixed effects dummies. The details of our empirical approach are in Section 1.4.

Appendix 1.F. Data source

We rely on the official data supplied by the National Bureau of Statistics (NBS) of China.

1.F.1. Capital

(1) Industry categorization

The infrastructure includes 4 industrial sectors: (i) production and supply of electricity, gas and water, (ii) transport, storage and post, (iii) information, transmission, computer service and software, (iv) management of water conservancy, environment, and public facilities. The non-infrastructure contains all other industries except the abovementioned four infrastructure industries. It is notable that we actually leave the investment in human capital (e.g. education and health) and social administration (e.g. government) in the group of non-infrastructure. Although these "social infrastructure" are different from the private capital, it is not necessary to extract them as an independent category because (1) their capital stock size is really small, and (2) the relevant information is implicitly utilized later when we adjust the level of labor by human capital.

(2) Efficiency-adjusted investment flow

(i) Indicator selection The NBS reports three types of capital investment series that can be used to construct capital stock data. One is "*Gross Fixed Capital Formation*"; another one is "*Total Investment in Fixed Assets*"; the last one is "*Newly Increased Fixed Assets*". We follow Jin (2016) and Wang and Szirmai (2012) to use "*Newly Increased Fixed Assets*", as the definition of this statistical item is more consistent with what we need – the investment-efficiency-adjusted capital investment flow data.

(ii) Available data We need the investment flow data of "*Newly Increased Fixed Assets*" for each single industry at province level, which is not fully reported by NBS. For each province, NBS provides the total investment data for all industries as a whole. However, separately for each industry, NBS only reports a (major) part of the investment flow. (1) Mainly used in the before-2003 statistics, by "*Channel of Management*" NBS divides the investment into four types: "*Capital Construction*", "*Innovation*", "*Real Estate Development*", and "*Others*". NBS only provides the data of "*Newly Increased Fixed Assets*" for the first two items "*Capital Construction*" and "*Innovation*", in *China Statistical Yearbook 1994-20*03. Although these two items count for the major part (around 50%) of investment, we still need to estimate the size of another two items "*Real Estate Development*" and "*Others*". (2) Mainly used in the after-2003 statistics, NBS groups the investment by "*Urban Area*" and "*Rural Area*". NBS only provides the data of "*Newly Increased Fixed Assets*" for "*Urban Area*", in *China Statisti-*

cal Yearbook 2004-2016. Although the "*Urban Area*" counts for the major part (around 90%) of investment, we still need to estimate the size in "*Rural Area*".

(iii) Estimating the missing data To estimate the missing part of the investment data at industry level, we follow the approach in Jin (2016) by utilizing the reported data of "*Newly Increased Fixed Assets*" for all industries as a whole in each province. (1) For the before-2003 statistics, we assume that in each industry, the ratio of total investment (as the sum of its four sub-items) to the sum of its first two sub-items "*Capital Construction*" and "*Innovation*" is the same. (Let us call it the "adjustment ratio".) Hence, we calculate this ratio for all industries as a whole, and then multiply the "*Capital Construction*" plus "*Innovation*" investment data by this ratio to obtain the estimated total investment data for each single industry. (2) For the after-2003 statistics, likewise, we assume that in each industry the ratio of total investment (as the sum of urban and rural parts) to the investment in "*Urban Area*" is the same. Hence, we calculate this ratio for all industries as a whole, and then multiply the "*Urban Area*" investment by this ratio to obtain the estimated total investment of each industry.

The investment data is distributed in several kinds of statistical yearbooks. (a) The 1993-2002 investment data for "*Capital Construction*" and "*Innovation*" items and 2003-2015 data for "*Urban Area*" at industry level is documented in *China Statistical Yearbook 1994-2016*. (b) The data of "*Newly Increased Fixed Assets*" for all industries as a whole in year 1996-1998, 2002-2012, 2014-2015 is reported by *Statistical Yearbook of the Chinese Investment in Fixed Assets 1997-1999, 2003-2013, 2015-2016*. This statistical yearbook series did not publish in year 2000-2002 and 2014. The data of 1999 and 2000 can be found in *China Real Estate Statistics Yearbook 2000* and *Report on the Chinese Investment in Fixed Assets 2001*, respectively. For the missing data of 2001 and 2013, we check the corresponding *Statistical Yearbook* of each province and get the data of 18 provinces in 2001 and 20 provinces in 2013. (c) Now we still lack the data for all provinces during 1993-1995 and some provinces in 2001 and 2013. Since we only need the value of "adjustment ratio" which should not be volatile within a short period, we can use the ratios in neighboring years to approximate. We use the ratio in 1996 to approximate the value during 1993-1995. And we use the average of the ratio in the previous and following year to approximate the value in 2001 and 2013.

(3) Investment efficiency

Because of the capital adjustment cost and waste, not all investment creates new capital. Since "*Newly Increased Fixed Assets*" is a good measure of the efficiency-adjusted investment flow, it is natural to calculate the investment efficiency through dividing "*Newly Increased Fixed Assets*" by the amount of raw investment before efficiency-adjustment. The size of raw investment is measured by the statistical item of "*Total Investment in Fixed Assets*".[19] The ratio of

[19] Since NBS only reports the industry level "*Newly Increased Fixed Assets*" for the sub-item "*Capital Construction*" plus "*Innovation*" in before-2003 data and for the sub-item "*Urban Area*" in after-2003 data, we also

"*Newly Increased Fixed Assets*" to "*Total Investment in Fixed Assets*" is equal to the item "*Rate of Projects of Fixed Assets Completed and Put into Operation*" reported by NBS. However, direct using this rate to measure investment efficiency may have problem. The "*Total Investment in Fixed Assets*" reports the size of raw investment within the current period. While the "*Newly Increased Fixed Assets*" measures the efficiency-adjusted investment that is completed and put into operation in this period, the whole investment project may span several periods and have been started before the current year. Thus, some of the "*Newly Increased Fixed Assets*" may be the fruit of "*Total Investment in Fixed Assets*" in the past periods. Consequently, if the investment has a sharp decline compared to last year, since some projects of the last period are completed and put into work in this period the calculated investment efficiency would be overestimated. Conversely, an abrupt growth of investment in a period tends to make the investment efficiency underestimated. Taking into account this problem, we use HP filter to get the smooth trend of the estimated investment efficiency. This smoothed indicator better reflects the investment efficiency over a long period.

(4) Capital price

NBS reports the price indices for investment in (i) "*Construction and Installation*", (ii) "*Purchase of Equipment and Instruments*", (iii) "*Others*", and calculates the "*Price Index for Investment in Fixed Assets*" as a weighted average of these three components. If infrastructure and non-infrastructure have significantly different investment components, we should deflate them using different price indices. Table 1.7 documents the investment components of infrastructure, non-infrastructure and all capitals as a whole based on the country-wide average during 2003-2015. It can be seen that the infrastructure has a higher share of building and lower share of equipment, compared to non-infrastructure investment. However, the difference is actually not large. In other words, the components of infrastructure and non-infrastructure are similar to that of all capitals as a whole. Therefore, we can directly use the "*Price Index for Investment in Fixed Assets*" for all capital types.

Table 1.7: **Investment components of infrastructure and non-infrastructure**

Investment component	**Building**	**Equipment**	**Others**	**Estimated δ (a)**	**Estimated δ (b)**
All capitals	63.3%	21.1%	15.5%	9.4%	12.9%
Infrastructure	66.9%	17.6%	15.5%	9.1%	12.4%
Non-infrastructure	62.0%	22.4%	15.6%	9.5%	13.1%

Note: (1) The investment component data is based on the country-wide average during 2003-2015. (2) "Estimated δ (a)" is based on the assumption that the depreciation rates of building, equipment and others are 6.9%, 14.9%, 12.1%, respectively. "Estimated δ (b)" is based on the assumption that the depreciation rates are 8%, 24%, 18%, respectively.

use the "*Total Investment in Fixed Assets*" data for these sub-items to calculate the investment efficiency.

(5) Depreciation rate

The most debatable variable is the depreciation rate of capital. Wu (2009) briefly investigates the literature and finds that "different rates of depreciation have been used, ranging from 3.6 to 17.0 per cent". Essentially, the infrastructure may depreciate at a different rate than non-infrastructure because they may have different capital components with dissimilar depreciation rates. The column "Estimated δ (a)" of Table 1.7 calculates the depreciation rates based on Zhang, Wu and Zhang (2004)'s assumption that the building, equipment and other capitals have depreciation rates of 6.9%, 14.9%, 12.1%, respectively. The column "Estimated δ (b)" calculates based on the assumption that building and machine's depreciation rates are 8% and 24% (Bai, Hsieh and Qian, 2006) and other capitals have a rate of 18%. We see that though the infrastructure has a lower rate than non-infrastructure, the difference is not large. This seemingly contradicts what we discussed in Section 1.3.3 that the depreciation rate difference should be substantial. However, we need to consider that the numbers of investment component shares provided in Table 1.7 is only informative about the amount, rather than the property, quality or utilization of infrastructure versus non-infrastructure. Especially it is possibe that the property of infrastructure building makes it less depreciated than non-infrastructure building. For instance, it is usual to find a bridge or road that was used for tens of years, rather than a house in factory or ironworks. Furthermore, the maintenance spending on public capital can largely extend the service life of infrastructure.

As a compromise between what we estimated in Table 1.7 and that discussed in Section 1.3.3, we choose a depreciation rate of 9.5% for non-infrastructure and 8% for infrastructure. This selection is conservative. Later in the robustness check at Section 1.6.3, we also alter our depreciation rates and redo our empirical procedure. The (not much different) results are reported there.

1.F.2. Labor

Three different variables are usually used to represent the aggregate labor supply – population, labor amount, and skill-adjusted labor amount. We follow Barro and Lee (2010) to calculate the skill-adjusted labor amount. The formula is $L_t = LAB_t * ADJ_t = (POP_t * LABRATIO_t) * ADJ_t$ where L_t is the amount of skill-adjusted labor; LAB_t is raw labor amount; POP_t is population; $LABRATIO_t$ is the ratio of labor in population which is represented by fraction of people aged 15-64; ADJ_t is a coefficient used to adjust the labor according to the skill level. For POP_t we do not use the population data reported in *China Statistical Yearbook* directly. Instead, we derive it by dividing nominal GDP by nominal GDP per capita as suggested in Li and Gibson (2013). The data of $LABRATIO_t$ is easily calculated from *China Population Statistics Yearbook 1994-2006* and *China Population and Employment Statistics Yearbook 2007-2016*. Since there are several unusual jumps in the $LABRATIO_t$ time series, which suddenly return to the original trend in the following years and are obviously the result of sample error, we smooth the series by HP filter. We do not multiply the labor amount by employment rate because the reported employment rate is often not regarded reliable.

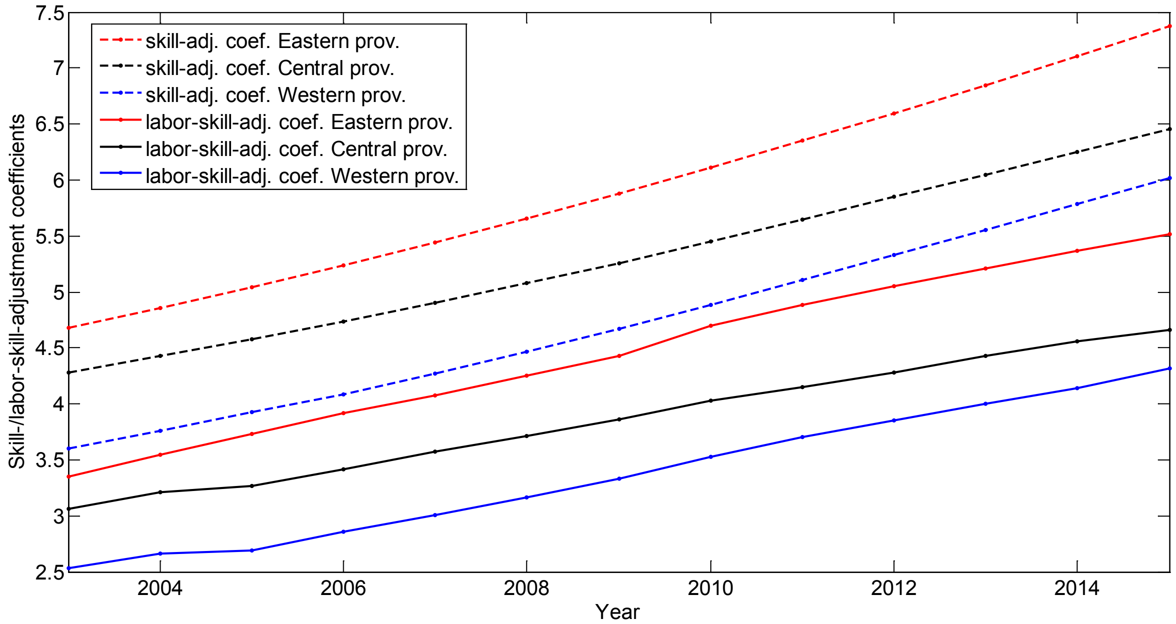
It is assumed that $ADJ_t = \Phi(s_t)$ where s_t is a proxy variable for human capital. As in Barro and Lee (2010), we use years of schooling of the worker s_t to proxy human capital, and we further assume that $\Phi(s_t) = e^{\theta s_t}$. The parameter θ can be calculated from $RS = LS * \theta$ where RS is the marginal rate-of-return to schooling and LS is share of labor in total output.

Chen and Hamori (2009), Zhu (2011) report the RS of 7%-8%, 9%-10% in China in recent years. This magnitude is also supported by a series of research such as Ren and Miller (2012), Zhang et al. (2005). Hence, we set RS=0.075. Admittedly, some studies (e.g. Li, Liu and Zhang, 2012) report a lower level of RS around or even below 5%. We check the case of lower RS, and find our estimation result is robust.

We also need to set the value of labor share parameter LS. It is widely found that the labor share in China declined in recent decade, and is around 40%. Chi and Qian (2013), Karabarbounis and Neiman (2014), Qian and Zhu (2012) among others discuss the associated evidences. Following their findings, we set LS=0.4. Therefore we have θ=RS/LS=0.1875. Of course it can be argued that the θ could be heterogeneous across different provinces, but unfortunately we have no data about that and can only set it country-widely constant.

Figure 1.9 shows the average value of labor-skill-adjustment coefficients $LABRATIO_t * ADJ_t$ and skill-adjustment coefficients ADJ_t for the eastern, central and western provinces. We see that the labor markets in the three districts are obviously different. Both the labor-skill-adjustment and skill-adjustment coefficients in the eastern provinces are highest. This is a result of both highest labor proportion and most schooling years. The western provinces, with the lowest level of labor ratio and schooling, have the smallest adjustment coefficients.

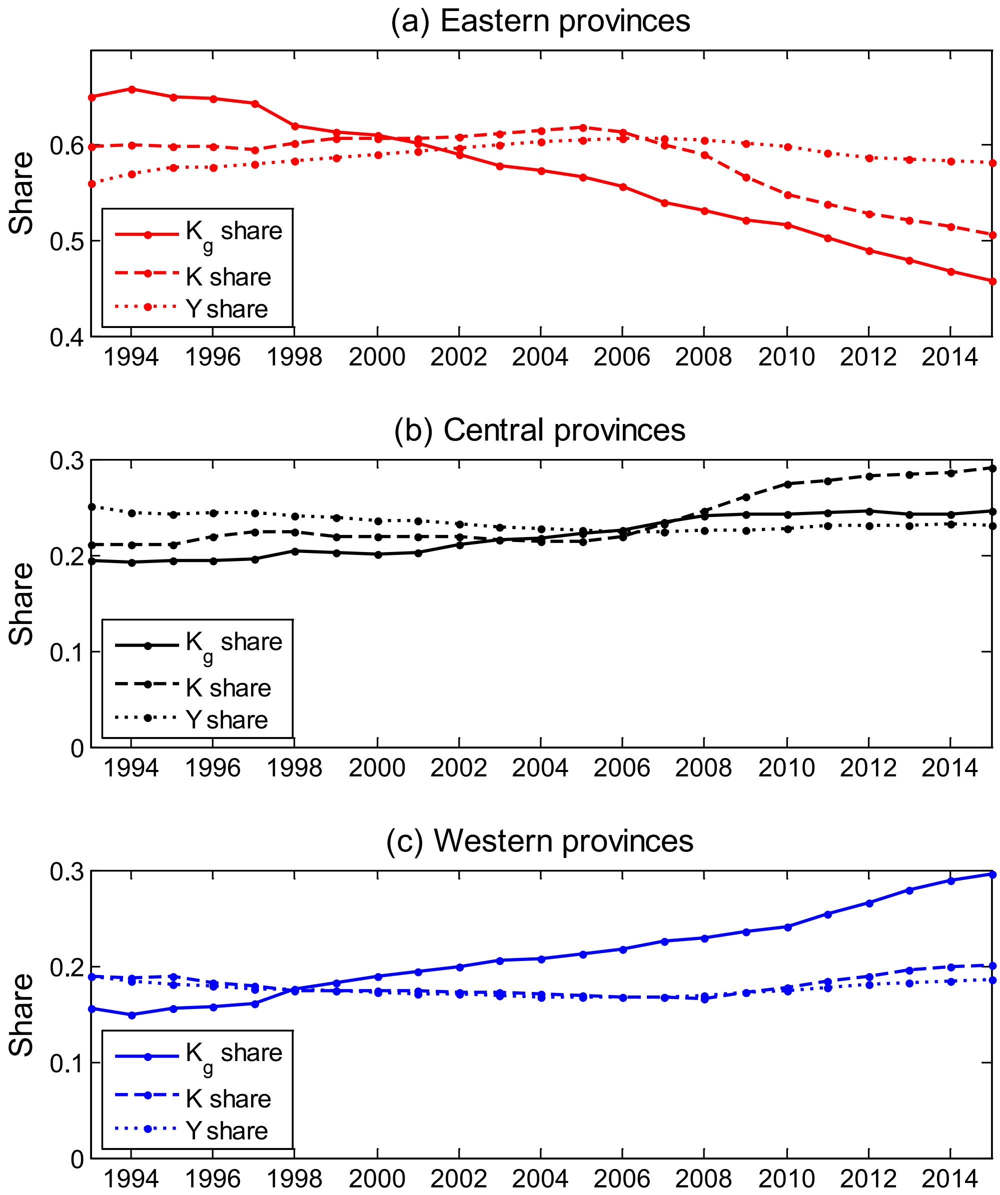
Figure 1.9: **Average skill-/labor-skill-adjustment coefficients for eastern, central and western provinces, 2003-2015**



Appendix 1.G. Evolution of K, K_g and Y shares (as fraction of country-wide sum) of eastern, central and western provinces, 1993-2015

A brief discussion on Figure 1.10 is at the end of Section 1.5.2.

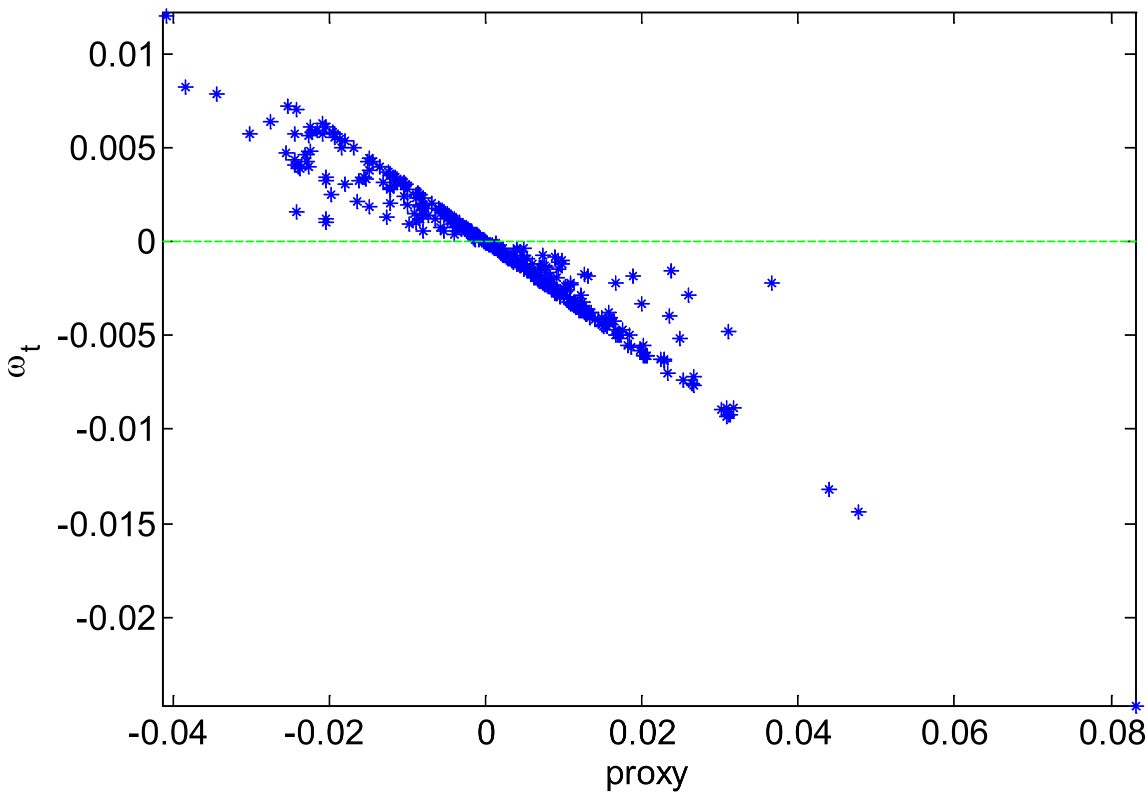
Figure 1.10: K_g, K and Y **shares of eastern, central and western provinces, 1993-2015**



Appendix 1.H. Test the monotonicity of proxy variable versus perceived TFP shock

Figure 1.11 tests the assumed monotonicity between the (first differenced) proxy variable and perceived TFP shock. The blue sample points plot the estimated $\widehat{\Delta\omega_t} = \widehat{\varphi}(z_t)\Delta proxy_t$ versus $\Delta proxy_t$. Clearly there is a monotonic negative correlation between proxy variable and estimated TFP shock. Thus the use of proxy variable shows its merit to control for TFP shock.

Figure 1.11: **Test the monotonicity of proxy variable vs. perceived TFP shock**



Appendix 1.I. Some supplementary support for our results in Section 1.6.2

Here we discuss some supplementary support for our argument that it is still desirable to invest more in infrastructure in China.

1.I.1. Crowding-in effect of infrastructure investment

A potential criticism on our inference of underinvestment of infrastructure by comparing the marginal products of capitals is that, we fail to fully consider the dynamic interaction of infrastructure and non-infrastructure investment. Public investment influences the private investment mostly through two channels: first, the public investment could alter the productivities of relevant industries and thus change the profitability of private investment; second, since public investment also needs funds, it usually directly changes the financial conditions of private investment either by taxation or competing in capital market. In the previous part of this paper we have already considered the marginal products of capitals and tax. But we assume the absence of financial friction. Within this setup, an increase of one unit of money in public investment accompanies the decrease of the exact amount of resource available for private investment (or consumption, of course). But in reality when government competes with the private sector in the capital market and tightens the budget of private investment, public investment tends to crowd out private investment, as long as the improvement of productivity induced by more public capital stock is not large enough to offset the deterioration of financial conditions. In China, more than 80% of infrastructure investment is from governments or state-owned firms. And it is widely observed that the banks in China rank the government-relevant investment as priority when making loan decisions. So, it is serious to ask whether infrastructure investment crowds out non-infrastructure investment in China. If the answer is true, our previous conclusion would be suspect.

However, the empirical evidences support us. (i) The strongest support comes from the results of SVAR analyses which directly find a net crowding-in effect of public infrastructure investment. Using the country-wide annual data of 1980-2011, Xu and Yan (2014) suggest that government investment in public goods and infrastructure in China crowds in private investment significantly. Guo, Liu and Ma (2015) have similar finding based on an annual county-level dataset for approximately 1800 Chinese counties over 2001-2009. Using quarterly data during 1995Q1–2009Q2, Hur, Mallick and Park (2014) find an increase of private investment both in impact and long-run as a response to expansionary government expenditure shocks in China. (ii) The indirect evidences concern a significant productivity enhancement in private sector by investing infrastructure. For instance, Zhang, Wang and Chen (2013) based on an intertemporal dynamic computable general equilibrium (CGE) model, show that higher infrastructure investment (financed by either foreign borrowing or production tax) substantially raises productivity in all sectors and income in all household categories. Wu (2008), using stochastic frontier approach, finds that capital efficiency (for all industries as a whole) is affected positively by the level of infrastructure development. (iii) We could also note the fact that the infrastructure investmen in many less developed Chinese western provinces, where the infrastructure investment rate is relatively high while the private industries are less flourishing compared to the eastern counterparts, is largely from the fiscal transfers by central government (with money mostly originates from the eastern regions). This kind of infrastructure investment should have no direct influence on the financial condition of, and thus should not crowd out local private investment.

1.I.2. High return of capital in infrastructure-relevant firms

Another doubt on our finding perhaps comes from the impression of low efficiency of state-owned enterprises (SOEs) in China. In recent years, more than 80% of investment of infrastructure industries comes from governments or state-owned firms. It is not unreasonable to guess that the relatively less efficiency of SOEs possibly results in a low return of infrastructure investment, and thus contradicts our previous findings. But in contrast, we actually also find firm-level evidence on our side. Ding, Guariglia and Knight (2012) investigate 2000-2007 data[20] of over 100,000 firms. Amongst all 10 industries, they find the 2 infrastructure-relevant sectors – electronic equipment industry and transport equipment industry – have the highest values of investment rate and "very high" return of capital (measured by both average and marginal revenue product of capital). Although these two industries are mainly invested by governments or SOEs, the inter-industrial efficiency difference crucially outweighs the average efficiency gap between SOEs and other firms . (Admittedly, the efficiency disparity across industries may be partially a result of market distortion – some economists warn that the government intervention maintains the production cost (accounting rate of return) of several industries at an artificially low (high) level. But inspecting this issue in detail is far beyond the scope of our paper. Anyhow, at least we see that infrastruture investment indeed owns a high marginal return of capital.)

[20]Using the data for more recent years could provide stronger support. But unfortunately, as far as we know the corresponding dataset does not provide new data after 2009. In the dataset, only two (i.e. electronic and transportation) of our previously defined infrastructure industries are documented. So we do not discuss another two (i.e. telecommunication and water) infrastructural industries.

Chapter 2

International financial liberalization and decreased external public debt in developing countries

This paper provides both empirical evidence and theoretical explanation that, international financial liberalization was linked to the decrease of external public debt in developing countries since the 1990s. It is often thought that financial globalization facilitates the international borrowing of governments. However since the 1990s we have seen a significantly negative comovement between increased financial globalization and decreased external public debt to GDP ratio in developing countries. Using a panel dataset for 46 developing economies during 1990-2007, this paper empirically confirms that financial liberalization in the home country was correlated with the retirement of external public debt. The estimated coefficient for financial openness in other countries is not sufficiently robust. We rely on cointegrating regression methods of FMOLS and DOLS because of the nonstationarity (and cointegration) of the relevant macroeconomic variables, which is often (incorrectly) ignored in previous empirical works. Our estimation is robust as we carefully check different data sources, possible reverse causality and omitted variable. We also provide a plausible theoretical argument why financial liberalization can help reduce external public debt ratio. The main mechanism is that financial globalization shrinks the interest rate differential between developing and advanced countries, which reduces the government's domestic financing cost and dampens its incentive to borrow externally.

Keywords: financial liberalization, external public debt, developing countries, FMOLS, DOLS

JEL Classification: F34, F62, H63, N10, O50

2.1 Introduction

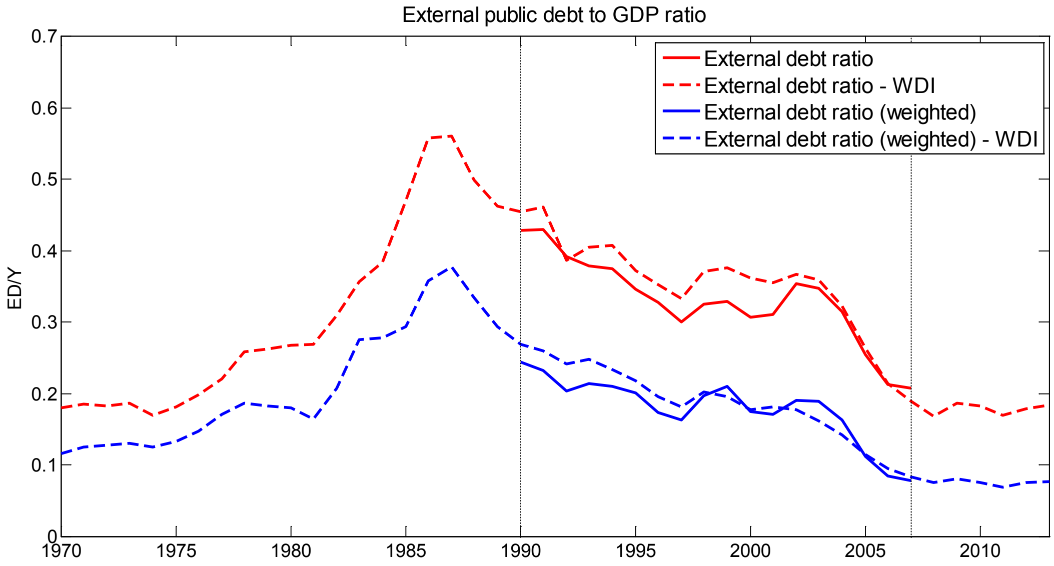
Does financial globalization affect the public debt choice of a country? This is a practically important question. On the one hand, government debt plays a role on both short-run business cycle fluctuation (e.g. via country-specific interest rate premium) and long-run economic development (e.g. via solvency of the public sector). On the other hand there are numerous debates on the pros and cons of financial liberalization, which potentially affects every aspect of the macroeconomy. This paper provides both empirical evidence and theoretical explanation that public debt is indeed impacted by financial liberalization. We propose that the link can be explained by the conventional demand and supply effect – the relative price of external borrowing was changed by financial liberalization.

Over the past decades we have seen a significant rise of financial liberalization both in advanced and developing countries.[1] In developed economies that trend was especially accompanied with a raised government debt. Azzimonti, de Francisco and Quadrini (2014) (henceforth AFQ) among others provide empirical evidence and theoretical explanation for the link. However, despite whether the literature offered sufficient arguments, the interesting thing is that since the early 1990s such a positive comovement between public debt ratio and financial openness disappeared. Even more surprisingly, if we focus on the developing countries we observe a significantly decreased external (and total) public debt to GDP ratio.[2] This phenomenon, which is demonstrated by Figure 2.1, 2.2 and 2.3 as below, cannot be explained by literature. Our paper aims to inspect the relationship between financial globalization and public debt in developing countries, and attempts to understand the underlying mechanism. (The domestic public debt ratio only slightly increased since 1990s. Thus the whole public debt dynamics was majorly driven by the change in external debt, see Figure 2.9 in Appendix 2.A.1. In this paper we primarily focus on external public debt, and discuss domestic debt if necessary.)

[1] Throughout this paper we define "financial liberalization" in the international context, as the reverse to "capital control". In other words, the removal of any restriction on the international capital movement is considered as financial liberalization. The terms of "capital account openness", "financial openness", "financial integration", "financial globalization" and "financial liberalization" all refer to the same thing in this paper. For the reduction of restrictions on domestic financial system, we call it "financial development". Financial liberalization is a comprehensive concept which involves many aspects such as the management on exchange rate, international capital inflow and outflow. Throughout the empirical part of this paper, financial liberalization is always measured aggregatively by some certain *de jure* indicators.

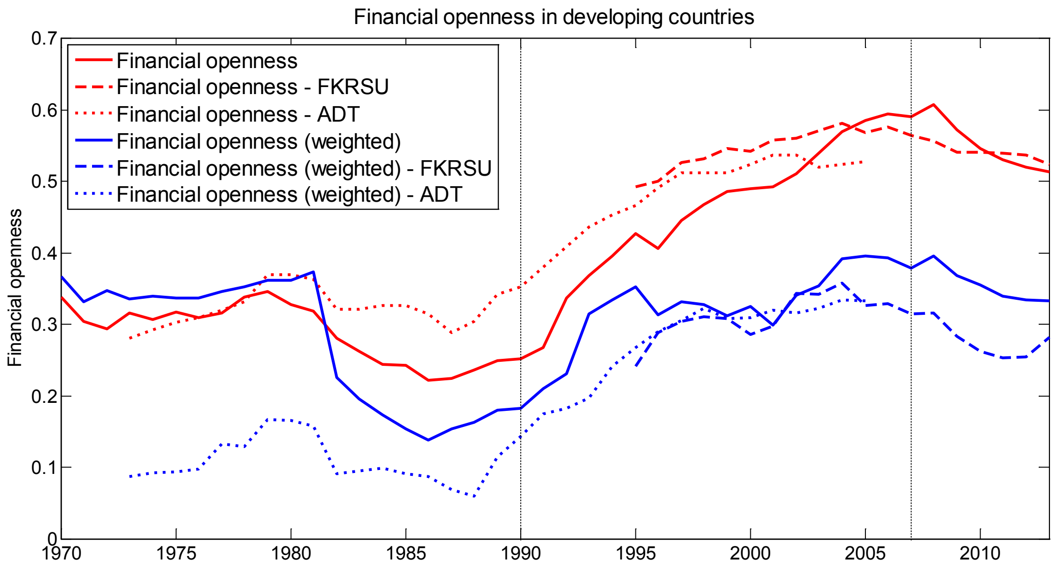
[2] In fact, even for the sample of 22 OECD countries in AFQ's study, except America the average public debt to output ratio persistently declined (until 2008 crisis) after the peak around 1993. The literature review at Section 2.2.2 presents further discussion on AFQ paper.

Figure 2.1: **External public debt to GDP ratios in 46 developing countries using data from two sources, 1970-2013**



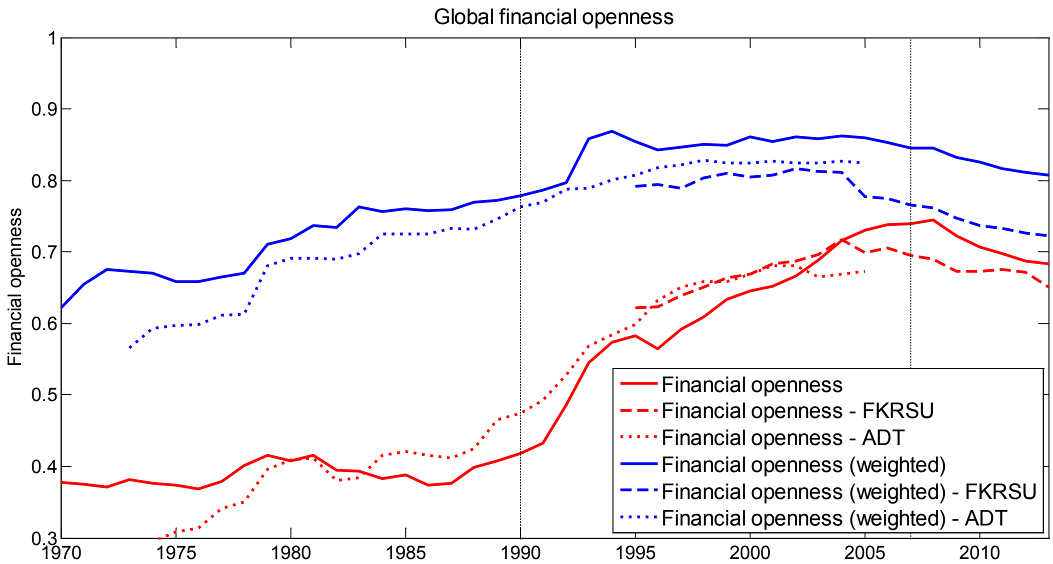
Note: (1) Data sources are Panizza (2008) and WDI. (2) Weighted average is calculated using constant 2005 US dollar real GDP as weight. This holds throughout the whole paper, when "weighted average" is mentioned.

Figure 2.2: **Financial openness in 46 developing countries using data from three sources, 1970-2013**



Note: (1) Data sources are Chinn and Ito (2006), Fernández et al. (2015) and Abiad, Detragiache and Tressel (2010). (2) FKRSU index is available only since 1995; ADT index gives the data for 1973-2005. (3) The curves by ADT index are rescaled and shifted to improve its comparability with other two indices in one figure. Figure 2.3 uses the rescaled curves as well.

Figure 2.3: **Global financial openness using data from three sources, 1970-2013**



Data source: Chinn and Ito (2006), Fernández et al. (2015) and Abiad, Detragiache and Tressel (2010).

Figure 2.1 displays the average external public debt ratios in 46 developing countries during 1970-2013 using data from Panizza (2008) and World Development Indicators (WDI).[3][4] Focusing on the period 1990-2007, the declining trend of external debt is obvious according to both data sources.[5] Figure 2.2 shows the *de jure* measurement of capital account openness in

[3]Similar figures, covering similar samples, about the dynamics of external debt ratio can also be found at e.g. Figure 16.1 in Panizza, Sturzenegger and Zettelmeyer (2013), Figure 2 in UNCTAD (2015). In literature there are three definitions for external (and correspondingly, domestic) public debt. (1) The first is based on the place of issuance and the legislation that regulates the debt (i.e. external debt is debt issued in and under the jurisdiction of foreign countries). Panizza (2008) data takes this definition. (2) The second is based on the residence of the creditor (i.e. external debt is debt held by foreigners). WDI data uses this definition. (3) In the third definition currency is the criterion (i.e. external debt is foreign currency debt). Data shows that the amount of external debts defined based on the first and second definition are highly consistent.

[4]We would like to mention two points about the sample. (1) We select the set of developing countries simultaneously covered by Panizza (2008) public debt dataset, Chinn-Ito capital account openness dataset, and FKRSU capital control dataset. We define "developing countries" as the countries not included in the list of "Advanced Economies" in *World Economic Outlook: Adjusting to Lower Commodity Prices* by IMF, October 2015. We also intentionally exclude some extremely debted, or petroleum exporting countries because they are outliers. The list of sample countries is at Appendix 2.C.1. (2) A significant part of the data before 1990 is unavailable but we still calculate the average value using the remaining samples. Admittedly, the curves before and after 1990 are not completely comparable because of the sample difference. However the basic dynamics of the variables should be clearly seen.

[5]It is notable that in the same period there existed some international debt reliefs, mainly through the Heavily Indebted Poor Countries (HIPC) Initiative and Multilateral Debt Relief Initiative (MDRI), for some highly indebted poor countries. Thus we need to concern whether the external debt declines in some countries were partially artificial as the result of debt relief. But the data shows that debt relief only counts for a small fraction of debt reduction, and further econometric analysis finds excluding some high debt relief countries does not alter our estimation result.

The data shows that average annual debt relief counts for less than 0.6% as simple average and 0.1% as weighted average of the GDP in our sample developing countries. (For more details about the debt relief please refer to the Figure 2.10 in Appendix 2.A.2.) Thus the debt relief is not the major reason of the large decline of external debt as observed in data. In the robustness analysis part in Section 2.3.3.2 we conduct the analysis excluding the countries with high debt relief ratio, and the basic result does not change.

those countries based on three data sources: Chinn and Ito (2006) (Chinn-Ito) capital account openness index, Fernández et al. (2015) (FKRSU) capital control index and the measurement of international capital flow liberalization by Abiad, Detragiache and Tressel (2010) (ADT). All indicators demonstrate a significant increase of financial openness. Figure 2.3 demonstrates the average level of global financial openness approximated by the average value over 77 economies around the world.[6] We see from the figure that before the 2008 financial crisis there was a persistent growth of global financial openness.[7] Combining Figure 2.1, 2.2 and 2.3, we can clearly see a negative comovement between external public debt ratio and financial globalization during 1990-2007.

However these figures are not sufficient to assert a definite relationship between the global financial liberalization and the dynamics of external debt, since the change of external debt depends on both demand and supply sides of international capital flows. Intuitively, financial globalization can both positively and negatively alter the international borrowing of governments. (1) With global financial liberalization it is easier to borrow from other countries (and the interest rate in developed countries are often lower than that in developing countries), thus the governments of developing countries would have incentive to hold more external public debt if they need. (2) Financial liberalization can potentially promote (or hinder in some cases) the growth of developing countries, and provide more channels to receive international capital besides external public debt, thus external public debt ratio could decline. Furthermore, we need to clearly distinguish between the financial liberalization within the "home country" and in other countries. As discussed in AFQ, whether the government in one country can borrow from foreigners is directly influenced by the financial openness in other countries. But the financial liberalization within one country can have indirect effects on the willingness and capacity of external debt accumulation of its government. Therefore in our empirical analysis we explore both of the financial liberalization in and out of each country.

Our econometric analysis finds strong evidence that financial liberalization negatively affects the external public debt in developing countries. The estimated coefficients are robust as we carefully check different data sources, possible reverse causality and omitted variable. In contrast to the empirical finding of AFQ, we do not see robustly significant effect of financial openness in foreign countries. After the econometric analysis we further provide a plausible theoretical explanation why financial liberalization can help reduce external public debt ratio. The main mechanism is that financial globalization shrinks the interest rate differential between developing and advanced countries, which reduces the government's domestic financing cost and dampens its incentive to borrow externally. The simulation of our theoretical model

[6]Besides the 46 developing countries aforementioned, most of the other samples among the 77 countries are developed economies. And the 77-countries group counts for roughly 95% of global GDP and thus is a good approximation of the whole world.

[7]A strange point is that, according to FKRSU data there is a sudden decline of global financial openness in 2005. But before that year the overall trend is increasing. In this paper we measure the financial liberalization mainly based on the Chinn-Ito index, since it provides data during a longer period compared to the FKRSU and ADT data.

generates results consistent with the stylized facts about the developing countries' public debt dynamics since the 1990s.

The rest of the paper proceeds as follows. Section 2.2 presents a brief literature review. Section 2.3 provides the core empirical evidence for the financial globalization and external public debt nexus. Section 2.4 discusses intuitively how foreign-domestic interest rate differential can be a possible reason why financial liberalization dampens external public debt. A theoretical model formalizing this plausible mechanism is presented in Section 2.5. Finally Section 2.6 concludes.

2.2 Literature review

This paper is mainly related to two streams of literature: the determinants of public debt, and the macroeconomic consequences of financial globalization. There is a huge amount of literature on the single topic of financial liberalization or public debt. But few of them intentionally combine these two topics together.

2.2.1 Empirical literature

Based on the selection of dependent variable in regression analysis, relevant empirical literature can be roughly divided into 3 groups. They investigate whether financial liberalization influences public debt component, fiscal deficit, size or growth of debt, respectively. The findings are controversial.

Forslund, Lima and Panizza (2011) estimate the determinants of the composition of public debt in 95 developing countries during 1994-2006. (Our current paper will utilize the same dataset as they used.) In their result the fraction of domestic debt in total public debt is positively influenced by the existence of capital controls. However, the fraction of domestic debt is the result of variation in both domestic debt and external debt. If we consider the domestic and external debt separately (see Figure 2.9 in Appendix 2.A.1), we find that since the 1990s the domestic public debt to output ratio increased but slightly, while the external pubic debt ratio declined dramatically – it is actually the dynamics of external public debt rather than domestic debt which is more important. (Moreover, their finding about capital control may need to be reexamined as they do not take into account the nonstationarity of data, which may generate largely biased estimation.)

In a sample of 94 countries for 1970-2010, Vuletin (2013) finds that capital controls, in the form of dual exchange rate regimes, induce higher fiscal deficits. In line with this finding, we may guess that capital liberalization helps reduce fiscal deficit and then the public debt. But as that study is specific to dual exchange rate regime, perhaps the situation is different when we consider more general forms of capital controls.

Opposite findings exist in the literature. Arcalean (2017) finds that, in a sample of OECD countries during 1980-2007, financial openness in other countries tends to increase fiscal deficits in these OECD countries. But financial liberalization in the home country does not have any significant effect. Investigating a sample covering 35 countries between 1993 and 2010, the results by Claessens, Klingebiel and Schmukler (2007) suggest that countries with more capital account openness have lower domestic currency government bond to GDP ratio, but higher foreign currency bond to GDP ratio and total government bond ratio. Liu and Sun (2016) employs a dataset for 206 subnational governments from 31 countries between 2004 and 2010. They find that financial openness positively impacts the size of subnational obligations in developing countries. The findings of these three papers may not be used to answer our research question because the subject and sample they studied are quite different. Arcalean (2017) works on OECD countries while we focus on developing economies. Claessens, Klingebiel and Schmukler (2007) also have a sample majorly including developed countries; and they focus on government bond which counts for a minor fraction (roughly 20%-30%) within developing countries' external public debt. Liu and Sun (2016) take a sample of subnational governments. As remarked in their paper, most local governments included in that study are capital cities or major economic centers of the country which may have special charateristics, and the subnational-level government debt may not reflect the situation of aggregate or central government debt. Moreover, they use 2004-2010 data where the 2008 financial crisis is just located in between.

Agnello and Sousa (2015) use dummy variables to represent the re-regulation or liberalization of international capital flows. In a sample of 89 countries over 1973-2005, they analyze the (in)existence of impact on public debt growth rate. What they find is a "ratchet effect": capital flow re-regulation contributes to a decline in public debt growth but liberalization does not show a significant effect. As their sample is a mixture of advanced and developing countries, and they do not distinguish external debt from total debt, it is unclear how their study helps answer our research question.

Besides its theoretical explanation, the AFQ paper also provides empirical evidence that global financial liberalization promotes the aggregate public debt growth in 22 OECD countries. But it seems that the findings are mainly driven by the data in the late 1980s and early 1990s. If we divide AFQ's full sample of 1973-2005 into 3 subsample periods (1973-1983, 1984-1994, 1995-2005) and run the regression for each subsample using their econometric model in the paper, we find that the coefficient for global capital mobility is *insignificant* for both periods 1973-1983 and 1995-2005 (see Table 2.7 in Appendix 2.B for details). We also collect the data for all 34 OECD countries during period 1993-2007 and run the regression (details not reported). That coefficient is again robustly *insignificant*. Thus the theory discussed in AFQ, which claims a positve correlation between financial globalization and government debt, loses its power after the early 1990s. A possible explanation is that AFQ's theory mainly states the situation of transition from financial autarky to financial openness, but in the early

1990s the financial liberalization was already at a high stage (which is around 0.8 measured by Chinn-Ito capital account openness index). The development from high financial openness to somehow higher openness does not make large change – after the 1980s the external financing constraint of government was already sufficiently loose. Another possibility is that AFQ check the degree of global financial liberalization but neglect the financial liberalization in the home country, which may have strong or even dominant indirect effect.[8] So, in order to investigate whether the period since the 1990s is really special or AFQ theory has a problem, we turn to consider the developing economies who were still at low openness in the early 1990s and then became largely more open later on. We also distinguish between domestic and external financial liberalization explicitly.

2.2.2 Theoretical literature

Financial liberalization can influence the willingness of government to borrow abroad. AFQ theoretically show that financial globalization can contribute to the increase in public debt of OECD countries. The key mechanism is as below. In the economy there are two types of agents – workers and entrepreneurs. Workers who earn wage income are unable to hold assets or borrow, but entrepreneurs who face up to idiosyncratic production shock have access to financial market by holding government bond. Since the population of workers is larger, the government mainly cares about workers' welfare. The government employs public debt to fund the lump-sum transfers to workers. In financial autarky both workers and entrepreneurs support the existence of a positive government debt, because the equilibrium interest rate is below the intertemporal discount rate such that government's borrowing improves workers' lifetime utility, and entrepreneurs can earn interest revenue and use financial asset to insure against the idiosyncratic risk. When international asset markets are highly integrated, the elasticity of domestic interest rate to government debt is small since the world interest rate equates. Compared to financial autarky, in an integrated world workers want the government to borrow more because the less elastic interest rate is still below the intertemporal discount rate. Although the domestic entrepreneurs do not prefer a public debt increase since the benefit of interest revenue is shared with foreign entrepreneurs, the government will still raise public debt because workers' utility has a larger weight. Financial liberalization can also influence the fiscal performance of government in a political-economic framework. Arcalean (2017) shows that financial liberalization may result in strong tax competition, which leads to a fiscal deficit bias. This can further cause high public debt. Both of AFQ and Arcalean (2017) work in the context of OECD countries and try to explain the observed debt increase in these countries. What they attempt to explain is in contrast to the trend of both decreased external and total public debt in developing countries.

[8] AFQ actually have talked about the possibility that "domestic liberalization can still affect domestic issuance through an indirect channel". But what they considered is whether in computing the global liberalization index we should exclude the country of reference. This is different from our study as we consider the liberalization in the home country as an independent explanatory variable, rather than just a part of world liberalization index.

There exits a theoretical literature which argues along the reverse direction. In addition to the empirical evidence, Vuletin (2013) uses a political-economic model to show that capital controls, under dual exchange rate regimes, induce higher fiscal deficits. This is because the government obtains utility from fiscal expenditure, which is easier under dual exchange rate system. This implies that, *ceteris paribus*, capital controls (financial liberalization) would tend to increase (reduce) the government debt level. But there are two weaknesses if we would like to directly use similar model to explain empirical finding: (i) in the political-economic framework the result is sensitive to the assumption on government's preference; (ii) fiscal deficit is directly linked to the level of total government debt but not the interaction between domestic debt and external debt.

Reverse causality between public debt and financial liberalization can also exist. Aizenman and Guidotti (1994) show that when public debt ratio is already high, it could be welfare-improving to impose capital controls since they reduce tax collection cost. In this case, a high (low) public debt ratio may induce capital controls (financial liberalization).

All in all, existing empirical and theoretical literature does not supply enough explanation for the observed negative comovement between financial liberalization and external debt ratio in developing countries. Regarding our research purpose, there are mainly four weaknesses in previous literature. (1) The focus is not on the sample of developing countries. (2) The obvious nonstationarity of data is not taken into account in the empirical analysis. (3) The literature does not distinguish between domestic and external public debt, which may be important because of potential tradeoff. (4) The effects of financial liberalization in home countries and in foreign countries are not investigated in a common framework. We will avoid these weaknesses in our study.

2.3 Empirical evidence

In this section, we formally demonstrate the empirical evidence that financial globalization was linked to reduce external public debt. We will start from a simple linear regression model to show that OLS estimation suffers from spurious regression problem, as the key variables are nonstationary. Then we take some first differenced models from literature, which avoid the spurious regression, to confirm that financial liberalization indeed matters for external public debt. After that we check the existence of cointegration relationship among variables, and finally report our estimations using FMOLS and DOLS cointegrating regressions and the associated robustness analysis. Besides the core explanatory variables regarding financial liberalization, our empirical analysis will take into account a relatively large set of control variables. In a nutshell we will show that even though we change different model specifications and variables, the claimed negative correlation between financial openness and external public debt ratio in the developing world is not shaken.

Our empirical analysis will utilize the data from many different sources. Regarding the public debt data, we primarily use the dataset provided by Panizza (2008). We also use the external public debt data from WDI for robustness check. For the indicator of of financial liberalization, we take the Chinn-Ito capital account openness index as the primary data source because it covers longer period and is widely used in literature. The data of (one minus) FKRSU capital control index and (rescaled) ADT financial liberalization index are also relied on to check the robustness. An advantage of using these *de jure*, rather than *de facto*, indicators is that they are less sensitive to business cycle fluctuations and thus less suffered from endogeneity problem. Because of the data availability from different datasets and for some other control variables, we finally extract the data of an unbalanced panel covering 46 developing countries during 1990-2007.

2.3.1 Model specification and variable

The baseline model specification is:

$$ED_{it} = \beta_1 FinanOpen_{it} + \beta_2 FinanOpenW_{it} + \theta' X_{it} + s_i + \sigma_t + \varepsilon_{it} \tag{2.1}$$

where the dependent variable ED_{it} is the public external debt to output ratio in country i at period t. Among the regressors, $FinanOpen_{it}$ is the level of financial openness; $FinanOpenW_{it}$ is the degree of worldwide financial liberalization i.e. the weighted average level of financial openness over all other countries[9]; and X_{it} is a vector of control variables. We as well include the time effect σ_t and section effect s_i. The error term ε_{it} is assumed exogenous and i.i.d. By construction, the larger values of $FinanOpen_{it}$ and $FinanOpenW_{it}$ mean higher financial openness i.e. less capital control. The vector of control variables X_{it} contains the indicators in five aspects. (In fact, not all of these potentially relevant control variables would be used in our baseline regression. The sample size of our highly unbalanced panel data and the fact that some variables are $I(1)$ but others are stationary, only allow us to contain part of these nonstationary variables within the framework of FMOLS and DOLS cointegrating regression. For the list of selected variables, see Table 2.2 which we will discuss later. The remaining variables would be used in robustness analysis.[10]) Below we discuss these regressors briefly. The details about the variable definition, data source and summary statistics are documented in Appendix 2.C.

[9] Since the main lenders to developing countries are those developed countries, we may construct $FinanOpenW$ only using the degree of financial openness in the developed world. We checked this possibility, and found that our estimation results in this paper are robust to this alternative definition of $FinanOpenW$.

[10] Since some of the remaining control variables are stationary, putting them in the cointegration regressions for robustness analysis may have problem. But this does not really matter, because we focus on the estimated coefficients for financial liberalization rather than those control variables.

(1) Public finance considerations

We first take into account the aspects of public finance including government domestic debt to output ratio and fiscal balance (% of GDP) – $[DD, FiscalBalance]$. Government domestic liability is a crucial control variable since government usually borrows both domestically and abroad. Government budget balance indicates whether the government needs money and thus directly affects public debt.

(2) General economic conditions

We consider the variables of logarithmic GDP per capita, M2 to GDP ratio, inflation, real interest rate, interest rate in the rest of world, gross fixed capital formation rate (% of GDP), domestic saving rate, and the occurence of economic and financial crisis in history – $[GDPpc, M2, Inflation, IR, IRrow, CapForm, SaveRate, Crisis]$. Definitely, *ceteris paribus* an increased GDP would reduce the external debt to GDP ratio. Moreover, the demand of external financing may be different at the distinct stage of economic development. M2 ratio is related to both economic growth and credibility of government policy, which are both relevant to external public debt. Inflation could have similar influence. Domestic and world interest rate jointly determine the burden of interest payment of public debt, which affects the willingness and ability of government to retire debt. Capital formation rate indicates whether capital investment is crucial in the economy, which further indicates the demand for public financing. Domestic saving rate indicates the intensity of the economies' internal financing, which can be expected negatively related to external debt. The history of crisis largely indicates the government's ability of debt repayment, which affects both the demand and supply sides of public borrowing.

(3) External payment variables

In this set we add the variables of trade balance (% of GDP), current account balance (% of GDP), and real effective exchange rate index (2010 = 100) – $[TradeBalance, CurrAcct, ER]$. These three variables are directly associated with international capital flow. We expect the estimated coefficients are negative for the first two, because they indicate the inflow of capital. The coefficient for exchange rate is also expected to be negative, since the external debt is majorly denominated by foreign currency while output is initially measured by local currency – thus *ceteris paribus* an appreciation of domestic currency directly reduces the external debt to GDP ratio. Moreover, exchange rate is related to several other key macroeconomic variables and hence may have some important indirect effects on debt.

(4) Institutional and demographic characteristics

This set of control variables contains the legal institutional quality, age dependency ratio and type of exchange rate regime – $[Legal, DepenRatio, ERR]$. A good quality of legal institution may enhance the fiscal discipline and reputation of government. This can affect both the demand and supply side of external debt. Different age dependency ratios represent distinct demographic cohort structures, which influence the policy priority (such as pension) of governments. Exchange rate regime is potentially important since it influences both the fluctuation of exchange rate and the implementation of capital control.

(5) Other variables linked to financial liberalization

Financial development and economic openness may be both tightly linked to financial liberalization. In the robustness analysis section we would like to check whether these two aspects change the relationship between financial globalization and government debt. We take two indicators, one comprehensive index and one *de facto* indicator, for each of the aspects – $[FinanDev, Credit, Globaliz, TradeOpen]$ where $FinanDev$ is the Svirydzenka (2016) financial development index; $Credit$ is private credit by deposit money banks (% of GDP); $Globaliz$ is the KOF globalization index (Dreher, 2006); $TradeOpen$ is the trade openness measured by import plus export (% of GDP).

2.3.2 Econometric issues

Before we lay out our formal regression analysis, let us first consider several potential econometric issues. We first check the nonstationarity of variables and confirm that spurious regression would exist if we directly use OLS estimator. Then we test whether these nonstationary variables are cointegrating. If cointegration relation exists, we can use the FMOLS and DOLS regression.

2.3.2.1 Nonstationarity and spurious regression

From a perspective of econometrics, both the variables of financial openness and external debt ratio are nonstationary since they have clear trends. Then the seemingly negative correlation as shown in Figure 2.1, 2.2 and 2.3 may be just a "spurious regression". Table 2.1 illustrates the spurious regression problem regarding our variables. The formal test of nonstationarity is discussed after that.

Spurious regression and preliminary analysis

Suppose that we naively put different variables together and run the OLS regression according to baseline model (2.1), we will obtain the results in column (1.1), (1.2) and (1.3) whose financial liberalization variable is based on the Chinn-Ito, FKRSU and ADT index, respectively. The control variable set X contains $[DD, GDPpc, M2, CapForm, TradeBalance]$. We see that the estimated coefficients for $FinanOpen$ are significantly negative. But we find the adjusted

R^2 is greatly larger than the value of Durbin-Watson statistic. This indicates the existence of spurious regression. Thus we should not directly use model (2.1) without revision. In model (1.4) we check the regression taking *EDShare*, the share of external debt in total public debt, as dependent variable. This aims to compare with the result in Forslund, Lima and Panizza (2011) where the dependent variable is the share of domestic debt $(1-EDshare)$. Our estimation generates negative coefficients for financial integration again, but still subject to obvious spurious regression problem.

Taking first difference on these variables (if they are $I(1)$ processes) is able to make them stationary. Column (1.6) is based on the first differenced one period lagged data with the time-fixed effect model:

$$\Delta ED_{it} = \beta_1 \Delta FinanOpen_{i,t-1} + \beta_2 \Delta FinanOpenW_{i,t-1} + \theta' \Delta X_{i,t-1} + \sigma_t + \varepsilon_{it} \tag{2.2}$$

where Δ refers to the first differencing operator. In model (1.7) we also try a regression specification similar to that in AFQ:

$$\begin{aligned} EDgr_{it} &= \beta_1 \Delta FinanOpen_{i,t-1} + \beta_2 \Delta FinanOpenW_{i,t-1} \\ &\quad + \alpha_1 ED_{i,t-1} + \alpha_2 EDShare_{i,t-1} + \alpha_3 GDPgr_{i,t-1} + \theta' \Delta X_{i,t-1} + s_i + \sigma_t + \varepsilon_{it} \end{aligned} \tag{2.3}$$

where *EDgr* is the growth rate of real public external debt stock (measured by constant 2005 US dollar) and *GDPgr* is the growth rate of real GDP. In model (1.8) we use dummy variables to indicate the policy changes on financial openness. We regress according to a specification similar to that in Agnello and Sousa (2015):

$$\begin{aligned} EDgr_{it} &= \beta_1 Regulation_{i,t-1} + \beta_2 Liberalization_{i,t-1} + \beta_3 \Delta FinanOpenW_{i,t-1} \\ &\quad + \alpha_1 EDgr_{i,t-1} + \alpha_2 GDPgr_{i,t-1} + \theta' \Delta X_{i,t-1} + s_i + \sigma_t + \varepsilon_{it} \end{aligned} \tag{2.4}$$

where *Regulation* and *Liberalization* are dummy variables such that

$$\begin{cases} Regulation = 1, Liberalization = 0 & \text{if} \quad \Delta FinanOpen < 0 \\ Regulation = 0, Liberalization = 0 & \text{if} \quad \Delta FinanOpen = 0 \\ Regulation = 0, Liberalization = 1 & \text{if} \quad \Delta FinanOpen > 0 \end{cases}$$

and the last period value of *EDgr* enters the equation to capture the pesistence of external debt growth. Similar to the model in level data, the estimated coefficients for home country financial liberalization $FinanOpen$ in these first differenced models (1.6) - (1.8) are still negative. However, a disadvantage of taking first difference is that it may destroy the long-run relationship among variables. In this case model (2.2), (2.3) and (2.4) are not fully reliable for our research purpose.

A useful alternative methodology is Autoregressive Distributed Lag (ARDL) model. It explicitly highlights both the long-run relationship and the short-run adjustment in the process. Its validity is ensured no matter the variables are $I(1)$ or $I(0)$. Model (1.5) gives the estimation result based on a simple ARDL regression where we select both 1 lag for the dependent variable and dynamic regressors. The estimated coefficient for $FinanOpen$ is still significantly negative. But in practice on our data, a problem emerges when we use ARDL model: the regressor matrix is easy to be nearly singular when financial openness variable is contained (perhaps because the index for financial openness is often constant for several sequential years in some countries, which makes the first differenced terms contained in ARDL framework have many zero elements). When more control variables are introduced, this "near singular matrix" problem is more severe. This phenomenon prevents us from using ARDL for more analysis.

Panel unit root test

Table 2.2 presents the panel unit root test result for variables of public external debt to GDP ratio, index of financial openness, and other relevant variables. Since we have a sample with a relatively large amount of sections where the cross-section heterogeneity would be important, we include an individual intercept and trend in test equation. Lag length is selected automatically based on Schwarz information criterion. Using other criteria would either give similar result or more strongly support the nonstationarity of most variables. In the table we report the results of 4 statistic tests: the Breitung t-, IPS (Im, Pesaran and Shin) W-, ADF-Fisher χ^2- and PP-Fisher χ^2-Statistic. Intentionally, the LLC (Levin, Lin and Chu) and Hadri test are not relied on because they are not informative for our sample, as LLC almost always rejects the unit root and Hadri always rejects the stationarity null hypothesis for almost all variables. It is notable that given our relatively short sample period of 18-years , the power of unit root tests may not be sufficiently strong. But the phenomenon of nonstationarity in most variables is already clear.

Table 2.1: **Illustration of the spurious regression, ARDL and first differenced model**

	Spurious regression				**ARDL**		**First differenced model**		
	Baseline	**FKRSU**	**ADT**	*EDShare*	*ED*		ΔED	*EDgr*	*EDgr*
	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)		(1.6)	(1.7)	(1.8)
FinanOpen	-0.058**	-0.101***	-0.042	-0.050***	-0.242***	$\Delta FinanOpen_{t-1}$	-0.090***	-0.141*	
FinanOpenW	5.472*	6.827**	-1.453	-2.146	0.725***	$\Delta FinanOpenW_{t-1}$	-4.933	-12.666	-6.987
DD	0.268***	0.216***	0.296***	-0.569***	0.070	ΔDD_{t-1}	0.074		
GDPpc	-0.392***	-0.595***	-0.369***	-0.285***	-0.274***	$\Delta GDPpc_{t-1}$	-0.299***		
M2	0.317***	0.315***	0.285***	0.206***		$\Delta M2_{t-1}$	-0.100*	-0.247	-0.189
CapForm	0.139	0.299*	0.523***	0.361***		$\Delta CapForm_{t-1}$	-0.072	-0.002	-0.560
TradeBalance	0.683***	0.606***	0.819***	0.328***		$\Delta TradeBalance_{t-1}$	-0.029	-0.480	-0.551
						ED_{t-1}		-0.370***	
						$EDShare_{t-1}$		-0.197**	
						$EDgr_{t-1}$			-0.058
						$GDPgr_{t-1}$		-0.965***	-0.861***
						$Regulation_{t-1}$			0.001
						$Liberalization_{t-1}$			-0.049**
Other control var.	No	No	No	No	No	Other control var.	Yes	Yes	Yes
Sample period	90-07	95-07	90-05	90-07	91-07	Sample period	92-07	92-07	92-07
Cross-sections	46	46	40	46	25	Cross-sections	46	46	46
Observations	746	562	597	746	372	Observations	562	564	568
Adjusted R^2	0.846	0.863	0.785	0.916	-	Adjusted R^2	0.270	0.289	0.228
Durbin-Watson stat.	0.517	0.676	0.474	0.432	-	Durbin-Watson stat.	1.990	2.039	2.006

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) In order to avoid "near singular matrix" problem in the ARDL regression, we exclude 21 sample countries which have relatively small variation of financial openness level (i.e. if the standard deviation of *FinanOpen* during 1990-2007 is smaller than the mean value over the full sample 46 countries). The regressors [*M2*, *CapForm*, *TradeBalance*] are not included for the same reason. (3) Compared to the elements in control variable vector X of model (1.1) - (1.4), in order to improve the regression fitness in the vector ΔX of model (1.6) - (1.8) we additionally put (original level or first differenced value of) all other control variables [$\Delta FiscalBalance$, *Inflation*, $\Delta IRrow$, $\Delta SavRate$, *Crisis*, *CurrAcct*, *Legal*, $\Delta DependRatio$, *ERR*] mentioned in section 2.3.1 except exchange rate index *ER* and domestic interest rate *IR*. Exchange rate and interest rate are not included to avoid collinearity and endogeneity problem, since they are highly correlated to several other control variables and reversely affected by dependent variable. Nonstationary variables are first differenced to obtain stationarity; other stationary control variables are directly used in levels.

Table 2.2: **Panel unit root tests for regression variables**

Variable	Test Statistics				$I(1)$	Included in Baseline Regression?
	Breitung	IPS	Fisher-ADF	Fisher-PP		
Dependent variable:						
ED	-0.55	-2.93**	140.55***	86.38	√	√
Key explanatory variables:						
FinanOpen	-2.08*	-0.03	80.95	84.44	√	√
FinanOpenW	1.26	-9.50***	232.17***	115.26	√	√
Public finance considerations:						
DD	1.57	-1.81*	139.25**	113.22	√	√
FiscalBalance	0.94	-1.59	126.79**	120.27*	√	
General economic conditions:						
GDPpc	2.52	-1.97*	128.82**	80.93	√	√
M2	5.70	0.33	117.20*	111.19	√	√
Inflation	-1.64	-6.15***	209.38***	261.10***		
IR	-3.73***	-10.06***	248.02***	314.48***		
IRow	-5.20***	3.93	28.78	34.13	√	
CapForm	-0.50	-2.29*	131.88**	88.10	√	√
SaveRate	3.20	-1.63	118.90*	116.46*	√	
Crisis	-12.65***	-11.87***	257.08***	312.73***		
External payment variables:						
TradeBalance	-0.12	-1.73*	109.33	101.62	√	√
CurrAcct	0.02	-4.93***	175.42***	189.24***		
ER	-1.18	-2.22*	80.73*	68.66	√	
Institutional and demographic characteristics:						
Legal	-4.42***	-6.77***	186.36***	150.32***		
DependRatio	4.03	2.18	142.04***	68.95	√	
ERR	-3.06**	-6.31***	165.45***	88.08		
Further control variables for robustness analysis:						
FinanDev	-2.26*	-3.66***	143.52***	155.21***		
Credit	9.05	1.32	123.78*	61.74	√	
Globaliz	2.79	-2.50**	139.05**	151.49***		
TradeOpen	2.56	-0.91	108.39	103.40	√	

Note: (1) */**/*** indicates the rejection of the null hypothesis of unit root at the 5%/1%/0.1% significance level, respectively. (2) In column "$I(1)$", "√" refers to the case that this variable is integrated of order 1. Nonstationarity is judged by the criterion that at least 2 out of 4 tests do not reject unit root hypothesis. (3) The column "Included in Baseline Regression?" documents the list of variables which are included in the baseline regressions in Table 2.1, 2.4 and 2.5.

Considering that sometimes different tests indicate distinct consequences, we judge whether the variable is stationary depending on whether at least 3 out of the 4 nonstationarity tests reject unit root hypothesis. As clearly seen in Table 2.2, most of the variables listed in the table cannot be regarded as stationary.[11] If we test the first differenced series of the variables (not

[11]Some variables, such as *ED*, *DD* and *FiscalBalance*, should not be nonstationary in economic sense – other-

shown in the table), we would find all variables are stationary after first differencing. Thus all the nonstationary variables are $I(1)$, as documented by the column "$I(1)$" in the table. This property enables us to implement analysis for possible cointegration.

2.3.2.2 Cointegration

Now we test whether the $I(1)$ variables have cointegration relationship. Given our sample size, it is infeasible to put all the nonstationary variables listed in Table 2.2 into a single large group for panel cointegration test. Thus we split them into five (overlapped) groups, and each time only test the cointegration for one group. The first to fifth group contains the elements of [ED, $FinanOpen$, $FinanOpenW$, DD, $GDPpc$], [ED, $FinanOpen$, $FinanOpenW$, $M2$, $CapForm$], [$FinanOpenW$, DD, $M2$, $CapForm$, $TradeBalance$], [ED, $FinanOpen$, $FiscalBalance$, $IRrow$, $SaveRate$] and [ED, ER, $DependRatio$, $Credit$, $TradeOpen$], respectively. Table 2.3 demonstrates the results of cointegration test.

Table 2.3: **Cointegration tests for groups of variables**

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Pedroni Residual Cointegration Test					
			Weighted Statistic		
Panel v-Statistic	-3.07	-2.68	-2.40	-2.14	-5.31
Panel rho-Statistic	5.91	6.02	6.09	5.99	5.99
Panel PP-Statistic	-2.90**	-2.81**	-3.45***	-5.63***	-9.30***
Panel ADF-Statistic	-4.99***	-5.95***	-10.23***	-6.57***	-11.72***
Group rho-Statistic	7.91	8.29	8.67	8.43	7.80
Group PP-Statistic	-6.79***	-5.18***	-6.56***	-10.67***	-21.63***
Group ADF-Statistic	-5.74***	-5.66***	-12.08***	-6.99***	-13.31***
Kao Residual Cointegration Test					
			t-Statistic		
ADF	-4.46***	-2.54**	-35.96***	-2.60**	-1.39
Johansen Fisher Panel Cointegration Test					
Hypothesized No. of CE(s)			Fisher Statistic (from trace test)		
None	234.5***	218.9***	223.0***	147.0***	255.7***
At most 1	1179***	1087***	1202***	488.7***	1274***
At most 2	710.6***	671.5***	779.6***	358.4***	962.1***
At most 3	916.5***	817.1***	890.1***	945.4***	1313***
At most 4	170.0***	153.5***	175.9***	104.8***	281.2***

Note: */**/*** indicates the rejection of the null hypothesis of no cointegration at the 5%/1%/0.1% significance level, respectively.

Most of the tests reject the null hypothesis of no cointegration. In other words, the nonstationary variables that we would like to analyze indeed have cointegration relationship, and thus could be investigated by methods of cointegrating regression.

wise they could be unbounded in the long run. But at least within our sample period, there is no problem to see that they were nonstationary in statistical sense.

2.3.2.3 Cointegration regression method: FMOLS and DOLS

With the nonstationary property of our variables, the usual OLS estimator can be largely biased in finite sample. Therefore we rely on two cointegrating regression methods: Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS). Both these two methods have been widely used in applied economic studies dealing with nonstationary and cointegrated data. The estimated coefficient by them reflects the long-run effect of variable. The FMOLS estimator is constructed by making corrections for the potential endogeneity and serial correlation to the OLS estimator. For a standard fixed-effect panel regression model: $y_{it} = \beta' x_{it} + s_i + \sigma_t + u_{it}$, the FMOLS estimator is given by:

$$\hat{\beta}_{FM} = \left[\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)' \right]^{-1} \left[\sum_{i=1}^{N} \left(\sum_{t=1}^{T} (x_{it} - \bar{x}_i)\hat{y}^*_{it} - T\hat{\Delta}^*_{\varepsilon u} \right) \right]$$

where the term $\hat{y}^*_{it}$ corrects for endogeneity, and $\hat{\Delta}^*_{\varepsilon u}$ corrects for serial correlation. For more details on FMOLS estimator, please refer to Pedroni (2000, 2001) among others.

DOLS estimator introduces the lead and lag differences of regressors to correct for possible serial correlation and endogeneity of the errors. It actually runs regression on the following model:

$$y_{it} = \beta' x_{it} + \sum_{j=-q_1}^{q_2} c_{ij} \Delta x_{i,t+j} + s_i + \sigma_t + v_{it}$$

Kao, Chiang and Chen (1999), Kao and Chiang (2000) among others provide more details on the implementation and properties of DOLS approach.

2.3.3 Cointegrating regression analysis

This subsection demonstrates the crucial empirical finding of this paper, which can be summarized as follows: financial liberalization in the home country was linked to the decline of external debt, but the liberalization in foreign countries had no sufficiently robust effect.

2.3.3.1 Regression result

Result by FMOLS

Table 2.4 shows the regression results by FMOLS. We use the pooled estimator with linear trend in cointegration. As mentioned before, the sample size of our highly unbalanced panel data only allows us to contain part of the $I(1)$ control variables in cointegrating regression. As documented in the last column of Table 2.2, the list of explanatory variables included in baseline regression is: [$FinanOpen$, $FinanOpenW$, DD, $GDPpc$, $M2$, $CapForm$, $TradeBalance$]. These variables are selected because of their relatively high data availability, logical relevance with public debt and statistical significance in regression. Other nonstationary control variables, namely [$FiscalBalance$, $SaveRate$, ER, $DependRatio$, $Credit$, $TradeOpen$] (and those stationary control variables) would be input in the robustness analysis later on.

The baseline result of FMOLS is listed in column (4.1) which is based on regression equation (2.1) with corrections according to FMOLS. Further results in model (4.2) - (4.9) are checked for robustness analysis. The finding by (4.1) is that financial liberalization, both in the home country ($FinanOpen$) and other countries ($FinanOpenW$), contributed to the decline of external debt ratio in developing countries. Hence the negative correlation between financial liberalization and external debt since 1990s is not just a coincidence. But it is not easy to explain the underlying mechanism. We leave the analysis on the possible reason in Section 2.4 and 2.5. The positive coefficient for domestic debt DD is consistent with our expectation, as high domestic debt level indicates a large government borrowing demand in which case the government would also borrow externally. The coefficient for GDP per capita is significantly negative which can be naturally expected, since *ceteris paribus* the debt to output ratio declines when economy grows. The coefficients for M2 ratio, capital formation rate and trade balance are all positive.

Model (4.2) - (4.9) differ from the baseline model (4.1) in some aspects. (1) We would like to check whether the estimated coefficients of financial liberalization is biased by the existence of other control variables. Model (4.2) and (4.3) are obtained by deleting some regressors from (4.1). In them, domestic financial liberalization and foreign financial openness are separately investigated. We see $FinanOpen$ and $FinanOpenW$ are still significant without depending on the existence of another. Model (4.4) is derived by adding all the remained control variables listed in Table 2.2 except [$FiscalBalance$, ER, ERR] into the regression. The fiscal balance and exchange rate variables are excluded at this moment to enable that sufficient many sample countries can be included in our regression based on this highly unbalanced panel datset – otherwise the amount of countries is reduced to only around 10 which makes the regression less meaningful. We will leave the investigation on the effects of government budget balance and exchange rate later on. (2) We further inspect whether alternative definitions of financial liberalization and external public debt bring about distinct estimation results. In model (4.5) the variables $FinanOpen$ and $FinanOpenW$ are constructed by FKRSU index instead of Chinn-Ito index. In model (4.6) ADT index for capital openness is relied on. In model (4.7) the dependent variable ED is calculated using WDI data. (3) We also examine the robustness of timing setup in the regression model. Model (4.8) uses the same model as in (4.1) but with the one-period lagged regressors. In this setup all regressors are predetermined. Under this model we do not see large difference in the estimated coefficients. The last column (4.9) reduces the sample period to 1994-2007 since there are many missing data in the sample of first several years. We still obtain significantly negative coefficient for $FinanOpen$, while the coefficient for $FinanOpenW$ is with opposite sign. In a nutshell, the regression results in model (4.2) - (4.9) further confirm that financial liberalization at home tends to reduce external debt. Regarding the financial liberalization in foreign countries, the estimated coefficient is found sensitive to sample period. We would further check the strength of its robustness in the following sections.

Table 2.4: **Regression result by Fully Modified OLS, *ED* as dependent variable**

	Baseline	**Alternative control variable**			**FKRSU**	**ADT**	**WDI**	**Lag 1**	**94-07**
	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)	(4.8)	(4.9)
FinanOpen	-0.070**	-0.079***		-0.199**	-0.099**	-0.068***	-0.092**	-0.077**	-0.130***
FinanOpenW	-0.323		-0.410*	-0.261	0.431	-1.005***	0.131	-0.076	2.412***
DD	0.093		0.093	-0.253	0.249***	0.262***	-0.033	0.097	0.080
GDPpc	-0.691***	-0.728***	-0.761***	-0.509*	-0.738***	-0.795***	-0.713***	-0.634***	-0.630***
M2	0.056	0.086		-0.089	-0.087	0.034	0.139*	0.087	0.028
CapForm	0.130		-0.262	0.611	0.726***	0.836***	0.296	-0.166	0.590***
TradeBalance	0.546***	0.569***		1.310**	0.858***	0.676***	0.547***	0.187	0.748***
Sample period:	91-07	91-07	91-07	91-07	96-07	91-05	91-07	92-07	94-07
Cross-sections:	45	46	46	17	42	36	38	42	44
Observations:	691	719	707	282	480	513	579	608	616

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) The estimated coefficients for *M*2, *CapForm* and *TradeBalance* are rescaled by multiplying 100 for better demonstration. This rescaling also applies to other regression result tables throughout this paper.

Result by DOLS

Table 2.5 shows the regression results by DOLS. We use the pooled estimator with linear trend in cointegration and data-driven automatic specification of leads and lags of regressors based on SIC criterion. The model setup in each column is just similar to the counterpart in Table 2.4. Model (5.1) is the baseline setup. Column (5.2) and (5.3) are obtained by deleting some regressors. In contrast, introducing more control variables produces (5.4). Model (5.5) and (5.6) take FKRSU and ADT index to measure financial liberalization; and (5.7) takes WDI data to measure external debt ratio. Lag 1 variables and 1994-2007 sample are used in model (5.8) and (5.9) respectively. The DOLS regression results are consistent with what we find by FMOLS: financial liberalization helps reduce external debt in developing countries. But just like the result of model (4.9), we find in (5.9) the coefficient for foreign liberalization is positve. In the next section where we conduct more robustness analysis, we attempt to understand more deeply.

Table 2.5: **Regression result by Dynamic OLS, *ED* as dependent variable**

	Baseline	Alternative control variable			FKRSU	ADT	WDI	Lag 1	94-07
	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)	(5.7)	(5.8)	(5.9)
FinanOpen	-0.068**	-0.089***		-0.070**	-0.064	-0.007	-0.095**	-0.047	-0.059*
FinanOpenW	-0.726***		-0.233	-0.482*	0.656**	-1.362***	0.023	-0.092	1.969***
DD	0.037		0.184**	0.313***	0.162**	0.397***	0.108	0.133*	0.168**
GDPpc	-0.807***	-0.856***	-0.922***	-0.568***	-0.724***	-0.307***	-0.654***	-0.590***	-0.788***
M2	0.135*	0.128*		-0.073	-0.071	0.006	0.174**	0.066	0.131
CapForm	0.663**		0.139	-0.094	0.549***				
TradeBalance	0.582***	0.473***		-0.158	0.620***	0.207	0.117	0.241*	
Sample period:	91-07	91-07	91-07	90-07	95-07	91-05	91-07	92-07	94-07
Cross-sections:	23	39	41	26	46	23	24	26	29
Observations:	391	624	663	349	562	345	400	413	401

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) In model (5.4) and (5.5) the static OLS leads and lags specification is imposed instead of data-driven automatic specification based on SIC criterion, because otherwise we do not have sufficient sample size to run regression. In model (5.6) - (5.8) the variable *CapForm* is deleted from the regression specification to fit the use of BIC, otherwise our sample size is not enough. Because of the same reason, model (5.9) deletes both *CapForm* and *TradeBalance*.

2.3.3.2 More robustness analysis

In order to strengthen our empirical finding, we further take into account the effect of international debt relief, and the potentially omitted variables of financial development, economic openness, fiscal balance, debt repayment ability, exchange rate, and foreign investor base. We also try to extend the sample to start from 1970.

Exclude the influence of debt relief

During the sample period, some international debt reliefs were conducted to reduce the external debt pressure on developing countries. The existence of debt relief may bias our estimation. In our initial sample selection, we already intentionally eliminated some highly debted poor countries who were also the most beneficiaries of international debt relief. But the potential bias of debt relief was not cleaned out completely. In fact over the past decades most developing countries, more or less, experienced some debt reliefs. In order to further exclude the impact of debt relief, we check the annual debt relief to GDP ratio in each country and redo the regression (4.1) and (5.1) excluding some sample countries with relatively large debt relief. To be precise, we delete 20% of the sample – a group of 9 countries with average annual relief larger than 0.7% GDP during 1990-2007.[12] After deleting them, the simple or weighted average annual

[12]The list of 9 countries is: Bolivia, Bulgaria, Ecuador, Ethiopia, Moldova, Nigeria, Panama, Uganda, Zambia. We have also tested the case of deleting more sample countries (not reported). With different samples, although the exact coefficient from the regression varies, the negative sign of the coefficient for financial liberalization does not change.

debt relief to GDP ratio in the remaining 37 countries was below 0.1%. Thus the impact of debt relief is negligible in this reduced sample. The column (13.1) in Table 2.13 and (14.1) in Table 2.14 at Appendix 2.D.2 give the FMOLS and DOLS regression result, respectively. The basic finding remains unchanged: both $FinanOpen$ and $FinanOpenW$ negatively affect external debt ratio.

Besides debt relief, we also consider that debt default and debt restructuring may also reduce the debt ratio. But the sample points accompanied with these default events, measured by "sovereign debt crisis" or/and "sovereign debt restructuring" in Laeven and Valencia (2013) dataset, only count for 4% of the full sample. Hence that is clearly not an important concern.

Exclude the influence of financial development and economic openness

As mentioned before, since financial development and economic openness may be both tightly linked to financial liberalization, there is possibility that our estimated effect of financial globalization is actually the effect of financial development or economic openness. Di Casola and Sichlimiris (2015) use ARDL model and empirically find financial development can help explain the dynamics of external debt ratio. (There are many reversely directed studies on how government debt affects the domestic financial development.) Baltagi, Demetriades and Law (2009) provide some evidence that domestic financial development may be linked to liberalization of capital account.

Thus we have to check the influence of financial development or economic openness. Table 2.12 in Appendix 2.D.1 documents the correlation coefficients between financial liberalization, financial development, and economic openness in our sample. The correlations between financial liberalization and other two factors are generally not too strong and sometimes controversial in sign. We furthermore add the financial development and economic openness as control variables and run the regression. The regression results are given in the column (13.2) - (13.3) of Table 2.13 and (14.2) - (14.3) of Table 2.14. The estimated negative coefficients for financial liberalization are hardly changed. Thus we can state that financial liberalization affects external government debt not via the change in domestic financial development or economic openness.

Investigate the influence of fiscal balance and repayment ability

Financial globalization may induce tax competition which has dynamic effects on public budget deficit. The deficit would change the size of public debt. Arcalean (2017) further shows that financial liberalization may have direct effects on the deficit besides tax competition. We consider this possibility. Instead of introducing variables representing tax competition, we directly consider the level of fiscal balance. We want to check whether the impact of financial openness takes effect majorly via fiscal balance. The column (13.4) - (13.5) of Table 2.13 and (14.4) - (14.5) of Table 2.14 show that, introducing fiscal balance in regression does not greatly change the coefficient for domestic liberalization, but makes oversea liberalization not significant. This may be partially interpreted in the sense that financial openness in foreign (home) countries is (not) largely linked to domestic budget deficit – the estimation result in Arcalean (2017) shows that financial liberalization in the rest of world significantly increases budget deficit while the effect of financial liberalization in the home country is insignificant.

Furthermore, we use the domestic saving rate and level of foreign currency reserve to control for the government's ability to repay external liability. It is possible that financial liberalization interacts with the state's debt repayment ability, which influences both the demand and supply of external financing. The column (13.6) - (13.7) of Table 2.13 and (14.6) - (14.7) of Table 2.14 document the regression results with the control variable of domestic saving rate and reserve as the ratio to GDP or total external debt. The estimated coefficients for $FinanOpen$, $FinanOpenW$, DD and $GDPpc$ are similar to that in baseline model. The coefficient for reserve to GDP ratio is positive, indicating that a country with higher repayment capacity is able to borrow more from other countries.

Investigate the influence of exchange rate

The value of exchange rate directly changes the relative size of external debt which is majorly denominated by foreign currency. Figure 2.11 at Appendix 2.A.3 shows the average real effective exchange rate index (2010 = 100) in developing countries. We see that during 1990-2007 the exchange rate fluctuated around the level of 90, and at 2007 it almost came back to the level in 1990. Hence the substantial decline of external debt ratio is not the result of large exchange rate change.

The regression results in column (13.8) - (13.9) of Table 2.13 and (14.8) - (14.9) of Table 2.14 investigate the influence of exchange rate. Regarding exchange rate, we consider the type of exchange rate regime and the level of real effective exchange rate. We find that, after introducing exchange rate as control variables, the estimated coefficient of $FinanOpenW$ is no longer significant. The coefficient of exchange rate is significantly negative. Hence, combining with the previous finding that the estimated influence of $FinanOpenW$ is sometimes positive and sometimes negative, we will doubt whether foreign liberalization really has large and clear effect. In contrast, under all cases the domestic financial openness generates robust negative impact on external public debt ratio.

Investigate the influence of investor base

Financial globalization involves both the demand and supply factors on developing countries' external borrowing. But the foreign creditors' fund supply is less under control of home country. We use the private external debt, total external debt and FDI to proxy the foreign investor base, and to some extent control for the supply factor. As displayed in the column (13.10) - (13.11) of Table 2.13 and (14.10) - (14.11) of Table 2.14, the additional control variables for investor base make the estimated coefficient for foreign financial openness *FinanOpenW* insignificant. This may not be surprising because investor base could cover the effect of *FinanOpenW*, which is majorly linked to the supply of foreign fund. And the coefficient for domestic liberalization *FinanOpen* is still significantly negative with a size close to the baseline estimation.

Extend the sample to start from 1970

Our baseline sample spans between 1990 and 2007. This 18-years period is relatively short in cointegrating regression, compared to the cross-section size of 46 countries. We also collect the data from alternative sources and extend the sample to start from 1970 and end at 2012. Particularly, the external debt, GDP per capita, M2, capital formation and trade balance data are from WDI; financial openness again from Chinn-Ito index; domestic debt data calculated from the total public debt by Abbas et al. (2011) minus external debt by WDI. Model (13.12) and (14.12) repeat our baseline regression based on the extended sample (but we are unable to implement more robustness checks because of the data lack on other control variables before the 1990s). We find foreign financial liberalization has a positive effect on external debt ratio. This is in contrast with the case with 1990-2007 sample, and implies that the previously estimated negative coefficient for *FinanOpenW* is not really robust. However the negative coefficient of *FinanOpen* is still significant.

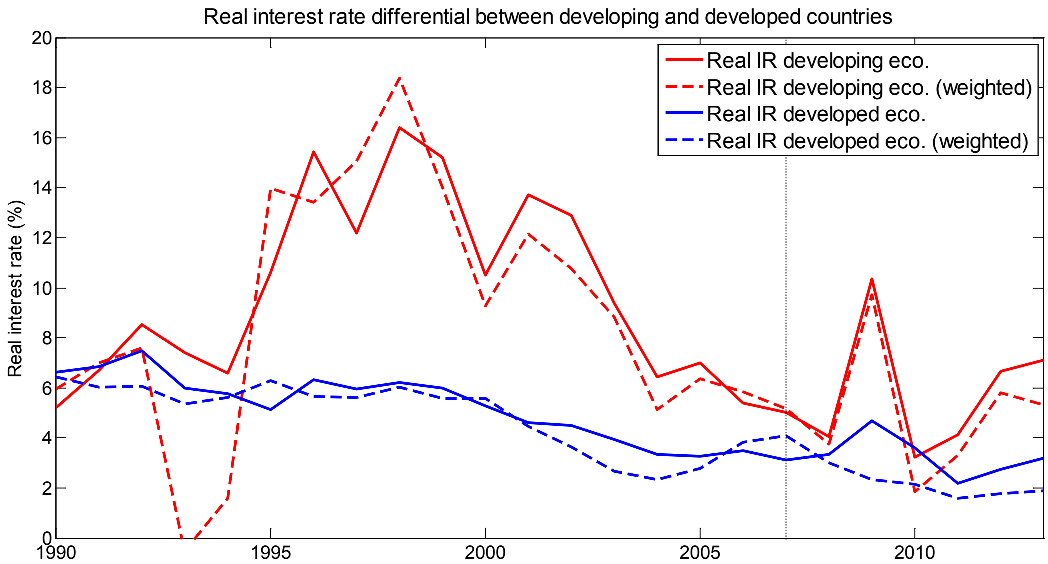
2.3.4 Further explorations: causality and the effect of financial liberalization on domestic public debt

The reduced form regressions in Section 2.3.3, though strongly confirm the link between financial liberalization and external public debt, are yet insufficient to assert the causality from financial globalization to external debt. Appendix 2.E presents a discussion on the causality and potential reverse causality effect. We will provide support for the causality using the Propensity Score Matching (PSM) method. And we also check whether the reverse causality of the influence from external debt to financial liberalization exists. Additionally, we investigate whether financial liberalization influences domestic public debt ratio. The findings can be summarized as follows: (1) the PSM analysis supports our previous finding from reduced form regressions that financial liberalization in the home country significantly reduces external debt ratio; (2) we do not see the existence of severe reverse causality which biases our core empirical finding; (3) financial globalization does not have evident influence on domestic public debt ratio.

2.4 Possible reason why financial liberalization dampens external public debt

In this section we propose a plausible explanation why financial liberalization may help reduce government external debt ratio in developing countries. It is regarding the financial market separation and domestic-foreign interest rate differential. The intuition is as follows. (i) In pre-liberalization period the domestic interest rate is higher than foreign rate, and then the financial liberalization pushes capitals into the developing countries which reduces the interest rate differential. (ii) In a largely separated domestic-international financial market, government's internal (external) borrowing cost is proportional to the domestic (foreign) interest rate. (iii) In the post-liberalization era the relative cost of domestic financing is reduced as a result of declined interest rate difference, then the government's willingness to borrow internally rises.[13]

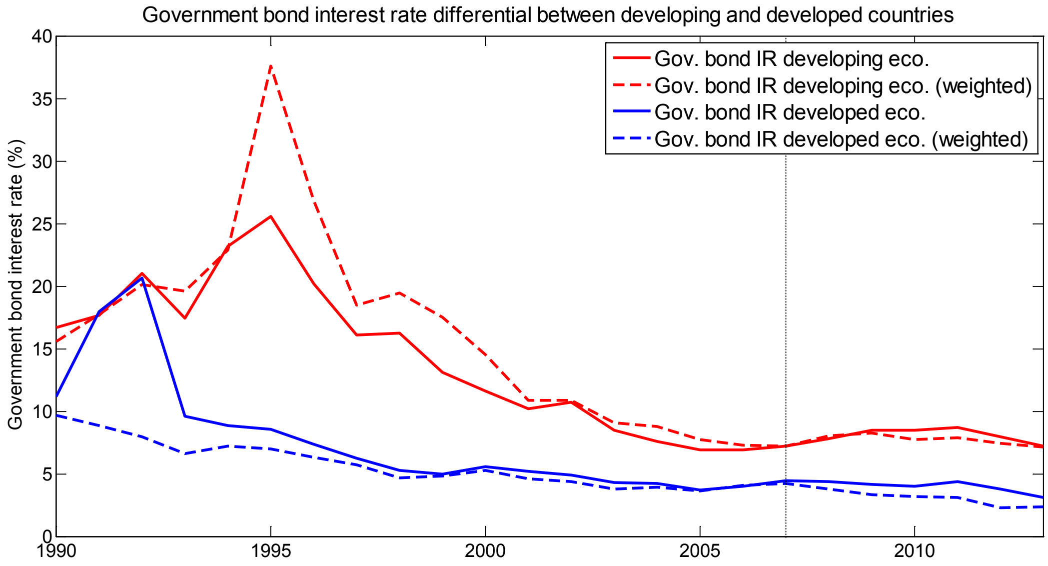
Figure 2.4: **Commercial lending real interest rate differential between developing and developed countries, 1990-2013**



Data source: WDI.

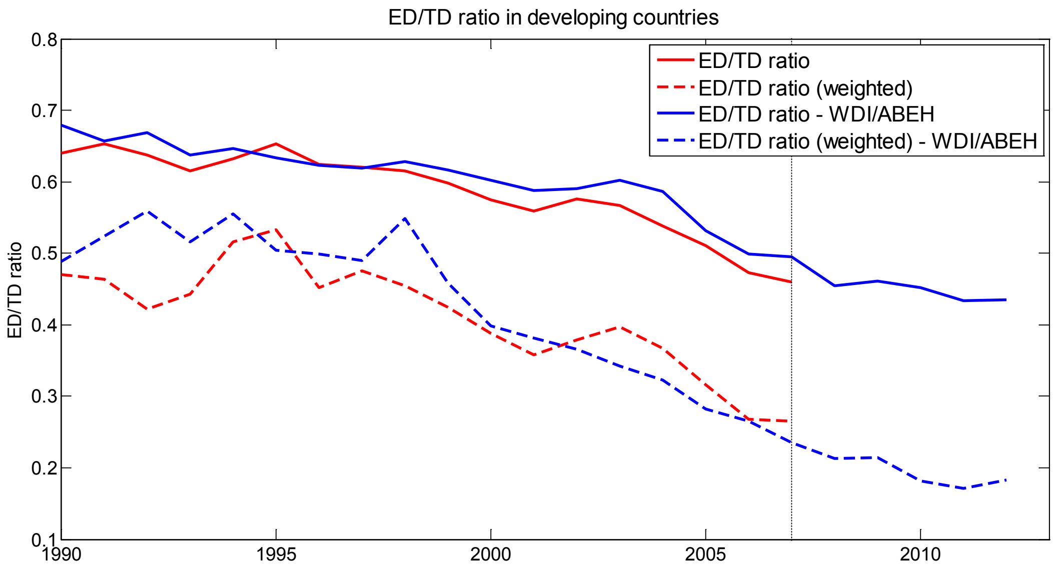
[13]An interesting empirical finding by recent studies (Andritzky, 2012; Arslanalp and Poghosyan, 2014; Ebeke and Kyobe, 2015; Ebeke and Lu, 2014) is that the increase in the share of government debt held by foreign investors would reduce the sovereign bond yield. In this way, financial liberalization can also reduce the government debt burden (of both domestic and external debt) via a rise of foreign bond investors. This leaves us an open question regarding how to consider the underlying mechanism in a theoretical model.

Figure 2.5: **Government bond interest rate differential between developing and developed countries, 1990-2013**



Data source: IFS (IMF International Financial Statistics).

Figure 2.6: **Share of external debt in total public debt in 46 developing countries, 1990-2012**



Data source: Panizza (2008), WDI and Abbas et al. (2011).

This argument is grounded on the hints from data. As indicated by Figure 2.4 and 2.5, during the whole sample period, the interest rate (in terms of both commercial bank lending rate and government bond yield) in developing countries is higher.[14] Thus the cost of borrowing is relatively lower if government borrows externally.[15] But the global financial integration shrinks the interest rate differential, by cross-border capital mobility such as the hot money and FDI. As demonstrated by the figures, there was a huge decline in the domestic-foreign rate differential and the absolute level of interest rate during the decades before 2008 crisis. (The figures show the levels of interest rate in two country-groups. If we consider the dynamics of difference, the curve is just very similar to that of interest rate in developing world. That is because the interest rate in advanced economies is relatively stable and only declines slightly and smoothly.)

This means the governments of developing countries would find the cost of internal financing declined. This gives them stronger incentive to borrow from domestic residents. As shown by Figure 2.6, the share of external debt in total public debt in developing countries declined along with the decline of domestic interest rate. Furthermore, data shows that the domestic public debt to GDP actually increased in the period (see Figure 2.9 in Appendix 2.A.1). In the next section we will use a theoretical model to formalize our intuitive explanation. The model is able to produce results consistent with the basic finding from Figure 2.4, 2.5 and 2.6.

[14]The data for many countries before 1995 is largely unavailable. Thus the shape of curves before 1995 may not reflect the real dynamics exactly. For Figure 2.5, we only have the data for 22 developing countries and 28 developed countries (compared to 42 and 31 in Figure 2.4). But, after checking some other data sources for several missing countries, we think the basic situation would not be largely different if we have a complete sample. Empirical literature also confirms that the covered interest rate parity (CIP) generally does not hold in emerging countries. Alper, Ardic and Fendoglu (2009) provide a comprehensive literature review.

[15]It is notable that in international market the developing country governments usually cannot borrow at developed country governments' rate. In our Figure 2.4, the interest rate is the *domestic* rate. In Figure 2.5, the bond rate is a *mixture of both domestic and foreign* borrowing cost. Hence, strictly speaking none of Figure 2.4 and 2.5 can explicitly validate our setup in theoretical model that the domestic borrowing cost of developing country government is higher than its external borrowing cost. Unfortunately we did not find any reliable data source on this issue. However, even though considering this point we can still justify our theoretical model based on the following argument.

It may be argued that, government does not finance externally directly at the international interest rate since it may be required to pay a risk premium – this premium would even make the government's effective borrowing cost at international market close to the internal borrowing cost. But as long as that premium is an increasing function of public external debt ratio, the shrinkage of the domestic-foreign interest rate differential would still reduce the government's demand for external financing. In the next section, see Footnote 20, we will formally show in a theoretical model that the existence of risk premium does not generate essentially different result.

2.5 Theoretical model

In this section, we illustrate the mechanism discussed in Section 2.4 using a micro-founded theoretical model. Our model is highly simplified and does not intend to precisely match the data in any specific country. But it is enough to illustrate the mechanism how international financial liberalization can contribute to reduce external public debt, via the decrease of financial market segmentation and interest rate differential. All the analysis is conducted in a real economy model without concerns about inflation, price rigidity, and exchange rate fluctuation. The model merely aims to provide an explanation how financial liberalization dampens external public debt, rather than measuring the associated distribution and welfare outcome.

2.5.1 Model setup

2.5.1.1 International environment and existence of capital control

We consider the home country as a small open economy such that foreign variables would not be affected by domestic dynamics. For simplicity we directly assume all foreign variables are constant. In light of the fact demonstrated in Figure 2.4 and 2.5, we assume the (steady state) domestic interest rate is significantly higher than the foreign interest rate. This can happen if e.g. the resource in the home country is relatively scarce and thus generates a higher investment return rate, or the domestic residents are less patient. As a result the domestic household will attempt to borrow from international market and hold domestic asset to take advantage of that domestic-foreign interest rate spread. But the government imposes capital controls on the international mobility of money.[16]

Particularly we consider the capital controls which directly work on household's collateral constraint in international borrowing. We will use two policy variables to adjust the degree of financial openness: (1) one is an international borrowing interest rate tax which alters the effective borrowing cost of domestic household; (2) another one is the LTV (loan-to-value) ratio in collateralized borrowing contract which varies with the efficiency of international contract enforcement. Both of these two capital control instruments were discussed in previous literature, such as Costinot, Lorenzoni and Werning (2014), Liu and Spiegel (2015) regarding the tax on international asset return and Faia (2011), Faia and Iliopulos (2011), Pisani (2011) regarding the LTV ratio in international collateral constraint. The details of these two instruments in our model will be explained later.

[16]In the sense that foreign source of productive capital is not easily available, capital control tends to reduce the domestic production efficiency (Abiad, Oomes and Ueda, 2008; Alfaro, Chari and Kanczuk, 2016; Larrain and Stumpner, 2015). But the implementation of capital control has some plausible reasons. The main purposes of capital control are majorly in four aspects: reducing the fluctuation and procyclicality of capital flow; reducing real exchange rate pressures; enhancing the independence of central bank especially under pegged exchange rate regime; reducing financial fragility by e.g. altering the capital flow composition toward longer maturity. However, all in all the effectiveness and welfare outcome are largely controversial.

In our model economy, the international financial market is highly segmented. Besides the household's foreign borrowing (private external debt), the only channel of international capital flow is the government's borrowing from foreign countries (public external debt). To simplify the analysis, we directly rule out the possibility of cross-border purchase of government bond: domestic residents are not allowed to buy foreign government bond or bond issued in foreign countries; likewise, foreign residents are unable to buy domestic bond.[17] In this way, the government of the home country can borrow domestically and externally at different rates. Throughout the model we focus on the case that government and agents never default on the debt.

2.5.1.2 Household

There is a unit continuum of infinitely lived households. The representative household maximizes the life-time utility subject to intertemporal budget constaint and international borrowing constraint. Household supplies labor to domestic firms to receive wage income. Besides that, household is able to hold one-period risk-free domestic government bond, and can borrow from foreign countries using domestic bond as collateral. The household's problem is expressed as:

$$\max_{\{C_t, L_t, B_{t+1}, B^F_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} + \phi_g \frac{G_t^{1-\sigma_g}}{1-\sigma_g} - \phi_n \frac{L_t^{1+\eta}}{1+\eta} \right]$$

$$st. \qquad (1+\tau_c)C_t + Q_t B_{t+1} + \tau_{t-1} R^F B^F_t + ACB_t + ACB^F_t = B_t + B^F_{t+1} + (1-\tau_w) W_t L_t$$

$$\tau_t R^F B^F_{t+1} \leqslant m_t B_{t+1} \tag{2.5}$$

where C_t, G_t, L_t, B_{t+1} and B^F_{t+1} denote the private consumption, government spending, labor supply, holding of domestic government bond, and borrowing from foreign countries, respectively. Q_t gives the price of risk-free one-period government bond such that $1/Q_t$ is the bond gross interest rate. R^F is the fixed foreign interest rate. W_t is the real wage. Parameters β, σ, σ_g and η are the discount rate, coefficient of relative risk aversion for private consumption and for public consumption, inverse of Frisch elasticity of labor supply, respectively. ϕ_g and ϕ_n measure the weights of government spending utility and labor disutility for household's welfare. τ_c and τ_w give the consumption tax rate and labor income tax rate. The variable τ_{t-1} denotes a capital control tax instrument employed by the government to adjust the effective foreign interest rate faced by household: if $(\tau_{t-1} - 1)$ is positive (negative), the government taxed (subsidizes) and impedes (encourages) international borrowing. In other words, a reduction of τ_{t-1} represents the occurrence of **financial liberalization**. In order to reflect the time lag between the announcement and implementation of legislation, we assume the capital control

[17] This assumption quite suits the case in the developing world. Empirical evidences show that in many developing countries the foreigners only hold a little part of domestic bond (e.g. the case of Mexico mentioned by Kumhof (2010)), and the fraction of foreign asset in domestic residents' portfolio is very small (e.g. home bias is 0.97 in emerging Asia, as mentioned in Chang, Liu and Spiegel (2015)).

tax τ_{t-1} is predetermined in $t-1$. The term ACB_t and ACB_t^F refer to adjustment costs of bond and borrowing. They are assumed to take the following quadratic forms:

$$ACB_t = \frac{\psi_b}{2}\left(\frac{B_{t+1}}{Y_t} - \frac{B}{Y}\right)^2 Y_t$$

$$ACB_t^F = \frac{\psi_b}{2}\left(\frac{B_{t+1}^F}{Y_t} - \frac{B^F}{Y}\right)^2 Y_t$$

where $\frac{B}{Y}$ and $\frac{B^F}{Y}$ are the steady state debt to output ratios. From a purely technical perspective, the adjustment cost terms ACB_t and ACB_t^F (or other alternative setups) are indispensable in our model since it helps maintain the model stationary. Schmitt-Grohé and Uribe (2003) provide a detailed and comprehensive discussion on the stationarity of small open economy model with incomplete asset market. We will set the parameter value ψ_b small such that the adjustment cost would not largely distort the equilibrium allocation in our model.

The international borrowing constraint, equation (2.5), reflects the typical imperfect contract enforement in business lending. This collateral constraint is widely discussed in literature (Kiyotaki and Moore, 1997). In our model, the foreign lenders protect themselves by requiring borrowers to collateralize their domestic assets B_{t+1}. The LTV (loan-to-value) ratio $m_t \in [0,1]$. The value of $(1-m_t)$ is the proportion of collateral that needs to be paid as transaction cost if domestic debtors default and foreign lenders liquidate the collateralized assets. Hence, this proportion refects the severity of international contract enforceability problem, which can be mitigated by financial liberalization such as the improved information transparency on international asset, enhanced institutional protection on cross-border property rights, and better infrastructure to reduce transaction cost. The higher the LTV ratio m_t is, the more relaxed the collateral constraint is. In other words, m_t can measure the degree of **financial liberalization**.

The household is price taker in the competitive market. Hence, for each household the domestic public bond's price Q_t and the wage W_t are exogenous. It is notable that we assume the government public spending G_t generates utility for households – this is the reason why government exists in this economy. But since the public spending is exogenous for each individual household and not taken into account in household's decision, we omit this part in household's optimization. We will discuss the behavior of government later. The first order conditions with respect to consumption and domestic bond generate an expression linking Lagrangian multipliers to domestic bond price :

$$\frac{\mu_t}{\lambda_t} = \frac{1}{m_t}\left[Q_t - E_t\{\Lambda_{t+1}\} + \psi_b\left(\frac{B_{t+1}}{Y_t} - \frac{B}{Y}\right)\right] \tag{2.6}$$

where μ_t and λ_t are the Lagrangian multipliers with respect to collateral constraint and budget constraint, respectively. The term $\Lambda_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t} = \beta\left(\frac{C_t}{C_{t+1}}\right)^{\sigma}$ is the intertemporal stochastic discount factor. If the international borrowing constraint is not binding (thus $\mu_t = 0$) and we omit the adjustment cost of bond (thus $\psi_b = 0$), equation (2.6) just becomes the familiar Euler equation: $\beta E_t \left\{ \left(\frac{C_t}{C_{t+1}} \right)^{\sigma} \frac{1}{Q_t} \right\} = 1$. In contrast, with binding collateral constraint ($\mu_t > 0$) the existence of external private borrowing introduces a wedge between Q_t and Λ_{t+1}. The wedge also depends on the LTV ratio m_t. Following typical literature, we will set household's discount rate β sufficiently small such that the collateral constraint will always bind around a neighborhood of the steady state.

The first order condition with respect to foreign borrowing is written as:

$$\tau_t R^F \left(\frac{\mu_t}{\lambda_t} + E_t \{\Lambda_{t+1}\} \right) = 1 + \psi_b \left(\frac{B^F_{t+1}}{Y_t} - \frac{B^F}{Y} \right) \tag{2.7}$$

This equation tells us that the capital control (gross) tax τ_t, joint with foreign interest rate R^F, affects the value of μ_t. This is because the effective gross foreign rate $\tau_t R^F$ decides how relatively cheaper the foreign borrowing is, and how profitable to borrow externally and invest domestically. Combining equation (2.6) and (2.7), it is not difficult to see that the effect of financial liberalization by changing τ_{t-1} and m_t will ultimately propagate to influence the equilibrium price of domestic government bond. As a result the amount of public bond will be affected.

As the last block of describing household's behavior, we have a usual equation describing the substitution between leisure and consumption:

$$\frac{(1-\tau_w)}{(1+\tau_c)} W_t = \phi_n L_t^{\eta} C_t^{\sigma} \tag{2.8}$$

2.5.1.3 Capitalist

The capitalist specializes in investment and accumulation of domestic private capital. The income of capitalist comes from the rent revenue of capital stock. For simplicity, we assume the population of capitalists is as the same as households. The representative capitalist's utility maximization problem is:

$$\max_{\{C_{c,t}, K_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta_c^t \left[\frac{C_{c,t}^{1-\sigma}}{1-\sigma} + \phi_g \frac{G_t^{1-\sigma_g}}{1-\sigma_g} \right]$$

$$st. \qquad (1+\tau_c) C_{c,t} + K_{t+1} + ACK_t = (R_t - \delta) K_t \tag{2.9}$$

where $C_{c,t}$, G_t and K_{t+1} denote the capitalist consumption, government spending and private capital stock, respectively. Just like the case of household, we assume public spending is a part of capitalist's utility but is decided by government and out of capitalist's direct control. The new capital investment has quadratic adjustment cost ACK_t:

$$ACK_t = \frac{\psi_k}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 K_t$$

Living in a completely competitive market, the representative capitalist takes the gross rent rate net of depreciation $(R_t - \delta)$ as given. We assume domestic capitalist has no direct access into international financial market – e.g. they cannot directly purchase foreign asset, borrow overseas, or invest in foreign firm. The first order condition with respect to capital provides us:

$$E_t\left\{\Lambda_{c,t+1}\left[(R_{t+1} - \delta) + \frac{\psi_k}{2}\left[\left(\frac{K_{t+2}}{K_{t+1}}\right)^2 - 1\right]\right]\right\} = 1 + \psi_k\left(\frac{K_{t+1}}{K_t} - 1\right) \tag{2.10}$$

where $\Lambda_{c,t+1} = \beta_c\left(\frac{C_{c,t}}{C_{c,t+1}}\right)^{\sigma}$ is capitalist's intertemporal stochastic discount factor. In the case of omitting capital adjustment cost ($\psi_k = 0$), equation (2.10) is nothing but an Euler equation: $\beta_c E_t\left\{\left(\frac{C_{c,t}}{C_{c,t+1}}\right)^{\sigma}(R_{t+1} - \delta)\right\} = 1$.

2.5.1.4 Firm

The representative firm produces in a competitive market, using domestic capital stock supplied by the capitalist and labor supplied by the household as input, according to the following Cobb-Douglas technique:

$$Y_t = A{K_t}^{\alpha} L_t^{1-\alpha} \tag{2.11}$$

where Y_t and K_t refer to output and aggregate private capital stock, respectively. We assume a constant TFP $A = 1$ in all periods. Firms are price takers. It is obvious that, based on the unit return to scale Cobb-Douglas production technique, the firm always earns zero profit: $Y_t - r_t K_t - W_t L_t = Y_t - \alpha Y_t - (1-\alpha)Y_t = 0$ where $r_t = R_t - 1$ is the return rate of rented private capital. The production inputs are priced at their marginal products. Straightforwardly, we can obtain the following equations:

$$R_t - 1 = \alpha {K_t}^{\alpha-1} L_t^{1-\alpha} = \alpha\frac{Y_t}{K_t} \tag{2.12}$$

$$W_t = (1-\alpha){K_t}^{\alpha} L_t^{-\alpha} = (1-\alpha)\frac{Y_t}{L_t} \tag{2.13}$$

2.5.1.5 Government

The government's role in the economy is to supply public consumption goods G_t which is financed by the tax revenue $[\tau_c(C_t + C_{c,t}) + \tau_w W_t L_t + (\tau_{t-1} - 1)R^F B_t^F]$, domestically issued bond $Q_t B_{t+1}$ and external public debt B_{t+1}^E. In principle the government can also receive tax revenue from corporate profit tax, but this is omitted in our model since the firms earn zero profit. The tax rates are predetermined; domestic bond price is decided in equilibrium; and government borrows in international market at the constant interest rate R^F.[18] Issuance of external public debt has an extra quadratic cost of $\frac{\psi_g}{2}\left(\frac{B^E_{t+1}}{Y_t}\right)^2 Y_t$, as a function of the external debt to output ratio. This cost comes from the disadvantages of external debt such as the exchange rate risk (related to the so-called "original sin" literature), risk of maturity mismatch when external borrowing is short-term, and external political pressure from creditor. Thus the government's budegt constraint is:

$$\begin{aligned} & G_t + B_t + R^F B^E_t + \frac{\psi_g}{2}\left(\frac{B^E_{t+1}}{Y_t}\right)^2 Y_t \\ = \;& [\tau_c(C_t + C_{c,t}) + \tau_w W_t L_t + (\tau_{t-1} - 1)R^F B^F_t] + Q_t B_{t+1} + B^E_{t+1} \end{aligned} \tag{2.14}$$

In this equation, a positive value of B_{t+1} and B^E_{t+1} means the government borrows from the domestic and foreign residents.

We consider the government as an independent actor who obtains utility from government spending. The government's problem is:

$$\max_{\{G_t, B_{t+1}, B^E_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta_g^t \left[\frac{G_t^{1-\sigma_g}}{1-\sigma_g}\right]$$

subject to the budget constraint (2.14).[19] Here the parameter β_g and σ_g measure the government's discount rate and coefficient of relative risk aversion for fiscal spending, respectively.

The first order conditions with respect to G_t and B_{t+1} generate:

$$1 = \beta_g E_t\left\{\left(\frac{G_t}{G_{t+1}}\right)^{\sigma_g} \frac{1}{Q_t}\right\} \tag{2.15}$$

Although there is extra holding cost of external debt, the government is still willing to borrow externally because of the lower interest rate $R^F < \frac{1}{Q}$. (The variables without time subscript

[18]In other words, in our model with separate financial market the government's internal (external) borrowing cost is proportional to domestic (foreign) interest rate. It may be argued that, government does not issue external bond directly at the international interest rate R^F since it is often required to pay a risk premium – this premium would make the government's effective borrowing cost at international market similar to the internal financing cost. But later (in Footnote 20) we will show that an introduction of risk premium in the model does not generate essentially different result, as long as the financial liberalization shrinks the domestic-foreign interest rate differential.

[19]It is notable that, though we model the government as a selfish utility-maximizer with its own objective function for public spending, to a large extent its behavior can still be desirable from the perspective of social welfare. Intuitively we can consider two points. (1) The selfish government's utility function $\frac{G_t^{1-\sigma_g}}{1-\sigma_g}$ is an additive part of household and capitalist's utility. This means that, *ceteris paribus*, an increase of government utility also raises the welfare of household and capitalist. (2) Being limited by the budget constraint, government is willing to ensure a high revenue which partly comes from the consumption tax $\tau_c(C_t + C_{c,t})$. This term is proportional to C_t and $C_{c,t}$ which is also a part of agents' utility. Of course, we need to check the whole genenral equilibrium effect in order to understand how the selfish government's behavior is consistent with a benevolent Ramsey planner who maximizes the social welfare. Since this is not a straightforward task, we leave it for the work in the future.

refer to the steady state values.) The benefit of lower interest payment will be surpassed by the extra holding cost of external debt if the stock of external debt B^E_{t+1} is too large. The breakeven point is given by the first order condition with respect to B^E_{t+1}:

$$\frac{B^E_{t+1}}{Y_t} = \frac{1}{\psi_g}\left(\frac{1}{Q_t} - R^F\right) \tag{2.16}$$

This equation, *ceteris paribus*, acts like the government's demand function for external borrowing. Here the "price" depends on the domestic-foreign government bond yield differential $\left(\frac{1}{Q_t} - R^F\right)$.[20]

The link between domestic interest rate (or government bond yield) and public debt ratio is widely discussed in empirical literature (e.g. Alexopoulou, Bunda and Ferrando, 2010; Baldacci and Kumar, 2010; Claeys, Moreno and Suriñach, 2012; Engen and Hubbard, 2005; von Hagen, Schuknecht and Wolswijk, 2011; Perović, 2015). The general finding is that the link between public debt ratio and interest rate is relatively weak in developed countries, but fairly substantial in emerging economies. Later we will rely on the empirical literature to set the parameter value of ψ_g.

2.5.1.6 Process of financial liberalization

As discussed in household's problem, the international borrowing tax rate τ_t and LTV ratio m_t in household's private external debt collateral constraint influence the degree of financial openness. Therefore, we model the process of financial liberalization in the home country as an exogenous reduction of tax rate τ_t or increase in LTV ratio m_t. This opens the door to allow larger volume of cheap foreign funds to come in, as now domestic household's collateral constraint is relaxed. Later we will investigate both the long-run consequences of permanent financial liberalization, and the impulse responses to a transitory financial liberalization shock.

[20]There is another way, which is essentially equivalent in our model, to consider this equation (2.16) instead of our assumption of holding cost. The key is about the risk premium on sovereign debt. Considering that default risk increases with the degree of debtedness, potential foreign creditors on sovereign debt would require a premium Φ_t as an increasing function of public external debt ratio $\frac{B^E_{t+1}}{Y_t}$. Without loss of generality we assume foreign creditors are risk-neutral. Then the non-arbitrage in international market requires the equality to hold that $R^F\Phi_t = \frac{1}{Q_t}$. We take the functional form similar to that in Schmitt-Grohé and Uribe (2003) and Prasad (2014): $\Phi_t = \exp\left[\psi_g\left(\frac{B^E_{t+1}}{Y_t} - \frac{B^E}{Y}\right)\right]$ where $\frac{B^E}{Y}$ is the steady state external debt ratio. Thus the demand function of foreign investors can be derived from:

$$\frac{1}{Q_t} = R^F\Phi_t = R^F_t \exp\left[\psi_g\left(\frac{B^E_{t+1}}{Y_t} - \frac{B^E}{Y}\right)\right]$$

i.e.

$$\frac{B^E_{t+1}}{Y_t} = \frac{1}{\psi_g}\left[\ln\left(\frac{1}{Q_t}\right) - \ln R^F\right] + \frac{B^E}{Y}$$

In equilibrium the demand and supply of B^E_{t+1} should be equal. In the case that interest rate is not too large, the above demand function is almost equation (2.16) up to an additive constant and rounding error.

In the case that we investigate the effects of permanent liberalization, we will make comparative static analysis to observe how steady state values are altered by a permanent change of τ_t or m_t. If we merely consider a temporary relaxation of capital control tax τ_t, we assume the following AR(1) process:

$$\log \tau_t = (1-\rho_\tau)\log \tau + \rho_\tau \log \tau_{t-1} + \varepsilon_{\tau,t} \tag{2.17}$$

where the persistence and size of relaxation are determined by parameter ρ_τ and scale of $\varepsilon_{\tau,t}$, respectively. A negative shock of $\varepsilon_{\tau,t}$ means a reduction of τ_t and hence a decrease of capital control. Similarly, for a temporary liberalization by raising m_t we assume the exogenous AR(1) process:

$$\log m_t = (1-\rho_m)\log m + \rho_m \log m_{t-1} + \varepsilon_{m,t} \tag{2.18}$$

For simplicity, we assume $\varepsilon_{\tau,t} \overset{iid}{\sim} N(0,\sigma_\tau^2)$, $\varepsilon_{m,t} \overset{iid}{\sim} N(0,\sigma_m^2)$ and there is no correlation between $\varepsilon_{\tau,t}$ and $\varepsilon_{m,t}$.

2.5.2 Equilibrium

In equilibrium each market clears. The aggregate resource constraint is:

$$\begin{aligned} Y_t &= C_t + C_{c,t} + G_t + [K_{t+1} - (1-\delta)K_t] + ACK_t + ACB_t + ACB_t^F \\ &\quad + \frac{\psi_g}{2}\left(\frac{B_{t+1}^E}{Y_t}\right)^2 Y_t + [R^F(B_t^F + B_t^E) - (B_{t+1}^F + B_{t+1}^E)] \end{aligned} \tag{2.19}$$

The link between international trade balance and capital flow is embeded in this equation. Other market clearing conditions were already expressed in the previous section implicitly.

The equilibrium of the economy consists of the allocations of variables $\{\mu_t,\ C_t,\ C_{c,t},\ G_t,\ L_t,\ K_{t+1},\ Y_t,\ B_{t+1},\ B_{t+1}^F,\ B_{t+1}^E\}$ together with a set of prices $\{W_t,\ R_t,\ Q_t\}$ and transversality conditions, given the exogenous process for the financial liberalization $\{\tau_t,\ m_t\}$, satisfying equations (2.5) - (2.19).

2.5.3 Parameterization

Table 2.6 gives the value and definition of the model's parameters. We calibrate the model for an "average" developing country. The model is set at annual frequency. Most parameters are typical in literature and clearly readable from Table 2.6. The last rows of Table 2.6 document the steady state values of some interested variables under our parameterization. We can see that the capital and debt to output ratios locate in a reasonable range.

Table 2.6: **Value and definition of the parameters in the theoretical model**

Para.	Value	Definition	Source/Target
β_c	1/1.08	capitalist discount rate	annual capital return rate $r-\delta=8\%$
β	β_c	household discount rate	the simplest case
β_g	Q	government discount rate	to satisfy equation (2.15) at steady state
σ	1	coefficient of relative risk aversion on private consumption	typical value in literature
σ_g	1	coefficient of relative risk aversion on public consumption	typical value in literature
η	1	inverse of Frisch elasticity of labor supply	typical value in literature
ϕ_n	$\frac{(1-\tau_w)(1-\alpha)}{(1+\tau_c)\frac{C}{Y}L^{1+\eta}}$	weight parameter for labor disutility in household's utility function	steady state $L=\frac{1}{3}$
δ	10%	capital depreciation rate	typical value in literature
τ_c	20%	consumption tax rate	close to the VAT rate in many countries
τ_w	10%	labor income tax rate	jointly with τ_c to match a reasonable domestic public debt level
α	0.45	income share of private capital in production	income share of labor in output is roughly 55%, according to PWT 9.0 data
ψ_g	0.15	scale parameter for government's holding cost of external public debt	amid Alexopoulou, Bunda and Ferrando (2010), Claeys, Moreno and Suriñach (2012) and Perović (2015)
ψ_b	$0.1\psi_g$	scale parameter for domestic household's bond adjustment cost	set it small to avoid large distortion in equilibrium allocation
ψ_k	2	scale parameter for capitalist's capital investment adjustment cost	Alvarez-Parra, Brandao-Marques and Toledo (2013)

Table 2.6 (cont.): **Value and definition of the parameters in the theoretical model**

Para.	**Value**	**Definition**	**Source/Target**
τ	1.03	steady state value of capital control tax rate on household's international borrowing	generate an intermediate level of domestic government bond interest rate
m	0.5	steady state value of LTV ratio in household's international borrowing collateral constraint	Mendicino (2012)
ρ_τ	0.63	persistence parameter in the AR(1) process of financial	within 5 years the influence of a one-shot temporary shock
ρ_m	0.63	liberalization	declines to less than 10% of its initial value
σ_τ	1.0097%	standard deviation of financial liberalization shock to τ	τ changes 1 percentage point after a shock of 1SD
σ_m	2%	standard deviation of financial liberalization shock to m	m changes 1 percentage point after a shock of 1 SD
Some steady state values:			
A	1	TFP level	the simplest case
L	1/3	labor supply	typical value in literature
$\frac{1}{Q}-1$	6.5%	domestic government bond risk-free interest rate	
$r-\delta$	8%	domestic capital return rate	
r^F	2%	foreign risk-free interest rate	
$(C+C_c)/Y$	59%	consumption to output ratio	
G/Y	15%	government spending to output ratio	roughly match data
K/Y	250%	capital stock to output ratio	
B^F/Y	9%	private external debt to output ratio	
B/Y	20%	domestic public debt to output ratio	
B^E/Y	30%	external public debt to output ratio	
$(B+B^E)/Y$	50%	total public debt to output ratio	

The steady state capital control tax rate τ, for which there is no explicit counterpart in real data, is simply set at 1.03. We set this value to generate an intermediate size of domestic government bond interest rate, as 3% is the half of the gap between the domestic capital return rate 8% and foreign interest rate 2% (discussed later). The steady state value of LTV ratio parameter m in equation (2.5) is set at 0.5, which is close to the average international lending LTV ratio for developing countries discussed in literature (see e.g. a review on the calibration of this parameter in Footnote 2 of Mendicino (2012)).

We set the steady state interest rates in developing and developed countries by observing Figure 2.4 and 2.5. At this moment we do not consider the interest rate data before 1995, because the interest rates demonstrated an unreasonably large volatility and the data for a large fraction of sample countries is unavailable during 1990-1995. In the theoretical model the foreign interest rate is assumed fixed. Thus we calculate the developed world's average interest rate in period 1996-2007 (we first calculate the weighted average in each year, and then take simple average over all years and over both commercial lending and government bond interest rates), which is 4.5%. Then we simply assume the risk-free and risk premium components of this interest rate are half-and-half, which gives us a risk-free foreign interest rate $(R^F - 1)$ of roughly 2% for theoretical model setup. Regarding the steady state domestic capital return rate $(R - 1 - \delta)$, we set it in the following way. We calculate the average interest rate for period 1996-2000 in developing countries, which is 16.7%. Then we take the half of it which is assumed as the risk-free component. That gives 8%. Consequently, given our parameterization of $\tau = 1.03$ and $m = 0.5$, we have the steady state government bond risk-free rate $(\frac{1}{Q} - 1)$ at 6.5%.

The parameterization for government's external debt holding cost and household's bond adjustment costs is not straightforward. We first think over the parameter ψ_g in equation (2.16). In our model this can reflect the price (interest rate) elasticity of public debt. Literature usually estimates the reverse relationship – the influence from government debt ratio DR_t to government bond yield $\tilde{R}_t = \frac{1}{Q_t}$:

$$\tilde{R}_t = \hat{\psi} DR_t + Control\ Variables$$

In our context of external public debt in equation (2.16), this effect can actually be regarded as a premium on high sovereign debtedness. As mentioned before, the idea of risk premium can equivalently generate our equation (2.16). Thus we can write down the following empirical relationship: $DR_t = \frac{B^E_{t+1}}{Y_t} = \frac{1}{\hat{\psi}} \tilde{R}_t + Control\ Variables$. Claeys, Moreno and Suriñach (2012) obtain an estimated value $\hat{\psi}$ of 0.22 for 17 emerging economies. Some literature gives lower estimates for $\hat{\psi}$ such as 0.05 in Alexopoulou, Bunda and Ferrando (2010) for 8 new EU countries, and 0.04 in Perović (2015) for 10 Central and Eastern European countries. We take a value of 0.15 in between. Given our steady state value of $\frac{1}{Q} = 1.065$ and $R^F = 1.02$, this implies an external public debt ratio around 30% in our model. This is close to the level in real data at the 1990s. Admittedly the exact value of $\hat{\psi}$ deserves more discussions, but the change of that value does not qualitatively alter our result. Regarding household's bond adjustment cost parameter ψ_b, we set it small at $\psi_b = 0.1\psi_g$ such that it would not largely distort the equilibrium allocation.

The consumption tax rate τ_c is set at 20% which is close to the VAT (value added tax) rate in many countries. Then the labor tax rate τ_w is set at 10% such that, according to the government budget balance, a steady state domestic debt to output ratio is 20% – a value close to the real data. Concerning the parameters (ρ_τ, ρ_m, σ_τ, σ_m) for financial liberalization processes, we do not have prior knowledge and can hardly find the empirical counterparts from real data. We simply set the persistence parameter ρ_τ and ρ_m of AR(1) process at 0.63 so that within 5 years the influence of a one-shot temporary shock declines to less than 10% of its initial value. We set the standard deviation $\sigma_\tau = 1.0097\%$ and $\sigma_m = 2\%$ such that τ and m will both change 1 percentage point after a shock of 1 standard deviation.

2.5.4 Consequence of financial liberalization

In this section we investigate the consequences of financial liberalization in the home country. We first focus on the long-run effect of financial liberalization, via the lens of different steady states by varying the degree of financial openness. Then we discuss the economic dynamics if a relaxation of capital control is temporary rather than permanent.

2.5.4.1 Long-run effect of financial liberalization

Over the past decades, many developing countries have greatly deregulated their capital accounts and maintained the liberalization for a long period. Even after the 2008 financial crisis because of which a set of countries intensified capital controls again, the overall financial openness in developing world is still dramatically higher than the level in the 1990s. Hence it is important to investigate the long-run effect of financial liberalization. We conduct a simple comparative static analysis on how financial liberalization changes the steady state public debt ratios.

Evaluating equation (2.7) and (2.6) at steady state entails us to write down the relationship between financial liberalization variable (τ, m) and government domestic bond price Q:

$$\frac{\mu}{\lambda} = \frac{1}{\tau R^F} - \beta$$

and

$$Q = \beta + \frac{\mu}{\lambda} m$$

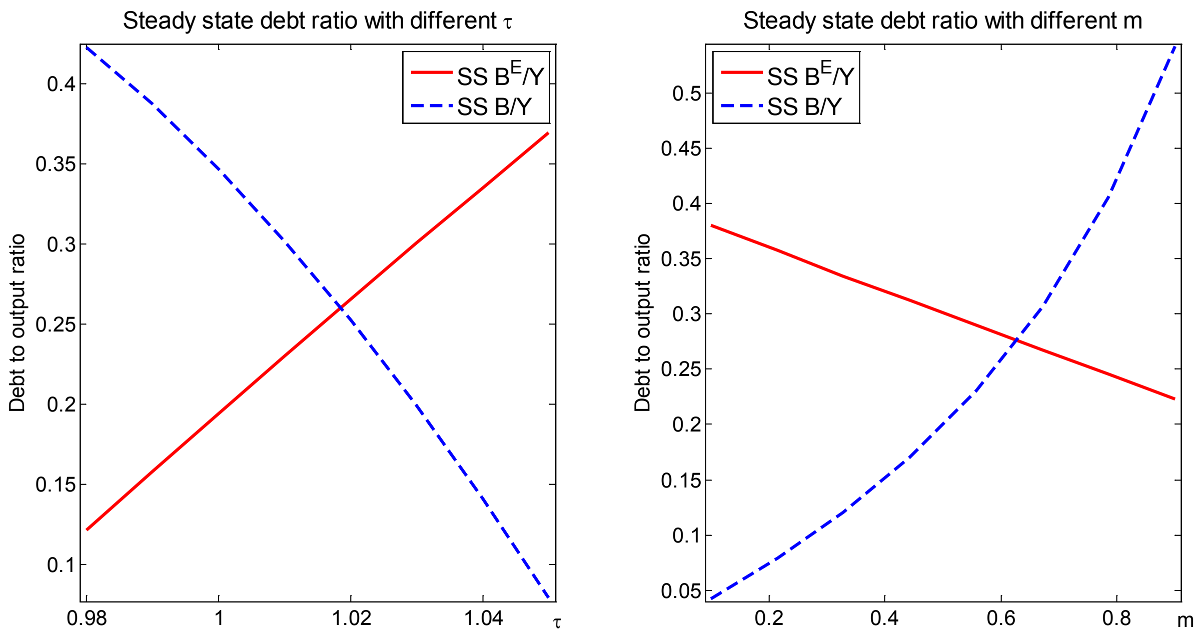
The implication of these two static equations is straightforward. (1) If capital control tax τ decreases, the domestic household's external borrowing cost declines and it is more profitable to borrow overseas and invest in domestic government bond. This makes the (discounted) shadow value of international collateral constraint, which is measured by $\frac{\mu}{\lambda}$, larger. In this circumstance, domestic household have stronger incentive to purchase domestic public bond and the demand is boosted, which pushes up the price Q. (2) If the collateral constraint's LTV ratio m is enhanced, the household is able to borrow more externally given any size of collateralized domestic government bond. This situation stimulates the demand for domestic public bond and raises its price Q.

Equation (2.16) gives us the steady state external public debt ratio depending on the domestic-foreign interest rate difference:

$$\frac{B^E}{Y} = \frac{1}{\psi_g}\left(\frac{1}{Q} - R^F\right)$$

As we just discussed, after the financial liberalization in both cases of decreasing τ and increasing m, the domestic bond price Q will be raised. Equivalently, the bond yield $\frac{1}{Q}$ i.e. the government's internal financing cost becomes smaller. Given the fixed foreign financing cost R^F, this naturally dampens the government's incentive to borrow externally and enhances the willing to borrow domestically.

Figure 2.7: **Steady state public debt ratios under different τ and m**



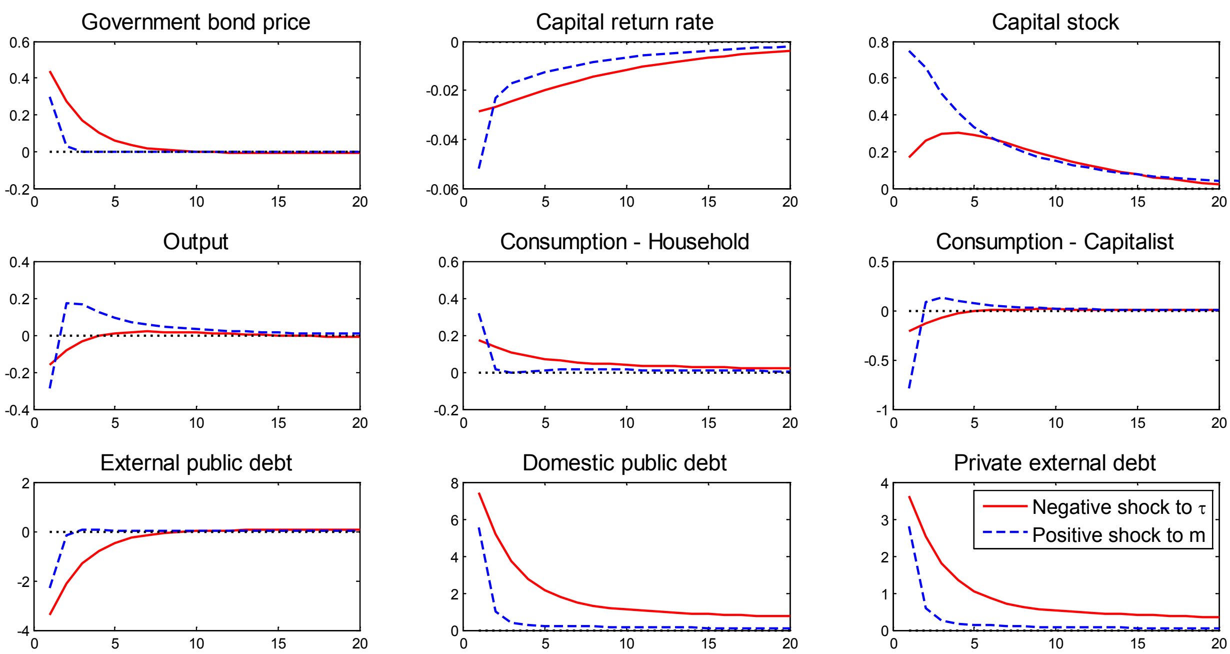
Note: In the left panel, τ varies within [0.98, 1.05] maintaining $m = 0.5$. In the right panel, m varies within [0.1, 0.9] maintaining $\tau = 1.03$.

Overall, (given the initial state that domestic interest rate is higher than foreign rate) our simple comparative static analysis demonstrates that permanent financial liberalization is able to make the government's domestic financing cost $\frac{1}{Q}$ to decrease, which motivates the government's external borrowing to decline. As the aggregate financing need of government is basically unchanged, the government would issue more domestic bond and have higher domestic public debt ratio. Figure 2.7 demonstrates the quantitative results on how financial liberalization, by decreasing τ or increasing m, depresses external public debt ratio $\frac{B^E}{Y}$ and spurs domestic public debt ratio $\frac{B}{Y}$ in the steady state of our model economy.

2.5.4.2 Economic dynamics after temporary financial liberalization shocks

Although many developing countries have persistently liberalized their capital accounts, some countries such as China and India still maintained its capital openness at a low level and only had some temporary regulation relaxation in some cases; some other countries such as Argentina and Brazil experienced frequent policy shifts between capital control and liberalization. Thus it is also important to investigate the macroeconomic dynamics if the government implemented a temporary (unexpected) financial liberalization.

Figure 2.8: **Impulse responses to temporary financial liberalization shocks**



Note: The deviations of bond price and return rate from the steady states are expressed in percentage points. Other variables are expressed by percentage deviation as the ratio to steady state output.

Negative shock to capital control tax τ

We first consider a transitory financial liberalization shock of exogenous reduction in capital control tax τ_t, which is expressed by equation (2.17). We simulate a situation that, after a negative shock of 1 standard deviation, τ_t temporarily declines by 1 percentage point from its steady state value. The abatement of τ_t means a reduction of obstacle on households' oversea borrowing. The impulse responses of key variables after this kind of financial liberalization are demonstrated by the red solid curves in Figure 2.8. It is clear to see two important results. (1) Domestic government bond yield and interest rate decrease. The reason is obvious: the surge of foreign funds B^F_{t+1} after the reduction of τ_t expands the households' investment in domestic government bond B_{t+1}, which elevates its price Q and lowers its yield $\frac{1}{Q}$. In our model, this lowered bond yield is further linked to a decline in capital marginal return rate R_t, as the capitalists invest more productive capital and the aggregate domestic capital stock increases. This happens because the households who are now richer supply less labor and firms demand more capital input as a response to the raised wage cost. The decline of interest rates in our model is consistent with Henry (2003) which finds empirical evidence that capital account liberalization reduces the cost of capital in developing countries, though that paper mainly focuses on stock market. (2) External public debt decreases and domestic public debt increases. The reason is also transparent: the relative price between domestic debt and external debt is altered. Since the external debt becomes more expensive in relative price, government's demand declines. Some external public debts are retired while the holding of domestic bond increases.

Compared to the initial state, the economy with higher financial openness has a lower domestic interest rate and lower external public debt share which is consistent to the stylized facts in Figure 2.4, 2.5 and 2.6. Moreover, our model predicts that after financial liberalization domestic government debt and private external debt ratio will be lifted. This prediction fits the observed trend in real data over the past decades (see Figure 2.9 in Appendix 2.A.1 and Figure 2.12 in Appendix 2.A.4), though our model overstates the size of increase. In the future it would be a promising extension to our model, if we can take into account other elements that influence the domestic public debt and private external debt ratio.

Positive shock to LTV ratio m

Now we move to investigate the effect of a temporary positive 1 standard deviation shock to LTV ratio m_t, which is expressed by equation (2.18). The shock raises m_t by 1 percentage point from its steady state. The impulse responses are displayed by the blue dashed curves in Figure 2.8. It is clear to see that the dynamics of interest rates and debt ratios are similar to the case of a negative shock to τ_t. This is unsurprising because, just like a decline of τ_t, an increment of m_t also loosens household's international borrowing constraint. Then the household's investment in domestic government bond shoots up because it is profitable to borrow externally and invest domestically. The expanded investment demand boosts domestic public bond price and lowers bond yield. Lowering domestic bond yield, the government's cost of issuing domestic debt declines and it would like to increase the share of domestic debt and reduce the fraction of external debt.

Overall, our impulse response analysis shows how a temporary relaxation of capital control on international capital flows can result in a decline of external public debt, via the change of the interest rate. Like the steady state comparison in Figure 2.7, our impulse response figures also indicate a quantitatively large effect of financial liberalization on the debt ratio.

2.5.4.3 Another possible link: sovereign default and sustainability of external debt

We have already discussed the consequence of financial liberalization on government debt, via the channel of financing cost variation. In our model, we rule out the possibility of sovereign default to make the analysis tractable. Some recent studies (e.g. Broner and Ventura, 2016; Di Casola and Sichlimiris, 2015) consider the possibility of default on both domestic and external sovereign debt. Default may be linked to the relationship between external public debt ratio and capital control. This stream of literature especially pays attention to the endogenous default cost and default probability, which determines the sustainability of debt ratio. If we can show that, a country with higher financial liberalization has larger motivation to default external debt (e.g. the government's default cost is lower in an integrated financial market), then the sustained external debt should be lower. However this idea regarding debt's sustainability may be suspect, given our previous empirical finding at least in some regression specifications that financial liberalization in foreign countries also tends to bring down external leverage. The logic is as follows: foreign financial liberalization can make more oversea funds available to domestic government and hence help sustain the external debt ratio – thus we should expect a positive correlation between the foreign liberalization and the external public debt of the home country, which contradicts our empirical finding. Admittedly, it may be possible that the effect of domestic liberalization dominates and the mechanism regarding debt sustainability indeed plays its role. We would like to check more evidences in the future.

2.6 Conclusion

This paper provides both empirical evidence and theoretical argument that, international financial liberalization was correlated with the decrease of external public debt in developing countries since the 1990s. We use the cointegration regression of FMOLS and DOLS to inspect the empirical links. Our estimation is robust under different model specifications and with different control variables. After the empirical analysis, we propose a theoretical model featured with the active government and capital controls, to show how financial liberalization can dampen external public debt ratio. The main mechanism is that financial globalization shrinks the interest rate differential between developing and advanced countries, which reduces the government's domestic financing cost and dampens its incentive to borrow externally.

At the end of this paper, we would like to give one additional remark on our finding. Although financial openness tends to reduce external government debt, our result does not necessarily mean financial liberalization helps developing countries obtain a better management on external public debt. Our study only links financial openness to the amount of debt. But the component of debt is also crucial. Mehl and Reynaud (2010) find that financial openness is relevant to an increase in the riskiness of public domestic debt compositions. It is yet unknown whether financial openness has similar effect on external debt.

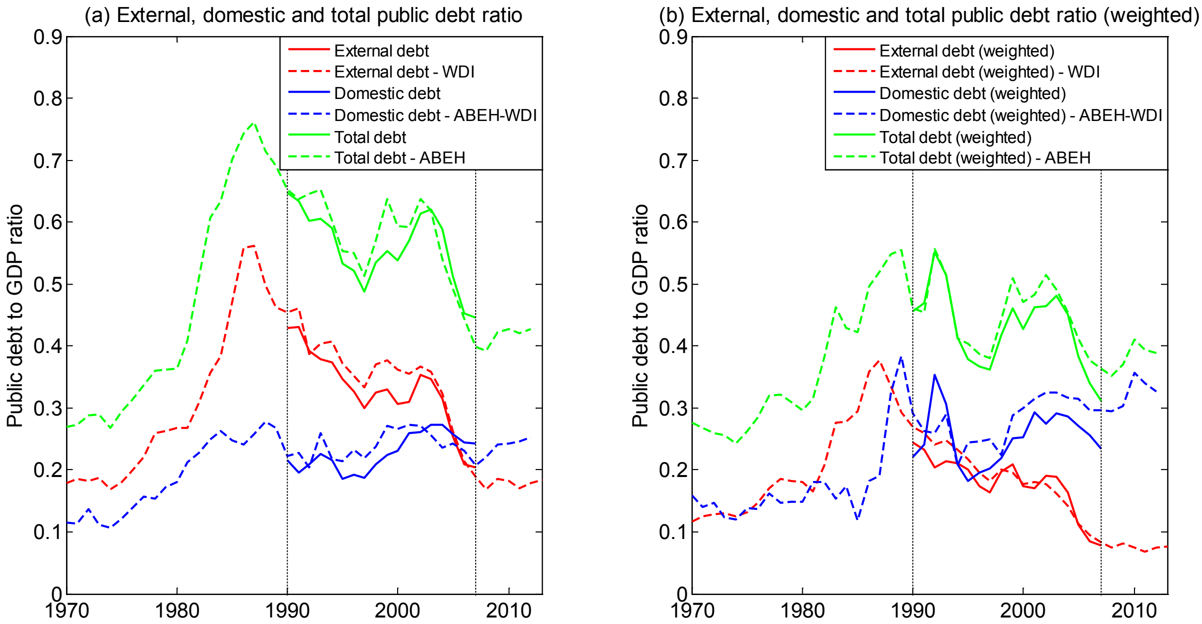
Appendix

Appendix 2.A. Dynamics of some relevant macroeconomic variables in developing countries

Our research topic – the link between financial liberalization and external public debt – is relevant to many macroeconomic variables. Here we document the dynamics of public debt, debt relief, exchange rate, private external debt and FDI in our sample developing countries. Investigating these variables is helpful for a better undestanding on the context of this paper.

2.A.1. Dynamics of external, domestic and total public debt in developing countries

Figure 2.9: **External, domestic and total public debt to GDP ratio in 46 developing countries, 1970-2013**



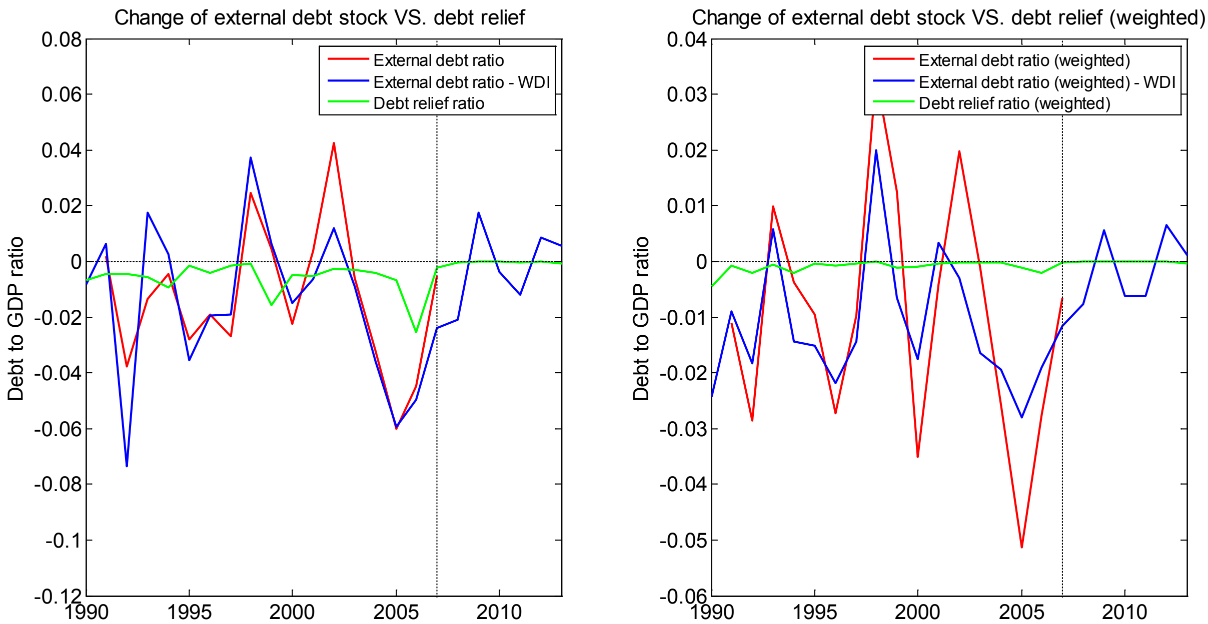
Data source: Panizza (2008), WDI and Abbas et al. (2011).

Figure 2.9 shows the (simple and weighted) average external, domestic and total public debt to GDP ratio in developing countries during 1970-2013 (also see Table 2 in Panizza (2008) or Forslund, Lima and Panizza (2011)). The total public debt ratio decreased in the period, which is mainly driven by the decline of external debt, as the domestic public debt to GDP actually slightly increased. This point is very clear from the simple average value of debt (left panel in the figure). For the weighted average (right panel), the fluctuation of total debt ratio is largely influenced by the substantial fluctuation in domestic debt. But throughout the whole sample period, total debt still displays a large decline which is the result of large decline of external debt ratio. The share of external debt in total public debt decreased evidently, as demonstrated by Figure 2.6 in Section 2.4.

2.A.2. Dynamics of debt relief in developing countries

Figure 2.10 compares the volume of debt relief with the year-to-year change of external public debt stock (both as ratio to GDP) in 46 developing countries, 1990-2013. It is obvious that the size of debt relief was much smaller than that of external debt change. In Section 2.3.3.2 we redo our regression excluding the countries with large debt relief, where our basic finding does not change.

Figure 2.10: **Year-to-year change of external public debt stock VS. debt relief to GDP ratio in 46 developing countries, 1990-2013**

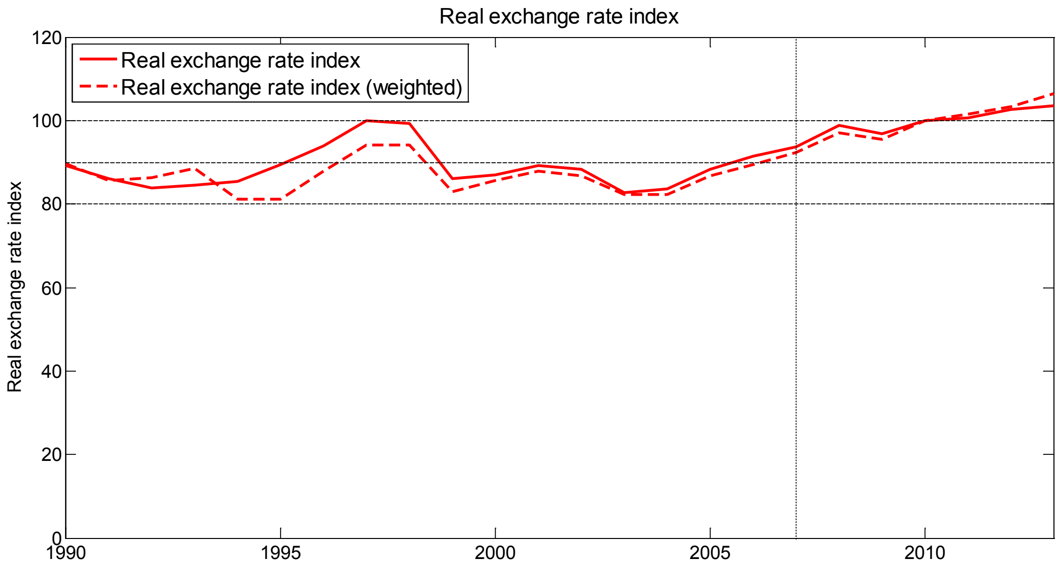


Data source: Panizza (2008) and WDI.

2.A.3. Dynamics of exchange rate in developing countries

Figure 2.11 shows the average real effective exchange rate index (2010 = 100) in developing countries. The sample size is reduced to 28 countries because of the data availability.

Figure 2.11: **Real effective exchange rate index (2010 = 100) in 28 developing countries, 1990-2013**

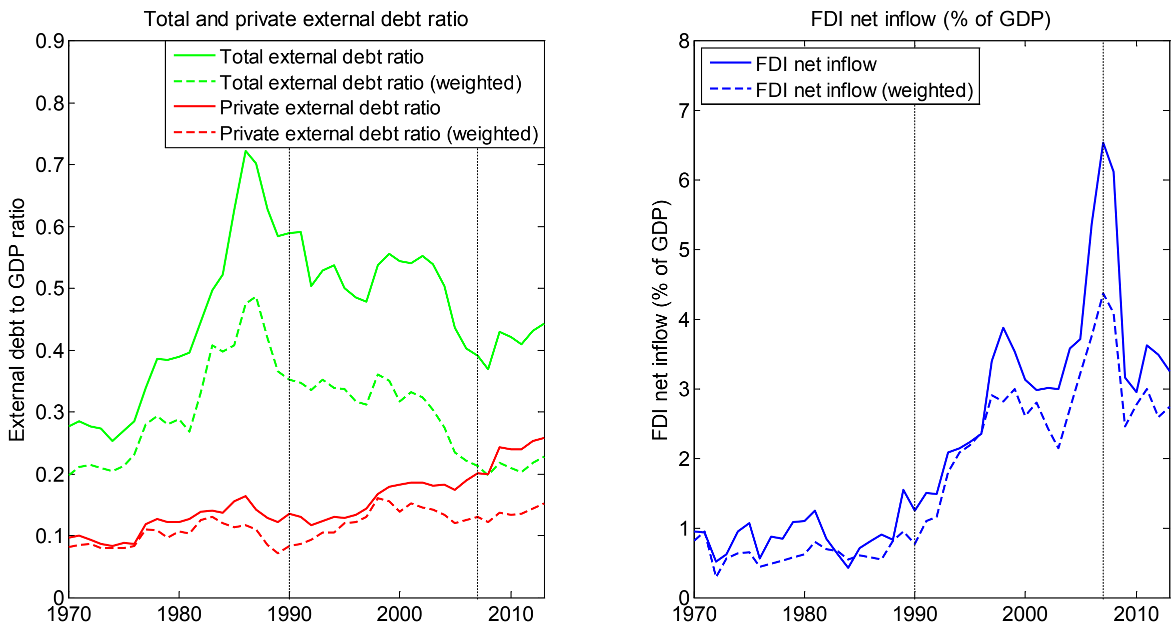


Data source: WDI.

2.A.4. Private external debt and FDI net inflow in developing countries

Figure 2.12 shows that, during 1990-2007 the private external debt to GDP ratio merely increased slightly and FDI expanded largely. (Here the volume of FDI is a flow data while debt is a stock data.)

Figure 2.12: **Total and private external debt to GDP ratio, and FDI net inflow (% of GDP) in 46 developing countries, 1990-2013**



Data source: WDI.

Appendix 2.B. A supplementary investigation on the empirical section of Azzimonti et al. (2014) paper

Table 2.7 presents a supplementary investigation on the empirical section of Azzimonti et al. (2014) paper. Particularly, we divide AFQ's full sample of 1973-2005 into 3 subsample periods (1973-1983, 1984-1994, 1995-2005) and run the regression for each subsample using their econometric model in the paper (please refer to AFQ paper for details of the model). The regression results show that the coefficient for global capital mobility (i.e. the row named "Lag change/Change in financial index") is *insignificant* for both periods 1973-1983 and 1995-2005.

Table 2.7: **Regression results dividing AFQ paper's sample into 3 subsamples**

	Comparable to Table O1 in AFQ Paper		
	1973-1983	**1984-1994**	**1995-2005**
Lag debt to GDP ratio	-0.285*	-0.315***	-0.035
Lag real GDP growth	-0.554	-1.117	-1.145***
Lag change in financial index	0.094	1.848***	1.185
Lag EMU dummy	-	-	0.007
Size * Lag change in FI	-1.775	-5.383	-6.689
Change in dependency ratio	0.011	0.083*	0.005
Change in inequality	0.005	0.062**	0.047***
Observations	189	228	231
R-squared	0.036	0.102	0.078
Number of countries	21	21	21
	Comparable to Table O2 in AFQ Paper		
	1973-1983	**1984-1994**	**1995-2005**
Lag debt to GDP ratio	-0.320	-0.331**	-0.023
Lag real GDP growth	-0.517	-1.786	-0.798***
Change in financial index	-0.101	0.291**	-0.569
Lag EMU dummy	-	-	0.013
Size * Change in FI	0.198	-1.171	0.526
Change in dependency ratio	-0.077**	-0.025	0.104
Change in top 1 percent share	0.405***	0.089	-0.011
Observations	116	164	155
R-squared	0.043	0.115	0.186
Number of countries	15	16	16

Note: */**/*** indicates the 10%/5%/1% significance level, respectively.

Appendix 2.C. Definition of variable and data source in regression for effects of financial liberalization

2.C.1. List of sample countries

There are 46 developing countries and 31 developed economies in the sample, as listed in Table 2.8 and 2.9. We have an unbalanced panel using the annual data betweeen 1990 and 2007.

Table 2.8: **List of 46 developing economies in the sample**

Argentina	Ecuador	Kyrgyz Republic	Peru	Turkey
Bangladesh	El Salvador	Lebanon	Philippines	Uganda
Bolivia	Ethiopia	Malaysia	Poland	Ukraine
Brazil	Georgia	Mauritius	Romania	Uruguay
Bulgaria	Guatemala	Mexico	Russia	Venezuela
Chile	Hungary	Moldova	South Africa	Zambia
China	India	Nigeria	Sri Lanka	
Colombia	Indonesia	Pakistan	Swaziland	
Costa Rica	Jamaica	Panama	Thailand	
Dominican Republic	Kazakhstan	Paraguay	Tunisia	

Table 2.9: **List of 31 developed economies in the sample**

Australia	Finland	Israel	New Zealand	Switzerland
Austria	France	Italy	Norway	United Kingdom
Belgium	Germany	Japan	Portugal	United States
Canada	Greece	Korea, Rep.	Singapore	
Cyprus	Hong Kong, China	Latvia	Slovenia	
Czech Republic	Iceland	Malta	Spain	
Denmark	Ireland	Netherlands	Sweden	

2.C.2. A documentary error on the 2006-2007 GDP data of El Salvador in Panizza (2008) dataset

In this paper, the public debt data used for graph demonstration and regression analysis is primarily extracted from Panizza (2008) public debt dataset. Particularly, we calculate the public debt to output ratio by dividing the number of public debt stock to the number of GDP documented in Panizza (2008) dataset. Compared to WDI dataset we find there is a documentary error on the 2006-2007 GDP data of El Salvador. This error, for example, makes the calculated external public debt ratio suddenly jumped from 29% in 2005 to more than 200% in 2006 and 2007. Hence we correct the number of GDP at these 2 sample points based on WDI dataset. In fact, at the early stage of writing this paper we studied without correcting these 2 points (and we also tried the case of simply getting rid of these 2 sample points). No finding of this paper was changed.

2.C.3. Summary statistics for external debt ratio and financial liberalization in the sample

Table 2.10 documents the summary statistics for external debt ratio and financial liberalization in our sample, 1990-2007. The correlation coefficient between *ED* based on Panizza (2008) dataset and WDI is quite high, though their exact definitions of external debt are not the same. The level of external debt and capital control in each country are generally not very stable during the whole sample period, as indicated by the nontrivial size in "Avg. SD" column. The inter-country heterogeneity is large, as indicated by the large values in "SD".

It is notable that the correlation between *ED* and *FinanOpen* can be positive, depending on which indicator of variable we use. This seemingly contradicts what we read from Figure 2.1 and 2.2 along the time dimension. That positive correlation is mainly because along the cross-section dimension the countries with high financial openness generally also have high external debt ratio. In our regression we will control for this inter-country heterogeneity.

Table 2.10: **Summary statistics for external debt ratio and financial liberalization in the sample, 1990-2007**

Variable	Min.	Mean	Med.	Max.	SD	Avg. SD	Obs.	Correlation Coefficient with						
								ED1	***ED2***	***FO1***	***FO2***	***FO3***	***FOW1***	***FOW2***
ED (Panizza, 2008)	0.006	0.329	0.260	2.077	0.279	0.116	767	1						
ED (WDI)	0.001	0.351	0.267	1.673	0.273	0.126	688	0.904	1					
FinanOpen (Chinn-Ito)	0	0.463	0.411	1	0.331	0.186	794	0.017	0.025	1				
FinanOpen (FKRSU)	0	0.548	0.550	1	0.351	0.101	598	0.208	0.181	0.712	1			
FinanOpen (ADT)	0	0.625	0.667	1	0.346	0.219	631	-0.154	-0.160	0.555	0.317	1		
FinanOpenW (Chinn-Ito)	0.777	0.846	0.855	0.897	0.027	0.027	828	-0.163	-0.160	0.148	-0.217	0.227	1	
FinanOpenW (FKRSU)	0.765	0.799	0.805	0.852	0.017	0.016	598	0.051	0.103	-0.155	-0.139	-0.014	0.516	1
FinanOpenW (ADT)	0.855	0.921	0.938	0.973	0.028	0.029	736	-0.163	-0.160	0.218	-0.093	0.254	0.814	0.503

Note: (1) "SD" refers to the standard deviation over all samples. "Avg. SD" refers to the (unweighted) average value of standard deviation in each country. "ED1", "ED2", "FO1", "FO2", "FO3", "FOW1", "FOW2" is short for the 1st to 7th variables in the column of "Variable", respectively. (2) FKRSU data starts at 1995. ADT data ends at 2005.

2.C.4. Variable definition and data source

Table 2.11 lists the definition of variable and data source for our empirical study. The values of several variables are not directly provided in the corresponding dataset, and hence are calculated using relevant variables. For example, the public external debt ratio (*ED*) from Panizza (2008) dataset is obtained by foreign debt stock (*debt_for*) divided by output (*gdp*).

Table 2.11: **Definition of variable and data source in regression for financial liberalization and external debt nexus**

Variable	**Definition**	**Data Source**
Dependent variable:		
ED	Public external debt to GDP ratio	Panizza (2008) (code *debt_for/gdp*); or WDI (code *DT.DOD.DPPG.CD/NY.GDP.MKTP.CD*)
Key explanatory variables:		
$FinanOpen$	Financial liberalization in the home country, ranges from 0 (lowest) to 1 (highest)	Chinn and Ito (2006) (code *ka_open*); or Fernández et al. (2015) (code 1 - *ka*); or Abiad, Detragiache and Tressel (2010) (code *intlcapital*/3)
$FinanOpenW$	Financial liberalization in the rest of world (real GDP weighted average over all other countries), ranges from 0 (lowest) to 1 (highest)	
Public finance considerations:		
DD	Public dometic debt to GDP ratio	Panizza (2008) (code *debt_dom/gdp*)
$FiscalBalance$	General government budget balance (% of GDP)	WEO (code *GGR_NGDP* - *GGX_NGDP*); or WDI (code *GC.BAL.CASH.GD.ZS*)
General economic conditions:		
$GDPpc$	logarithmic GDP per capita (constant 2005 1000US$)	WDI (code *NY.GDP.PCAP.KD*/1000)
$M2$	Money and quasi money (M2) as % of GDP	WDI (code *FM.LBL.MQMY.GD.ZS*)
$Inflation$	Inflation, GDP deflator (annual %)	WDI (code *NY.GDP.DEFL.KD.ZG*)
IR	Real interest rate (%), measured by lending interest rate adjusted for inflation	WDI (code *FR.INR.RINR*)
$IRrow$	Real interest rate (%) in the rest of world (real GDP weighted average)	
$CapForm$	Gross fixed capital formation rate (% of GDP)	WDI (code *NE.GDI.FTOT.ZS*)
$SaveRate$	Gross domestic savings (% of GDP)	WDI (code *NY.GDS.TOTL.ZS*)
$Crisis$	Occurrence of "*Systemic Banking Crisis*", "*Currency Crisis*", "*Sovereign Debt Crisis*", or/and "*Sovereign Debt Restructuring*"	Laeven and Valencia (2013)
External payment variables:		
$TradeBalance$	Difference between exports and imports of goods and services (% of GDP)	WDI (code *NE.EXP.GNFS.ZS* - *NE.IMP.GNFS.ZS*)
$CurrAcct$	Current account balance (% of GDP)	WEO (code *BCA_NGDPD*)
ER	Real effective exchange rate index (2010 = 100)	WDI (code *PX.REX.REER*)

Note: WDI, GFDD and WEO refer to World Bank World Development Indicators, Global Financial Development Database, IMF World Economic Outlook, respectively.

Table 2.11 (cont.): **Definition of variable and data source in regression for financial liberalization and external debt nexus**

Variable	Definition	Data Source
Institutional and demographic characteristics:		
Legal	Legal institutional quality, ranges from 0 (lowest) to 1 (highest)	Kunčič (2014) (code *legal_abs*)
DepenRatio	Age dependency ratio, old (% of working-age population)	WDI (code *SP.POP.DPND.OL*)
ERR	Classification of exchange rate regimes (fixed, intermediate, or floating)	Shambaugh Exchange Rate Regime Classification (set value 1/2/3 for group *peg*/ *nonpeg-softpeg*/ *nonpeg-nonsoftpeg*)
Further control variables for robustness analysis:		
DebtRelief	Debt forgiveness or reduction (% of GDP)	WDI (code *DT.DFR.DPPG.CD/NY.GDP.MKTP.CD*)
FinanDev	Comprehensive financial development index	Svirydzenka (2016) (code *FD*)
Credit	Private credit by deposit money banks (% of GDP)	GFDD (code *GFDD.DI.01*)
Globaliz	KOF globalization index	Dreher (2006) (code *index*)
TradeOpen	Sum of imports and exports of goods and services (% of GDP)	WDI (code *NE.IMP.GNFS.ZS* + *NE.EXP.GNFS.ZS*)
Reserve	Foreign currency reserve (ratio to GDP, or % of total external debt)	WDI (code *FI.RES.TOTL.CD/NY.GDP.MKTP.CD*; or *FI.RES.TOTL.DT.ZS*)
PrivateED	Private external debt to GDP ratio	WDI (code *(DT.DOD.DECT.CD - DT.DOD.DPPG.CD) /NY.GDP.MKTP.CD*)
TotalEDall	Average total external debt to GDP ratio over all 46 sample countries (real GDP weighted average)	WDI (code *DT.DOD.DECT.CD/NY.GDP.MKTP.CD*)
FDI	FDI net inflow (% of GDP)	WDI (code *BX.KLT.DINV.WD.GD.ZS*)
FDIall	Average FDI net inflow into developing countries (% of GDP, real GDP weighted average over all 46 sample countries)	
Other variables discussed in the paper:		
TD	Total public debt to GDP ratio	Panizza (2008) (code *debt_total/gdp*); or Abbas et al. (2011)
-	Total external debt to GDP ratio	WDI (code *DT.DOD.DECT.CD/NY.GDP.MKTP.CD*)
-	Government bond interest rate, percent per annum	IMF International Financial Statistics (IFS)
-	FDI stock in the host economy (% of GDP)	United Nations Conference on Trade and Development (UNCTAD) Bilateral FDI Statistics (code *instock*)
-	labor income share	Penn World Table (PWT), version 9.0 (code *labsh*)

Note: WDI, GFDD and WEO refer to World Bank World Development Indicators, Global Financial Development Database, IMF World Economic Outlook, respectively.

Appendix 2.D. Regression results for more robustness analysis

2.D.1. Correlation coefficient between financial liberalization, financial development, and economic openness

Table 2.12: **Correlation coefficient between financial liberalization, financial development, and economic openness**

Corr(x, y)	*FinanOpen* (Chinn-Ito)	*FinanOpen* (FKRSU)	*FinanOpen* (ADT)	*FinanDev*	*Credit*	*Globaliz*
FinanOpen (Chinn-Ito)	1					
FinanOpen (FKRSU)	0.712	1				
FinanOpen (ADT)	0.555	0.317	1			
FinanDev	-0.010	-0.307	0.256	1		
Credit	0.110	-0.157	0.060	0.604	1	
Globaliz	0.279	0.043	0.397	0.589	0.347	1
TradeOpen	0.188	-0.033	0.154	0.164	0.339	0.297

2.D.2. Regression results for more robustness analysis

Table 2.13 and 2.14 present the regression results for more robustness analysis, corresponding to section 2.3.3.2 in the main text. Model (4.1) and (5.1) represent our baseline FMOLS and DOLS regression in Table 2.4 and 2.5. We rewrite them here to facilitate comparison. Column (13.1) and (14.1) are obtained by running the model (4.1) and (5.1) excluding 9 high debt relief countries. Column (13.2) - (13.3) and (14.2) - (14.3) are obtained by introducing control variables representing financial development and economic openness. Model (13.4) - (13.5) and (14.4) - (14.5) are obtained by introducing control variable for government budget balance. Model (13.6) - (13.7) and (14.6) - (14.7) control for government debt repayment ability. Model (13.8) - (13.9) and (14.8) - (14.9) control for exchange rate regime or exchange rate index. Foreign investor base is introduced in (13.10) - (13.11) and (14.10) - (14.11). The last columns (13.12) and (14.12) display the regression results based on 1970-2012 sample.

Table 2.13: **Regression result for more robustness analysis by Fully Modified OLS, *ED* as dependent variable**

	Baseline	Debt relief	Financial develop. and eco. openness		Fiscal balance		Repayment ability		Exchange rate		Investor base		70-12
	(4.1)	(13.1)	(13.2)	(13.3)	(13.4)	(13.5)	(13.6)	(13.7)	(13.8)	(13.9)	(13.10)	(13.11)	(13.12)
FinanOpen	-0.070**	-0.058**	-0.104***	-0.100***	-0.189***	-0.038	-0.098***	-0.108**	-0.104***	-0.118***	-0.141***	-0.100***	-0.188***
FinanOpenW	-0.323	-0.438**	-0.138	-0.002	-0.247	-0.171	-0.330	-0.423	-0.033	-0.079	-0.164	0.256	1.094***
DD	0.093	0.064	0.106	0.085	0.122*	0.013	0.117*	0.031	0.093	0.455***	0.232***	0.052	-0.035
GDPpc	-0.691***	-0.738***	-0.644***	-0.607***	-0.723***	-0.918***	-0.705***	-0.754***	-0.687***	-0.533***	-0.539***	-0.625***	-0.905***
M2	0.056	0.139**	0.055	0.105	-0.014	0.126	0.027	-0.046	0.056	-0.032	-0.202***	0.040	0.374***
CapForm	0.130	0.412**	0.197	0.110	0.654***	0.728**	1.332***	1.452***	0.188	0.066	0.439*	0.184	0.605***
TradeBalance	0.546***	0.722***	0.618***	0.624***	0.926***	1.113***	1.659***	1.633***	0.586***	0.283*	0.691***	0.565***	0.469***
FinanDev			-0.095										
Credit				-0.117*									
Globaliz			0.001										
TradeOpen				0.025									
*FiscalBalance*1					-0.001								
*FiscalBalance*2						0.003							
SaveRate							-0.011***	-0.012***					
*Reserve*1							0.191*						
*Reserve*2								-0.016					
ERR									0.004				
ER										-0.120***			
PrivateED											0.514***		
TotalEDall												-0.301*	
FDI											0.027		
FDIall												-3.703***	
Sample period:	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	71-12
Cross-sections:	45	36	43	42	43	28	41	34	42	25	32	42	37
Observations:	691	569	675	666	595	390	651	536	658	394	508	666	1172

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) The estimated coefficients for *FinanDev*, *Credit*, *Globaliz*, *TradeOpen*, *Reserve*2, *FDI* and *FDIall* are rescaled by multiplying 100 for better demonstration. This rescaling also applies to Table 2.14. (3) *FiscalBalance*1 and *FiscalBalance*2 use the fiscal surplus data from WEO and WDI, respectively. *Reserve*1 and *Reserve*2 denote the foreign currency reserve as ratio to GDP and % of total external debt. Table 2.14 also employs these variables.

Table 2.14: **Regression result for more robustness analysis by Dynamic OLS, *ED* as dependent variable**

	Baseline	**Debt relief**	**Financial develop. and eco. openness**		**Fiscal balance**		**Repayment ability**		**Exchange rate**		**Investor base**		**70-12**
	(5.1)	(14.1)	(14.2)	(14.3)	(14.4)	(14.5)	(14.6)	(14.7)	(14.8)	(14.9)	(14.10)	(14.11)	(14.12)
FinanOpen	-0.068**	-0.077**	-0.068**	-0.084***	-0.148***	-0.027	-0.072**	-0.062	-0.082**	-0.073**	0.007	-0.051	-0.159***
FinanOpenW	-0.726***	-0.702***	-0.402	-0.290	-0.106	-0.117	-0.026	0.033	-0.176	-0.385	-0.478**	0.227	0.862***
DD	0.037	0.038	0.036	0.189**	-0.048	0.267*	0.205**	0.096	0.239***	0.580***	0.292***	0.241***	0.149**
GDPpc	-0.807***	-0.817***	-0.718***	-0.346***	-0.687***		-0.714***	-0.816***	-0.838***	-0.551***	-0.580***	-0.609***	-1.057***
M2	0.135*	0.132*	0.061	-0.010									0.369***
CapForm	0.663**	0.627**											0.914**
TradeBalance	0.582***	0.542***											0.150
FinanDev			0.352**										
Credit				-0.125									
Globaliz			-0.002										
TradeOpen				0.140**									
FiscalBalance1					-0.001								
FiscalBalance2						-0.006							
SaveRate							0.000	-0.001					
Reserve1							0.012						
Reserve2								-0.033					
ERR									0.012				
ER										-0.167***			
PrivateED											0.406***		
TotalEDall												-0.272	
FDI											0.100		
FDIall												-4.644***	
Sample period:	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	91-07	71-12
Cross-sections:	23	22	23	23	19	19	32	25	31	23	23	32	28
Observations:	391	374	391	391	308	291	529	413	505	371	381	529	870

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) In model (14.2) - (14.11) a set of control variable (*GDPpc*, *M2*, *CapForm*, *TradeBalance*) are deleted from the regression specification to fit the use of BIC, otherwise our sample size is not enough.

Appendix 2.E. Further explorations: causality and the effect of financial liberalization on domestic public debt

The reduced form regressions in Section 2.3.3, though strongly confirm the link between financial liberalization and external public debt, are yet insufficient to assert the causality from financial globalization to external debt. Here we present a discussion on the causality and potential reverse causality effect. We will provide support for the causality using the Propensity Score Matching (PSM) method. And we also check whether the reverse causality of the influence from external debt to financial liberalization exists. Additionally, we investigate whether financial liberalization influences domestic public debt ratio. For simplicity, in the econometric model we merely interchange ED with the new dependent variables but still regressing on the same group of other explanatory variables.

2.E.1. Check the causality using Propensity Score Matching

Conventionally we can resort to the method of Difference-in-Difference (DID) to identify the treatment effect of policy implementation. But in our application the DID is not highly suitable. (i) DID is typically grounded on the "parallel trends assumption", which means in the absence of treatment the average change of different samples' outcome variables should be similar. That may not be true when we consider public debt in distinct countries with many heterogenous characteristics, even after we introduce some control variables in regression. (ii) DID is well designed to evaluate the effect of "one-off" policy change. But financial liberalization is usually a successive and long-run process, and sometimes with policy reversal. Hence it is actually difficult to compare the "treatment" group with the "control" group, as it is often ambiguous to point out which them are. Although we can look at the change of financial openness indicator of each country at each period, it is not sufficient.[21] In fact we have tried DID, with a set of different model specifications. The result (not reported) shows negative estimated coefficient (i.e. capital liberalization reduces external public debt) in almost all cases, but often insignificant. On the one hand, we can negatively interpret it as a doubt on the effect of financial liberalization. But on the other hand, this is plausibly the result of the violation of "parallel trends assumption" and the incapacity to identify where the policy implementation is.

Considering the potential difficulty to utilize DID, we turn to the method of Propensity Score Matching (PSM) which is increasingly popular in recent years. This method, different from typical reduced form regressions but to some extent similar to DID, is powerful to help identify treatment effect and infer causality. Using PSM we find financial liberalization indeed has treatment effect to reduce external public debt. The basic idea of PSM is as follows. It

[21] For example we can consider such a case: country A's financial openness index increases sequentially from year t to $t+3$; and country B's index increases from t to $t+1$, keeps that level at $t+2$ and then increases again at $t+3$. It may be unreasonable to assert that in period $t+2$ sample A is the "treatment" and B is "control", since B's economic response to liberalization in t may be lagged and then quickly affected by the subsequent policy change.

first "matches" units that experience an intentional intervention (such as a treatment or policy change like financial liberalization in our case) with those "similar" units without a treatment, where the "similarity" is measured by the socalled "propensity score". Then it uses information from these "matched" units to identify the treatment effect i.e. what would have happened to treated samples in the absence of intervention. In our application, we estimate the Average Treatment Effect (ATE):

$$ATE = E(\Delta ED_i | T_i = 1) - E(\Delta ED_i | T_i = 0)$$

where $T_i = 1$ means a policy change and $T_i = 0$ means no change.

Results summary

The use of PSM enables us to mitigate the potential difficulties to employ DID. (i) Since PSM compares treatment group with "similar" control group, it tends to reduce the violation of "parallel trends assumption". (ii) Regarding the identification of "treatment group", we check two different strategies. In the first situation, we just assume the financial liberalization in one year can be independent of the other years. That means we directly consider the year-to-year change of capital account openness index as an occurrence of "treatment". Secondly, observing that the change of liberalization index often lasts for 3 to 5 years, we consider 5-years is a period of policy change completion. Thus we inspect whether a 5-years difference in financial openness affects the 5-years difference in external debt. The details and primary results of our PSM analysis are documented in Table 2.15 which, from a more clear way of causality inference, supports our previous finding from reduced form regressions: financial liberalization in the home country significantly reduces external debt ratio.

Implementation details

There are several different softwares, with different default procedures, to implement PSM. We select the "*teffects psmatch*" command in *Stata*. (1) We first examine the "treatment" of year-to-year change of financial liberalization i.e. how $\Delta FinanOpen_{t-1}$ impacts ΔED_t. We study two directions of policy intervention: "financial liberalization" which means $\Delta FinanOpen > 0$; and "financial re-regulation" which means $\Delta FinanOpen < 0$. The control group consists of the samples with $\Delta FinanOpen = 0$. As the first step of PSM, we estimate the propensity score (not reported here) using the explanatory variable set of [$GDPpc$, $CapForm$, $TradeBalance$, $FinanDev$, $CurrAcct$]. (Our PSM result is not very sensitive to the selection of explanatory variables.) In the second step, we match sample units and estimate treatment effect based on the estimated propensity score in the first step. In order to ensure the robustness of PSM, we consider 5 model variants. (a) The "Default" model use logit regression to estimate propensity scores, with one-to-one match with nearest neighbour algorithm and with replacement. (b) Accordingly, the model of "Probit" uses probit regression. (c) "nn(2)" matches two controls to one treatment sample. (d) "More var." adds [$M2$, $GovSize$] into the propensity score explanatory variable set. (e) Finally, the model "Large change" only considers the treated sample with large policy change, which is defined as an absolute value of $\Delta FinanOpen$ larger than one standard deviation of $\Delta FinanOpen$ i.e. 0.11. (2) Then we investigate the "treatment" as 5-years liberalization process i.e. how $(FinanOpen_t - FinanOpen_{t-5})$ impacts $(ED_t - ED_{t-5})$. Because an invariability of financial openness over 5-years period is relatively scarce, we take 1SD of $\Delta FinanOpen$ i.e. 0.24 as threshold of policy change. The "Large change" is defined as 1.5SD which is 0.36.

The estimated average treatment effect (ATE) and associated robust standard error are reported in Table 2.15. It shows that financial liberalization significantly reduces external public debt ratio. As expected, a 5-years liberalization has much larger effect than 1-year liberalization. This result strengthens our finding in Section 2.3.3. On the other hand, financial re-regulation does not generate significant influence. It seems that a "ratchet effect" of financial liberalization on the external debt reduction exists. Given the overall trend of financial liberalization and external debt reduction in the past decades, this "ratchet effect" does not contradict our basic finding.

Table 2.15: **Result of using Propensity Score Matching to check causality**

Treatment	**Estimated Average Treatment Effect (ATE) Coefficient**			
	$Liberalization_{t-1}$	$Liberalization_{5year}$	$Regulation_{t-1}$	$Regulation_{5year}$
Default	-0.024*	-0.058**	-0.002	0.017
	[0.013]	*[0.028]*	*[0.022]*	*[0.025]*
Probit	-0.024**	-0.047	0.009	0.018
	[0.012]	*[0.031]*	*[0.022]*	*[0.026]*
nn(2)	-0.019	-0.064***	-0.003	0.016
	[0.012]	*[0.024]*	*[0.022]*	*[0.023]*
More var.	-0.032**	-0.024	0.007	0.024
	[0.015]	*[0.037]*	*[0.023]*	*[0.022]*
Large change	-0.023*	-0.092**	0.001	0.046
	[0.013]	*[0.040]*	*[0.020]*	*[0.035]*
Total obs.	509	472	436	380
Matched treatment	125 (58)	141 (79)	52 (28)	49 (14)

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) The number in "[ ]" provides the "AI Robust SE" which is the robust standard error of the estimated coefficient, based on the method of Abadie and Imbens (2012). (3) The amount of matched treatment samples is documented in the row "Matched treatment". Number in "( )" indicates the amount in model "Large change" i.e. when we only consider the sample with large policy change.

2.E.2. Check the (in)existence of reverse causality effect

We investigate whether external debt ratio influences the government's decision of capital account openness. Particularly we use the following model specification:

$$FinanOpen_{it} = \alpha_1 FinanOpenW_{it} + \alpha_2 ED_{it} + \theta' X_{it} + s_i + \sigma_t + \varepsilon_{it}$$

with the corresponding corrections with respect to FMOLS or DOLS. In the regression it is also important to control for domestic debt ratio. For example, a country with public debt as 100% of GDP in which 30% is external debt may not concern the external debt much, since the majority of its liability comes from domestic pressure. In contrast, a country with public debt as 30% of GDP which is all external debt definitely can behave differently (on e.g. the default decision), as all its liability is connected to foreigners.

We conjecture that the coefficient α_2 could be negative, since when the government sees a high external debt ratio it has the incentive to implement capital control and want to retain financial resources domestically. And we expect the coefficient α_1 is positive since the global trend of financial openness would impose pressure on the countries who is still financially closed. The original data of financial liberalization index is bounded between 0 and 1. This raises problem when $FinanOpen$ is taken as dependent variable in the regression. Following von Hagen and Zhou (2005), we transform the financial liberalization data x using the formula $x^* = \log(\frac{x}{1-x})$ after replacing 0 with 0.01 and 1 with 0.99.

Results summary

Table 2.16 as below gives the regression result if we take the transformed financial openness index $FinanOpen\_Trs$ as dependent variable. There is no much evidence that external debt ratio ED significantly explains the financial liberalization in the home country. Table 2.17 gives the Granger causality test results for the variable ED vs. $FinanOpen$ as well as $FinanOpen\_Trs$. While there are evidences that $FinanOpen$ or $FinanOpen\_Trs$ Granger causes ED, the support for the reverse Granger causality is very weak. In short, we do not see the existence of severe reverse causality which biases our core empirical finding that financial globalization dampened external public debt in developing countries.

Implementation details

Table 2.16 gives the regression result if we take the transformed financial openness index $FinanOpen\_Trs$ as dependent variable. In most cases the estimated coefficient for ED is not significant. Table 2.17 presents the Granger causality test results for the variable ED vs. $FinanOpen$ as well as $FinanOpen\_Trs$. The result strongly rejects the null hypothesis that financial openness does not Granger cause external debt change. In contrast, the inexistence of reverse Granger causality is not rejected in most cases. Although the reverse Granger causality is found in the case of 4 lags, logically we can rule out this possibility since it is obviously unreasonable to believe that financial liberalization policy reponses to the external debt ratio four years ago.

Table 2.16: **Regression result by FMOLS and DOLS, $FinanOpen\_Trs$ as dependent variable**

	FMOLS				DOLS			
	Base-line	**FKRSU**	**ADT**	**WDI**	**Base-line**	**FKRSU**	**ADT**	**WDI**
	(16.1)	(16.2)	(16.3)	(16.4)	(16.5)	(16.6)	(16.7)	(16.8)
$FinanOpenW$	3.699	1.002	16.607**	1.884	4.263	0.503	20.058*	1.954
ED	-1.487**	-0.517	-4.156***	-0.934	-1.135	-0.091	-3.303	-0.851
DD	0.856	-0.516	0.715	1.756**	1.677	-0.880	-0.862	3.139**
$GDPpc$	-1.158	0.075	-2.956	0.264	-1.816	-0.572	-0.859	0.477
$M2$	-0.697	-0.792	-0.031	0.615	-1.559		-0.623	-1.800
$CapForm$	0.877	-1.895	12.901**	-0.059	-0.971			-1.921
$TradeBalance$	-2.252	-0.014	3.688	-1.302	-2.494		7.505	-2.941
Sample period:	91-07	96-07	91-05	91-07	91-07	96-07	91-05	91-07
Cross-sections:	46	44	38	39	26	36	27	22
Observations:	703	503	544	589	442	427	405	374

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) $FinanOpen\_Trs$ is the after-transformation financial openness index. (3) In model (16.6) the regressors [$M2$, $CapForm$, $TradeBalance$] are deleted from the regression specification to fit the use of BIC, otherwise our sample size is not enough. Similarly, in model (16.7) the regressor $CapForm$ is excluded.

Table 2.17: **Granger Causality Tests: ED vs. $FinanOpen$**

Null Hypothesis:	F**-Statistic**			
	Lags: 1	**Lags: 2**	**Lags: 3**	**Lags: 4**
ED does not Granger Cause $FinanOpen$	1.885	1.089	0.590	4.323***
ED does not Granger Cause $FinanOpen\_Trs$	0.690	0.336	0.361	4.665***
$FinanOpen$ does not Granger Cause ED	1.417	6.484***	5.083***	6.072***
$FinanOpen\_Trs$ does not Granger Cause ED	1.308	3.034**	2.381*	3.695***

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) Following von Hagen and Zhou (2005), we transform the original financial liberalization data x using the formula $x^* = \log(\frac{x}{1-x})$ after replacing 0 with 0.01 and 1 with 0.99. $FinanOpen\_Trs$ is the after-transformation variable. (3) Different VAR lag order selection criteria imply different lag selections for the Granger causality test. We report the cases from lag 1 to lag 4 in the table.

2.E.3. The effect of financial liberalization on domestic public debt

In Section 2.3.3 we found that financial liberalization is linked to the decrease in external public debt in developing countries. Then a correlated question is whether domestic public debt can also be impacted by financial liberalization.

Results summary

Table 2.18 demonstrates the regression result for domestic public debt *DD* as dependent variable. It is clear from the regression result that financial globalization does not have evident influence on domestic public debt ratio. Under different econometric specifications, the estimated coefficients for variables *FinanOpen* and *FinanOpenW* are genenrally statistically insignificant and uncertain in sign. On the contrary, domestic economic characteristics have relatively strong affect. GDP growth reduces domestic debt ratio. Capital formation rate is also relevant to reduce domestic debt, which may happen if high capital formation rate is associated with high economic growth or the priority to borrow externally.

The regression result here shows the importance to distinguish between domestic debt and external debt, when we explore the potential influence of financial liberalization on government liability. If we further regress taking total public debt ratio *TD* as dependent variable, as in Table 2.19, we would obtain significantly negative coefficient of home country financial openness just like for external debt. This confirms that financial liberalization affects public debt majorly via external debt.

Implementation details

Table 2.18 and 2.19 demonstrate the regression results taking domestic public debt *DD* and total public debt *TD* as dependent variable, respectively. The econometric model specification in each column is similar to its counterpart in Table 2.4 and 2.5. In Table 2.19 we do not have *ED* or *DD* as explanatory variable, because they are a part of the dependent variable *TD*. For the model (19.4) and (19.8), the total public debt data from Abbas et al. (2011) is used.

Table 2.18: **Regression result by FMOLS and DOLS, *DD* as dependent variable**

	FMOLS				DOLS			
	Base-line	**FKRSU**	**ADT**	**WDI**	**Base-line**	**FKRSU**	**ADT**	**WDI**
	(18.1)	(18.2)	(18.3)	(18.4)	(18.5)	(18.6)	(18.7)	(18.8)
FinanOpen	0.014	0.010	0.009	0.070**	0.004	0.005	-0.031	0.051
FinanOpenW	0.054	0.669**	-0.659**	-0.009	0.229	0.322	0.632	0.356
ED	0.103**	0.185***	0.199***	-0.002	0.024	0.205***	0.417***	0.091
GDPpc	-0.308***	-0.041	-0.226**	-0.337***	-0.519***	-0.399***	-0.398***	-0.387***
M2	0.027	0.206***	0.034	0.022	-0.046		-0.213***	-0.097
CapForm	-0.149	-0.337*	-0.545***	-0.111	-0.556**			
TradeBalance	0.134	-0.054	-0.362***	0.150	0.143		-0.316*	0.170
Sample period:	91-07	96-07	91-05	91-07	91-07	95-07	91-05	91-07
Cross-sections:	45	42	37	39	23	31	23	26
Observations:	693	481	522	593	391	368	345	431

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) In model (18.6) the variables [*M2*, *CapForm*, *TradeBalance*] are deleted, and in model (18.7) and (18.8) the variable *CapForm* is deleted from the regression specification to fit the use of BIC, otherwise our sample size is not enough.

Table 2.19: **Regression result by FMOLS and DOLS, TD as dependent variable**

	FMOLS				**DOLS**			
	Base-line	**FKRSU**	**ADT**	**ABEH**	**Base-line**	**FKRSU**	**ADT**	**ABEH**
	(19.1)	(19.2)	(19.3)	(19.4)	(19.5)	(19.6)	(19.7)	(19.8)
$FinanOpen$	-0.056	-0.102	-0.074**	-0.267***	-0.100**	-0.004	-0.072*	-0.300***
$FinanOpenW$	-0.402	1.391***	-2.102***	0.419*	-0.032	1.822**	-1.338**	0.151
$GDPpc$	-1.111***	-0.964***	-1.359***	-1.300***	-1.179***	-1.366***	-1.374***	-1.228***
$M2$	0.094	0.168	0.083	0.541***	0.112	0.313**	-0.131	0.717***
$CapForm$	-0.005	0.494	0.612*	0.460*	-0.713**		-0.795*	0.504*
$TradeBalance$	0.739***	0.967***	0.530***	0.536***	0.291		-0.754***	0.687***
Sample period:	91-07	96-07	91-05	71-12	91-07	96-07	91-05	71-12
Cross-sections:	46	42	37	44	33	32	25	36
Observations:	707	483	528	1435	546	379	375	1231

Note: (1) */**/*** indicates the 10%/5%/1% significance level, respectively. (2) In model (19.6) the variables [$CapForm$, $TradeBalance$] are deleted from the regression specification to fit the use of BIC, otherwise our sample size is not enough.

Chapter 3

Financial development and output volatility nexus: Industrial heterogeneity matters

Is financial development positively, negatively, or not linked to the aggregate output volatility? Very controversial debates exist in both empirical and theoretical literature. This paper argues that financial development can either exacerbate or dampen output volatility, depending on the type of industry whose credit access is expanded. Using a two-sector real business cycle model augmented with the collateral constraint à la Kiyotaki and Moore (1997), we show that if the borrowing constraint is relaxed in the consumption goods sector, macroeconomic volatility will rise. On the contrary, if the financial friction is lessened in the capital goods sector, output volatility may decline or be roughly unchanged. The underlying intuition is that the sensitivity of output to economic shocks crucially depends on the intensity of firms to adjust their production inputs, which relies on the marginal products of capital and labor. Financial development increases the labor marginal product, but alters the overall capital marginal product through two opposite effects on the capital allocation dynamics. Credit expansion mainly causes an *inter-industry capital reallocation* if it occurs only in consumption industry, while the reallocation effect is dominated by the *economy-wide capital expansion* if the financial development occurs in capital industry. In the latter case the overall marginal product of capital decreases, but in the former case no substantial change is induced. Therefore, the industrial heterogeneity and the associated capital allocation are crucial, in order to analyze the effect of financial development on aggregate output volatility.

Keywords: financial development, collateral constraint, output volatility, developing countries

JEL Classification: E23, E44, G20

3.1 Introduction

A strong argument supporting financial development is that the reduction of financial frictions will dampen macroeconomic volatility. However, empirical literature investigating the effect of financial development on economic volatility is highly controversial, inconclusive and even confusing. While some research shows that financial development is linked to a decline of output volatility, a set of studies explicitly deny the existence of significant negative correlation. Even worse, a positive relationship can be found by some literature. Concerning the possible nonlinear effects, some studies reckon upon a U-shaped relation while an inverse-U-shaped is supported by some other studies.

Along with the indeterminacy in empirical evidence, the theoretical literature does not present explicit guidelines either. Throughout this present paper, we stick to using the availability of lending credit as the proxy of financial development.[1] To be more precise, "financial development" refers to an increase of LTV (loan-to-value) ratio in collateralized borrowing à la Kiyotaki and Moore (1997) (KM henceforth). Following the KM modelling approach, some theoretical literature demonstrates that financial development can induce lower output volatility. But in the literature we can also find the contrary arguments elsewhere.

Considering the confusing controversy in the existing literature, it is natural to conjecture that the underlying relation may be conditional on one certain factor which was overlooked before. Our paper demonstrates that the industrial heterogeneity matters in the story. Our paper is different from the previous studies mainly in the following aspects. (1) We do not focus on the degree of economy-wide credit access *per se*. Instead, we distinguish the different types of firms who can borrow in the financial market. (2) Moreover, rather than focusing on the inter-firm heterogeneity (e.g. public/private firms, small/large firms) mainly because of the difference in ownership or TFP level, we discuss the industrial distinction. We construct a two-sector model with one consumption goods production sector and one capital goods production sector, and study the interaction between the two industries.

Our model shows that if domestic financial friction is reduced in the consumption goods sector, macroeconomic volatility will rise. On the contrary, if financial friction is lessened for capital goods producers, output volatility may decline or be roughly unchanged. Obviously, the output volatility effects would be dissimilar if the "financial development" in two countries occurs in different industries, though the degrees of "financial development" measured by the traditional credit to GDP ratio indicator are alike. Our finding will contribute to the literature mainly in two aspects. (1) Relevant to the policy analysis, we emphasize the industrial heterogeneity as a crucial factor which may change the effect of financial development on macroeconomic volatility. Thus our finding calls for a better measurement of financial development, which identifies the type of credit owner rather than an overall ratio of credit access.

[1] Undoubtedly, the concept of "financial development" contains numerous other elements which are far beyond the current paper. A more comprehensive analysis on financial development, including the access, depth, and intermediation efficiency, is presented by Dabla-Norris et al. (2015) among others.

(2) We add new condiment into the KM type financial friction literature, as we show that a one-sector (representative or heterogeneous) firm model is not sufficient to unfold the full picture of output dynamics.

A potential criticism on our study is that the degree of credit access may exhibit no significant difference across industrial categories. Our study argues that rather than only caring about the degree of economy-wide credit access *per se*, we should inspect the type of industry whose credit is expanded. However, if there is no industrial heterogeneity of financial development level in reality, or there is no way to discriminate against different industries in commercial lending practice, the practical value of our analysis would be gravely weakened. Although we do not have data at hand regarding the exact degree of financial development in consumption industry and investment industry, we have some indirect supportive materials that the industrial heterogeneity of financial development level indeed exists. Our arguments are from three aspects. (1) First, the typical firm size is dissimilar across industries. Since big firms usually have better access to market credit than small firms, the industries typically with large firms possibly have looser borrowing constraint. (2) Second, some industries are more closely linked to the government, which may facilitate the borrowing of those industries at the cost of depressing other business sectors. (3) The external financing dependence of distinct industries can greatly differ. This implies that an economy-wide financial development faintly affects the credit availability of some industries, while largely improves the credit access of some other industries. A more detailed discussion on the difference of financial development level across industries is documented in Appendix 3.A.

The rest of the paper proceeds as follows. Section 3.2 presents a brief literature review. Section 3.3 provides a two-sector real business cycle model calibrated to a typical developing country. Section 3.4 demonstrates the model simulation results and discusses how the effect of financial development depends on the industrial heterogeneity. Finally Section 3.5 concludes.

3.2 Literature review

Our paper is primarily linked to the literature on the effect of financial frictions and financial development on macroeconomic volatility. Although our paper is theoretical, we first briefly discuss the empirical literature as the indeterminacy in empirical evidence is the main motivation of our paper.

3.2.1 Empirical literature

As already summarized in the introduction section, there is no consensus in empirical studies. In Table 3.3 at Appendix 3.B, we list some recent empirical findings and mark how different they are. Some empirical studies, e.g. Dabla-Norris and Srivisal (2013), Denizer, Iyigun and

Owen (2002), Ferreira da Silva (2002), Larrain (2006), Mallick (2014), Manganelli and Popov (2015), Raddatz (2006), Raheem, Bello Ajide and Adeniyi (2016), Xu (2009), find that financial development is associated with the decrease of output volatility. But the robustness of that negative correlation is yet doubtful. The studies by Acemoglu et al. (2003), Beck, Degryse and Kneer (2014), Beck, Lundberg and Majnoni (2006), Ferreira Tiryaki (2003), Fidrmuc and Scharler (2013), Hahn (2003), Levchenko, Rancière and Thoenig (2009), Tharavanij (2007) do not confirm the existence of significant correlation. Based on a firm-level dataset, Dodonov (2009) finds that financial development may significantly raise volatility in construction and manufacturing sectors. Regarding the possible nonlinear effects, Easterly, Islam and Stiglitz (2000), Ibrahim and Alagidede (2016) and Yang and Liu (2016) show a U-shaped relationship, which implies that financial development may be helpful in developing countries but unpleasant in developed economies. Those findings are, however, in constrast with the inverse-U-shaped relation found by Alatrash et al. (2014) and Kunieda (2008).

On the one hand, the controversy may emerge because different studies employ distinct samples, econometric methods, and definitions of the core variables. On the other hand, it is possible that the essential relation is conditional on one certain factor which can largely influence, or even drive the result, but is not taken into account by these studies. Our paper attempts to illustrate the industrial heterogeneity as a candidate.

3.2.2 Theoretical literature

The financial friction in our paper takes the form of the well known collateral constraint mechanism à la Kiyotaki and Moore (1997). Hence we neglect the bulk of the literature on the other financial accelerator mechanisms, primarily the BGG (Bernanke, Gertler and Gilchrist, 1999) literature. KM show that if the debt needs to be secured by collateral, even a small economic shock may cause large and persistent economic fluctuations. Following the KM modelling approach, a set of studies investigate whether the financial development, proxied by the LTV ratio in collateral constraint, helps reduce macroeconomic volatility.

Although some theoretical literature, e.g. Mendicino (2007), Mitra (2012), Wang and Wen (2010), Wang, Wen and Xu (2016), show that financial development can cause a decline of output volatility in certain circumstances, Jensen et al. (2017), Jensen, Ravn and Santoro (2016), Mendicino (2012) and Pinheiro, Rivadeneyra and Teignier (2016) demonstrate that an increase of volatility can be the direct result of a raised LTV ratio unless its value is unusually high.[2] A closer inspection on these theoretical models seemingly exhibits that the result is sensitive to

[2] To be precise, some theoretical literature actually argues that financial development can generate an inverse-U-shape effect on output volatility: financial development increases volatility if the degree of financial development is below a certain threshold; and it decreases the volatility once the threshold is exceeded. However, in those studies the threshold measured by the LTV ratio in borrowing constraint is rather high, e.g. around 0.8 (Jensen et al., 2017; Jensen, Ravn and Santoro, 2016), 0.9 (Mendicino, 2012) or even higher (Pinheiro, Rivadeneyra and Teignier, 2016), and only few advanced countries (if any) have a level close to the threshold. In other words, the implication for developing countries is actually that financial development increases macroeconomic volatility.

the exact way of model setup.

Here we try to compare most of these models in a unified framework. The basic ideas of them can be summarized as follows. Financial development (FD) affects the output volatility because it changes the responsiveness of the credit constrained firms to economic shocks. And after a shock this "Aggregate Output Responsiveness" depends on the size of "$MPK \cdot \Delta K \cdot Weight$" where MPK is the marginal product of capital of credit constrained firms (or the MPK gap between constrained and unconstrained firms, if the latter exist in the model); ΔK is the amount of capital redistributed to the constrained firms; $Weight$ measures the importance such as the output share of the constrained agents. The models of Jensen et al. (2017), Jensen, Ravn and Santoro (2016), Pinheiro, Rivadeneyra and Teignier (2016) emphasize the mechanism that FD may increase output volatility by expanding the term ΔK. Mendicino (2012) notes that FD decreases the MPK gap but increases the $Weight$ measured by the output share. Since the rise of $Weight$ dominates in her model, FD overall raises output volatility if the degree of FD is not sufficiently high. In constrast, FD can dampen output volatility as in Mendicino (2007), where FD greatly decreases the MPK gap between constrained and unconstrained entrepreneurs. Somehow departing from the idea of "$MPK \cdot \Delta K \cdot Weight$", Mitra (2012), Wang and Wen (2010), Wang, Wen and Xu (2016) show how FD reduces the aggregate output volatility by considering the possibility that low productivity firms may not produce at all. In an economy with heterogeneous firms subject to idiosyncratic productivity shocks, only highly productive firms produce and those low productivity firms lend. FD makes the output correlation between high and low productivity firms more negative (Mitra, 2012); or renders the firms' investment decisions less dependent on their own internal cash flows and thus less responsive to aggregate shocks (Wang and Wen, 2010; Wang, Wen and Xu, 2016). These studies that we just discussed all take into account some certain important parts of the economy. However, based on the existing models we cannot yet explain why some empirical works find that FD decreases output volatility but some others do not.

Several recent studies attempt to resist against this arbitrariness by investigating the different stories among heterogeneous firms. Thesmar and Thoenig (2011) and Mitra (2016) demonstrate that financial development can increase public firms' output volatility and decrease private firms' volatility. Focusing on labor market dynamics, Epstein and Shapiro (2016) find that unemployment and wage volatility will drop if only small firms have improved credit access, which is not the case if financial development occurs only for large firms. Regarding aggregate output volatility, they find financial development in either firm group only results in slightly lower output volatility, with the development for small firms has a relatively stronger effect.

In line with the heterogeneous firm literature, our model also pays close attention to differentiate diverse firms. But we do not categorize them based on whether they are public or private, big or small. Instead, we group them into either consumption goods industry or capital goods industry. Our study shows that credit expansion in the two industries has disparate implication on the aggregate output volatility.

3.3 Theoretical model

In this section we lay out our real business cycle model with KM type collateral constraint in a closed economy. The model is extremely simple but powerful to demonstrate our core idea. The model consists of three types of representative agents: (1) households who supply labor, save and lend to domestic entrepreneurs (firms); (2) consumption goods production entrepreneurs who own the consumption goods firms, make production decisions, and borrow from households conditional on collateralizing capitals; (3) capital goods production entrepreneurs who specialize in capital reproduction, sell capitals to the households and entrepreneurs in consumption industry, and also borrow from household savers. The government and external sector are not assumed in our model economy.

The key feature of our model is that we divide production into two distinct industries: consumption goods and capital goods. Consumption goods are used up in each period to directly generate utility for the entrepreneurs and households, while capital goods are stored and utilized for production input in the future.[3] This type of two-sector model has long history, stretching back to Uzawa (1961). Although the two-sector model was originally designed to analyze economic growth, it has been shown to also be powerful for business cycle analysis (e.g. Jaimovich and Rebelo, 2009; Buera, Kaboski and Shin, 2011). However the employment of a two-sector model is not typical in theoretical literature on KM type financial frictions, which usually assumes a one-to-one convertibility between consumption and capital goods (perphaps subject to an investment adjustment cost).[4] Our analysis below will demonstrate that in an environment with heterogenous industries together with the consumption-capital inconvertibility, the traditional measurement of financial development by an economy-wide credit to output ratio fails to differentiate the impacts of different credit expansions on output volatility.

[3]An explicit categorization regarding which industry in the real economy should belong to consumption goods sector or capital goods sector is sometimes ambiguous. A simple, though not completely rigorous, criterion to categorize is that the consumption goods sector refers to the industries that produce items purchased by individuals rather than by manufacturers and industries. The consumption sector includes the companies involved with food, clothing, beverages, automobiles for household, sport, entertainment, services and so on. The investment goods sector includes the enterprises for cement, machinery, building, industrial energy equipment, raw material, pollution and waste management and so forth.

[4]Of course, we do not mean that our paper is the only one using a two-sector model to study financial frictions. For example, the two-sector model is used by von Hagen and Zhang (2014) to explain the patterns of international capital flows, and by Alvarez-Parra, Brandao-Marques and Toledo (2013), Monacelli (2009) to study the large volatility of durable spending. But on our research topic i.e. the effect of financial development on aggregate output volatility, the employment of the two-sector model is relatively novel. It is notable that Mendicino (2007) also analyzes the financial development and output volatility nexus based on a two-sector model (whose basic framework can be found in Cordoba and Ripoll (2004)). But our model differs from hers in several key aspects. (1) Ownership relation between consumption and capital goods sectors. In her model each entrepreneur owns both consumption and capital sectors simultaneously, and thus capital will be reallocated between sectors to maximize overall output in each period. In our model the two industries are completely separate such that the two sectors cannot control each other directly. (2) Source of lending. In her model the credit constrained entrepreneurs borrow from those unconstrained entrepreneurs. In our model all entrepreneurs borrow from households such that all entrepreneurs are credit constrained. (3) Result. The result of her model is that financial development reduces output volatility monotonically. In our model financial development can either increase or decrease volatility, dpending on which industry obtains credit expansion.

3.3.1 Consumption goods entrepreneur

3.3.1.1 Agent's optimization problem

The consumption goods entrepreneurs maximize their life-time utility by making decisions about employing production inputs and borrowing domestically. The optimization problem is expressed as:

$$\max_{\{C_{1t},K_{1t},L_{1t},B_{1t}\}} \quad E_0 \sum_{t=0}^{\infty} \beta_1^t \frac{C_{1t}^{1-\varphi}}{1-\varphi}$$

subject to the flow budget constraint:

$$C_{1t} + Q_t[K_{1t} - (1-\delta)K_{1,t-1}] + B_{1,t-1}R_{t-1} = Y_{1t} - W_t L_{1t} + B_{1t} \tag{3.1}$$

and the collateralized borrowing constraint:

$$R_t B_{1t} + \Omega W_t L_{1t} \leq \gamma_{1t} E_t \{Q_{t+1} K_{1t}\} \tag{3.2}$$

where β_1, φ, δ are the discount rate, coefficient of relative risk aversion and capital depreciation rate, respectively. C_{1t} is consumption; B_{1t} is the borrowing from domestic household savers. Consumption goods production Y_{1t} employs labor L_{1t} and capital $K_{1,t-1}$ as inputs. W_t is the real wage; Q_t is the price of capital relative to consumption goods; R_t is the interest rate. In a competitive environment, the wage, capital price and interest rate are all taken as given and endogenously determined in equilibrium.

To insure themselves against the default risk, household creditors require the entrepreneurs to collateralize their capital K_{1t}. This is reflected by the borrowing constraint (3.2). Within this constraint, the term $\Omega W_t L_{1t}$ represents a working capital requirement in production. That means a share of wage bill, whose size is determined by the parameter Ω, should be paid before the creditors receive the interest payment.

In the borrowing constraint, the value of $\gamma_{1t} \in [0,1]$ gives the loan-to-value (LTV) ratio in a debt contract. The value of $(1-\gamma_{1t})$ measures the proportion of collateral that needs to be paid as transaction cost if the lenders liquidate the collateralized assets in the case that debtors default. Accordingly this proportion reflects the severity of the contract enforceability problem, which can be mitigated by financial development such as the enhanced institutional protection on property rights, and improved information transparency on collateralized asset. The higher the LTV ratio γ_{1t} is, the higher the degree of financial development is. Throughout this paper, if not particularly specified we always refer to an increase of the LTV ratio when we mention "financial development". In the empirical literature, financial development is mostly measured by the indicator of "credit to GDP ratio". Our model entails a direct correspondence between the LTV ratio and credit to output ratio, and thus can be directly linked to the empirical literature.

Following the recent literature (e.g. Iacoviello, 2015; Nolan and Thoenissen, 2009) which emphasizes the importance of financial shocks for business cycles, we assume γ_{1t} is not constant. Instead, it follows an exogenous AR(1) process as follows:

$$\ln\gamma_{1t} = (1-\rho_\gamma)\ln\gamma_1 + \rho_\gamma \ln\gamma_{1,t-1} + \varepsilon_t^\gamma \tag{3.3}$$

where the LTV ratio shock $\varepsilon_t^\gamma \overset{iid}{\sim} N(0,\sigma_\gamma^2)$.

3.3.1.2 Production technique

The entrepreneurs own the firms which produce in a completely competitive market using the following Cobb-Douglas technique:

$$Y_{1t} = A_{1t} K_{1,t-1}^{\alpha_1} (X_t L_{1t})^{1-\alpha_1} \tag{3.4}$$

where A_{1t} denotes the TFP level, which follows an exogenous AR(1) process:

$$\ln A_{1t} = (1-\rho_a)\ln A_1 + \rho_a \ln A_{1,t-1} + \varepsilon_t^a \tag{3.5}$$

with the technology shock $\varepsilon_t^a \overset{iid}{\sim} N(0,\sigma_a^2)$. The variable X_t is used to represent an economic growth trend. We use g_t to denote the economic growth rate. Then X_t evolves according to $\frac{X_t}{X_{t-1}} = e^{g_t}$ with:

$$g_t = g \tag{3.6}$$

Recent literature (Aguiar and Gopinath, 2007) argues that the exogenous shock to economic growth trend may be important for business cycles, especially in emerging economies. But the validity of introducing this shock into model is yet suspect, as analyzed by García-Cicco, Pancrazi and Uribe (2010) among others. We test whether a possible "trend shock" largely alters our result in the robustness analysis at Section 3.4.4, and find no much difference.

3.3.1.3 First order conditions

The first order conditions with respect to C_{1t} and K_{1t} give us the following equation:

$$\frac{Q_t}{C_{1t}^{\varphi}} = \beta_1 \frac{1}{C_{1,t+1}^{\varphi}} \left[\alpha_1 \frac{Y_{1,t+1}}{K_{1t}} + Q_{t+1}(1-\delta)\right] + \mu_{1t}\gamma_{1t}Q_{t+1} \tag{3.7}$$

where μ_{1t} is the Lagrangian multiplier with respect to the borrowing constraints (3.2). The optimal choice of B_{1t} requires the following condition:

$$\frac{1}{C_{1,t}^{\varphi}} = E_t \left\{ \beta_1 \frac{R_t}{C_{1,t+1}^{\varphi}} \right\} + \mu_{1t} R_t \tag{3.8}$$

Although the labor market is completely competitive, the wage is not exactly priced at labor's marginal product because of the working capital requirement in entrepreneur's borrowing constraint. That introduces a wedge between wage and labor's marginal product:

$$(1-\alpha_1)\frac{Y_{1t}}{L_{1t}} - W_t = \Omega \mu_{1t} W_t C_{1t}^{\varphi} \tag{3.9}$$

3.3.2 Capital goods entrepreneur

The capital goods entrepreneurs' problem is analogous to that of its counterpart in consumption goods industry. The main difference is that their output is capital, which is an intermediate input for consumption goods production. Of course, the capital goods sector's production technique can be different from that in consumption goods industry. The capital goods entrepreneurs sell their newly produced capitals to the consumption goods industry and households (who need e.g. residential house or durable goods in consumption bundle), and use the sale revenue to buy consumption goods which generate utility. Since the equations for capital goods entrepreneurs are quite similar to those in another industry, we only briefly write down those equations without much detailed interpretation below.

3.3.2.1 Agent's optimization problem

The optimization problem is:

$$\max_{\{C_{2t}, K_{2t}, L_{2t}, B_{2t}\}} \quad E_0 \sum_{t=0}^{\infty} \beta_2^t \frac{C_{2t}^{1-\varphi}}{1-\varphi}$$

subject to the budget constraint:

$$C_{2t} + Q_t[K_{2t} - (1-\delta)K_{2,t-1}] + B_{2,t-1}R_{t-1} = Q_t Y_{2t} - W_t L_{2t} + B_{2t} \tag{3.10}$$

and borrowing constraint:

$$R_t B_{2t} + \Omega W_t L_{2t} \leq \gamma_{2t} E_t \{Q_{t+1} K_{2t}\} \tag{3.11}$$

The LTV ratio $\gamma_{2t} \in [0,1]$ evolves according to an exogenous AR(1) process:

$$\ln \gamma_{2t} = (1-\rho_\gamma) \ln \gamma_2 + \rho_\gamma \ln \gamma_{2,t-1} + \varepsilon_t^{\gamma} \tag{3.12}$$

with ε_t^γ as the same as in equation (3.3). The value of γ_{2t} represents the degree of financial development in capital goods industry.

3.3.2.2 Production technique

The capital reproduction firms employ the labor L_{2t} and old capital stock $K_{2,t-1}$ to manufacture new capital Y_{2t}, based on the following Cobb-Douglas technique:

$$Y_{2t} = A_{2t} K_{2,t-1}^{\alpha_2} (X_t L_{2t})^{1-\alpha_2} \tag{3.13}$$

where A_{2t} denotes the TFP level, which follows an exogenous AR(1) process:

$$\ln A_{2t} = (1-\rho_a)\ln A_2 + \rho_a \ln A_{2,t-1} + \varepsilon_t^a \tag{3.14}$$

with ε_t^a as the same as in equation (3.5). The economic growth trend X_t is as the same as in consumption goods industry. Thus the equation (3.6) also applies.

3.3.2.3 First order conditions

The optimization generates the following first order conditions:

$$\frac{Q_t}{C_{2t}^\varphi} = \beta_2 \frac{1}{C_{2,t+1}^\varphi}\left[Q_{t+1}\alpha_2 \frac{Y_{2,t+1}}{K_{2t}} + Q_{t+1}(1-\delta)\right] + \mu_{2t}\gamma_{2t}Q_{t+1} \tag{3.15}$$

$$\frac{1}{C_{2,t}^\varphi} = E_t\left\{\beta_2 \frac{R_t}{C_{2,t+1}^\varphi}\right\} + \mu_{2t}R_t \tag{3.16}$$

$$Q_t(1-\alpha_2)\frac{Y_{2t}}{L_{2t}} - W_t = \Omega \mu_{2t} W_t C_{2t}^\varphi \tag{3.17}$$

3.3.3 Household

The households obtain utility from consumption, capital goods (e.g. house or durable goods) utilization, and leisure. Their income comes from labor wage and interest payment from firms' borrowing.

3.3.3.1 Agent's optimization problem

The representative household solves the following intertemporal problem:

$$\max_{\{C_{3t},K_{3t},L_{3t},B_{3t}\}} \quad E_0 \sum_{t=0}^{\infty} \beta_3^t \left[\frac{C_{3t}^{1-\varphi}}{1-\varphi} + j_{t-1} \ln K_{3,t-1} - \tau \frac{L_{3t}^{1+\eta}}{1+\eta} \right]$$

subject to the following budget constraint:

$$C_{3t} + Q_t[K_{3t} - (1-\delta)K_{3,t-1}] + B_{3t} = W_t L_{3t} + B_{3,t-1} R_{t-1}$$

where C_{3t}, $K_{3,t-1}$, L_{3t} are consumption, capital goods stock and labor, respectively. τ is the weight parameter for labor disutility, and η is the inverse of Frisch elasticity of labor supply. The term j_t represents the weight of household residence utility, which is possibly subject to an exogenous house demand shock in AR(1) process:

$$\ln j_t = (1-\rho_j) \ln j + \rho_j \ln j_{t-1} + \varepsilon_t^j \tag{3.18}$$

with $\varepsilon_t^j \overset{iid}{\sim} N(0, \sigma_j^2)$. The shock to house demand may be potentially important in explaining macroeconomic fluctuations, as paid attention by Iacoviello (2005), Liu, Miao and Zha (2016) among others.

3.3.3.2 First order conditions

The first order conditions give us the following relationships:

$$\frac{Q_t}{C_{3t}^{\varphi}} = E_t \beta_3 \left\{ (1-\delta) \frac{Q_{t+1}}{C_{3,t+1}^{\varphi}} + \frac{j_t}{K_{3t}} \right\} \tag{3.19}$$

$$\frac{1}{C_{3t}^{\varphi}} = \beta_3 E_t \left\{ \frac{R_t}{C_{3,t+1}^{\varphi}} \right\} \tag{3.20}$$

$$\tau L_{3t}^{\eta} = \frac{W_t}{C_{3t}^{\varphi}} \tag{3.21}$$

3.3.4 Market clearing and equilibrium

The population of consumption goods entrepreneur, capital goods entrepreneur, household is set to ω_1, ω_2, ω_3, respectively. The economy-wide resource constraint on consumption goods is given by:

$$\omega_1 Y_{1t} = \omega_1 C_{1t} + \omega_2 C_{2t} + \omega_3 C_{3t} \tag{3.22}$$

The term $\omega_1 Y_{1t}$ represents the aggregate consumption in the country. In each period, the newly produced capital goods Y_{2t} are distributed to replace the depreciated old capital and for net investment. We define the aggregate capital stock in the economy as:

$$K_t = \omega_1 K_{1t} + \omega_2 K_{2t} + \omega_3 K_{3t} \tag{3.23}$$

Then K_t evolves according to:

$$K_t - (1-\delta)K_{t-1} = \omega_2 Y_{2t} \tag{3.24}$$

Labor market clearing gives:

$$\omega_1 L_{1t} + \omega_2 L_{2t} = \omega_3 L_{3t} \tag{3.25}$$

Debt market clearing gives:

$$\omega_1 B_{1t} + \omega_2 B_{2t} = \omega_3 B_{3t} \tag{3.26}$$

The aggregate output, which is the main variable of interest in our paper, is the sum of output in both industries. Normalizing the price of consumption goods as unit, it is notable that the capital goods' relative price Q_t is variable. Thus we need to distinguish the real output and nominal output, though they do not differ too much when the economic fluctuation is not huge. The real output Y_t is:

$$Y_t = \omega_1 Y_{1t} + \omega_2 Q Y_{2t} \tag{3.27}$$

where Q is the capital price at the steady state.[5] The nominal output Y_t^N is:

$$Y_t^N = \omega_1 Y_{1t} + \omega_2 Q_t Y_{2t} \tag{3.28}$$

In the case that the mean economic growth rate g is not zero, in order to obtain a stationary model we should detrend the variables. That can be done if variables are divided by X_t. Ultimately, the equilibrium consists of 28 variables: $\{C_{1t}, C_{2t}, C_{3t}, K_{1t}, K_{2t}, K_{3t}, L_{1t}, L_{2t}, L_{3t}, B_{1t}, B_{2t}, B_{3t}, Q_t, R_t, W_t, \mu_{1t}, \mu_{2t}, Y_{1t}, Y_{2t}, K_t, Y_t, Y_t^N, g_t, j_t, A_{1t}, A_{2t}, \gamma_{1t}, \gamma_{2t}\}$ satisfying equations (3.1) - (3.28).

[5]Here we follow the idea of "Laspeyres index" to calculate the real GDP by fixing the price at its value in the base period (i.e. steady state in our model). This approach is just one of several different ways for GDP accounting. In national accounting practice this approach is usually infeasible because we cannot check the exact price level and production amount of every type of good and service. Instead, a compromise "deflation" method is often employed. In this case we first calculate the nominal GDP and a weighted average price index, and then deflate the nominal GDP by the price index. In our model the price index can be $P_t = w_1 + \frac{Q_t}{Q}(1-w_1)$ where $w_1 = \frac{\omega_1 Y_1}{\omega_1 Y_1 + \omega_2 Q Y_2}$ is the steady state share of consumption output in GDP. Then real GDP is $Y_t = \frac{Y_t^N}{P_t}$. We compare the value of real GDP calculated in this way with that by equation (3.27), and find only negligible difference.

3.4 Simulation

3.4.1 Parameterization

We list the parameterization details in Table 3.1 and 3.2. Without any specific country in our mind, the model is calibrated at quarterly frequency matched to the general case of a developing country.

The discount rate of household is set at $\beta_3 = 0.99$ to generate an annual saving interest rate around 4%. The entrepreneurs have lower discount rates at $\beta_1 = \beta_2 = 0.97$. Hence in the neighborhood of steady state the borrowing collateral constraints will bind, as long as the economic shocks are not huge. The coefficient of relative risk aversion is set at a typical value $\varphi = 1$, which makes the consumption utility logarithmic. We use a typical value in literature $\eta = 0.5$ for the inverse of Frisch elasticity of labor supply. Then, with weight parameter for labor utility $\tau = 3$, the steady state labor supply is around 1/2. The capital depreciation rate $\delta = 0.025$ is typical. The capital share in consumption goods production function is $\alpha_1 = 0.45$ to match the labor income share of 55% for typical developing countries, according to the Penn World Table (PWT) 9.0 dataset. The capital share parameter in capital goods industry is set at a lower value $\alpha_2 = 0.35$. In the robustness analysis section, we will test whether our model is sensitive to the values of α_1 and α_2. Following Finocchiaro and Mendicino (2016), we assume the working capital requirement in the borrowing constraint consists of all the wage payment and hence set $\Omega = 1$. Later we will change its value for robustness check. Regarding the population share of different agents in the economy, we do not have prior knowledge. Typical literature, for the purpose of simplicity, just assumes a uniform population share for all agent types. But that is no very reasonable in our model, because we expect the scale of investment industry should be smaller than the consumption industry. We set $\omega_1 = \omega_3 = 0.4$ and $\omega_2 = 0.2$. The robustness of the values is tested later. The mean economic growth rate is $g = \ln 1.01$ such that the economy is corresponding to a developing country with optimistic growth prospect of annual growth rate around 4%. The steady state value of the weight parameter for house residence utility is $j = 0.1$, to simply follow the setup in Iacoviello (2005), Iacoviello and Minetti (2006). The steady state TFP level, for convenience, is normalized to unit $A_1 = A_2 = 1$.

Table 3.1: **Parameterization (and some steady state values) of the model**

Para.	**Value**	**Definition**	**Target/Source**
β_1	0.97	discount rate of consumption goods entrepreneur	annual capital return rate $\approx 12\%$, in the case without financial friction
β_2	0.97	discount rate of capital goods entrepreneur	
β_3	0.99	discount rate of household	annual saving interest rate $\approx 4\%$
φ	1	coefficient of relative risk aversion	typical value in literature
τ	3	weight parameter for labor disutility	in steady state $L_3 \approx 1/2$
η	0.5	inverse of Frisch elasticity of labor supply	typical value in literature
δ	0.025	capital depreciation rate	typical value in literature
α_1	0.45	capital share in consumption goods industry	labor share is 55%, matched to data for developing countries according to PWT 9.0
α_2	0.3	capital share in capital goods industry	lower than the capital share in consumption goods industry
Ω	1	intensity of working capital requirement	Finocchiaro and Mendicino (2016)
ω_1	0.4	population share of consumption goods entrepreneur	there is no prior knowledge, we will change the values in robustness analysis section later
ω_2	0.2	population share of capital goods entrepreneur	
ω_3	0.4	population share of household	
g	$\ln 1.01$	mean economic growth rate	annual growth rate $\approx 4\%$
j	0.1	steady state value of weight parameter for utility from house residence	Iacoviello (2005), Iacoviello and Minetti (2006)
A_1	1	steady state TFP level in consumption goods industry	for convenience
A_2	1	steady state TFP level in capital goods industry	for convenience
γ_1	0.45	steady state LTV ratio for consumption goods entrepreneur	generate an annual credit to GDP ratio of 65%, which is the 75% quantile value of 50 developing countries data during 2010-2014
γ_2	0.45	steady state LTV ratio for capital goods entrepreneur	
Some steady state values:			
$\omega_1 B_1/Y$	53% annually	consumption goods entrepreneur debt to output ratio	roughly match data
$\omega_2 B_2/Y$	12% annually	capital goods entrepreneur debt to output ratio	
$\omega_3 B_3/Y$	65% annually	total debt to output ratio	
K/Y	141% annually	total capital to output ratio	
$\omega_1 Y_1/Y$	71%	total consumption to output ratio (= output share of consumption goods sector)	
$\omega_2 Q Y_2/Y$	29%	total investment to output ratio (= output share of capital goods sector)	

The LTV ratios γ_1 and γ_2 are the key parameters in our model. Although the realistic counterpart of the LTV ratio parameter is clear, the exact calibration in literature locates within a wide interval. Taking the US for instance, some studies use high value such as 0.89 in Iacoviello (2005), but there also exists much lower estimation such as 0.189 by Catherine et al. (2017). In literature, one way to estimate γ_1 and γ_2 is that we check the fraction of firm's value that is lost in debt enforcement process. But that is practically hard because we do not have data for different industries. For simplicity we assume in our baseline economy the steady state LTV ratio γ_1 in consumption industry and γ_2 in investment industry are the same, and we match the private credit to output ratio to the 75% quantile value of 50 developing countries data during 2010-2014. The list of those countries is at Appendix 3.C. The matched annual credit ratio is around 65%. That gives us the steady state LTV ratio in borrowing constraint, i.e. γ_1 and γ_2, at 0.45. This value is roughly consistent with the finding by Djankov et al. (2008) that an average 48% of a firm's value is lost in debt enforcement worldwide. Later in order to investigate the effect of financial development, we conduct counterfactual experiments to vary the LTV ratio.

Table 3.2: **Parameter for shock process in the model**

Shock type	**Persistence para.**	**Standard deviation**
TFP	$\rho_a = 0.9$	$\sigma_a = 0.5\%$
LTV ratio	$\rho_\gamma = 0.9$	$\sigma_\gamma = 1\%$
House demand	$\rho_j = 0.9$	$\sigma_j = 5\%$

As expressed in Section 3.3, we suppose that there are 3 types of shocks in the economy: TFP, LTV ratio, and house demand shock. In literature it is popular to utilize real macroeconomic data to calibrate the shock processes based on GMM or Bayesian estimation. However the calibration of shock processes is quite subtle, as different methods produce very distinct results and the results even depend on how many shocks we assume at the beginning. Actually we find the key results of our paper are robust to the assumption of shock processes. Hence at this moment we set these parameters in an *ad hoc* manner, and demonstrate the robustness later. As documented in Table 3.2, we assume the autocorrelation coefficients for all shocks' AR(1) processes are just 0.9. In this way, the remaining size of a shock after 5 years is less than 10% of its initial scale. The standard deviation of TFP shock is 0.5%. The LTV ratio shock and house demand shock have standard deviations of 1% and 5%, respectively. The TFP shocks in two industries are perfectly correlated. And the same LTV ratio shock hits both industries simultaneously. We simply set the covariance among different types of shocks at zero. With the assumed shock processes, each shock counts for roughly 20%-50% of aggregate output variance according to the variance decomposition (not reported) in our model simulation.

3.4.2 Impulse response

We obtain impulse responses of different variables to transitory technology shock, financial shock and house demand shock. Figure 3.1, 3.2 and 3.3 demonstrate the impulse responses to 1 standard deviation positive TFP shock, LTV ratio shock, and house demand shock, respectively. Besides the economy with baseline parameterization, in each figure we also plot the dynamics in an economy with a higher financial development level in either consumption goods sector or capital goods sector. Particularly we consider two cases. In the first experiment, γ_1 is increased to 0.6 while γ_2 is unchanged. In the second experiment, γ_1 is kept constant while γ_2 rises to 0.9. In both cases the annual credit to GDP ratio increases to the level of 90%. In Figure 3.1, 3.2 and 3.3, the green solid curves are for the baseline calibration, blue dashed curves for financial development only in consumption industry (with γ_1 increased from 0.45 to 0.6), and red dotted curves for that only in capital industry (with γ_2 increased from 0.45 to 0.9). In the figures the green and red curves are almost mutually overlapped such that it is not easy to distinguish them. If we sufficiently amplify the figures, we will actually observe that the red dotted curves are generally closer to the steady state lines than the green solid curves. Below we briefly discuss the economic dynamics after different shocks.

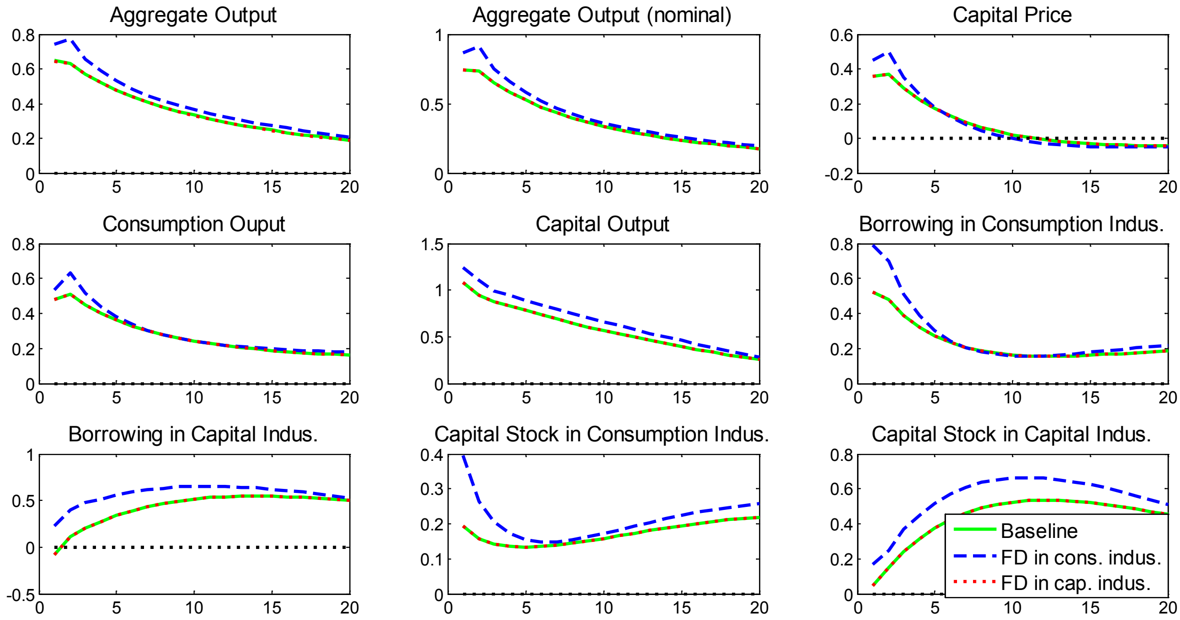
Note that in this subsection we will merely discuss how the existence of collateral constraint amplifies the effects of economic shocks, without concerning the difference when the LTV ratio in the borrowing constraint has a different value. In other words, we will analyze why the curves have the demonstrated shapes, but will not analyze why the blue and red curves are (or are not) different from the green curves. In fact, analyzing the effect of varying LTV ratio is not a straightforward task.[6] We postpone our analysis on the effects of changing parameter γ_1 and γ_2 to Section 3.4.3.

3.4.2.1 TFP shock

After one positive TFP shock (Figure 3.1), the production in both industries is more profitable. Thus, the demand for physical capital rises and the firms borrow more to expand investment and production. Because borrowing requires collateral, the capital price is pushed up. The raised capital price, via the KM type financial accelerator effect, generates positive feedback effect on firms' borrowing and production capacity. This accelerator effect is the reason that the aggregate output increases more than the original size of TFP shock.

[6] As mentioned in the previous literature review at Section 3.2, no much regularity is found in literature. Some nonlinear effects, contributed to different reasons, are discussed in literature. For instance, the reason can be the occasionally binding borrowing constraint in Jensen et al. (2017) and Jensen, Ravn and Santoro (2016), the relative importance of output share versus productivity gap in Mendicino (2012), and the relative importance of durable input reallocation effect versus intermediate input demand effect in Pinheiro, Rivadeneyra and Teignier (2016). The mechanism in our model is not linked to the occasionally binding constraint as we rule out this possibility by assumption, but is more or less related to Mendicino (2012) and Pinheiro, Rivadeneyra and Teignier (2016). See Section 3.4.3 for details.

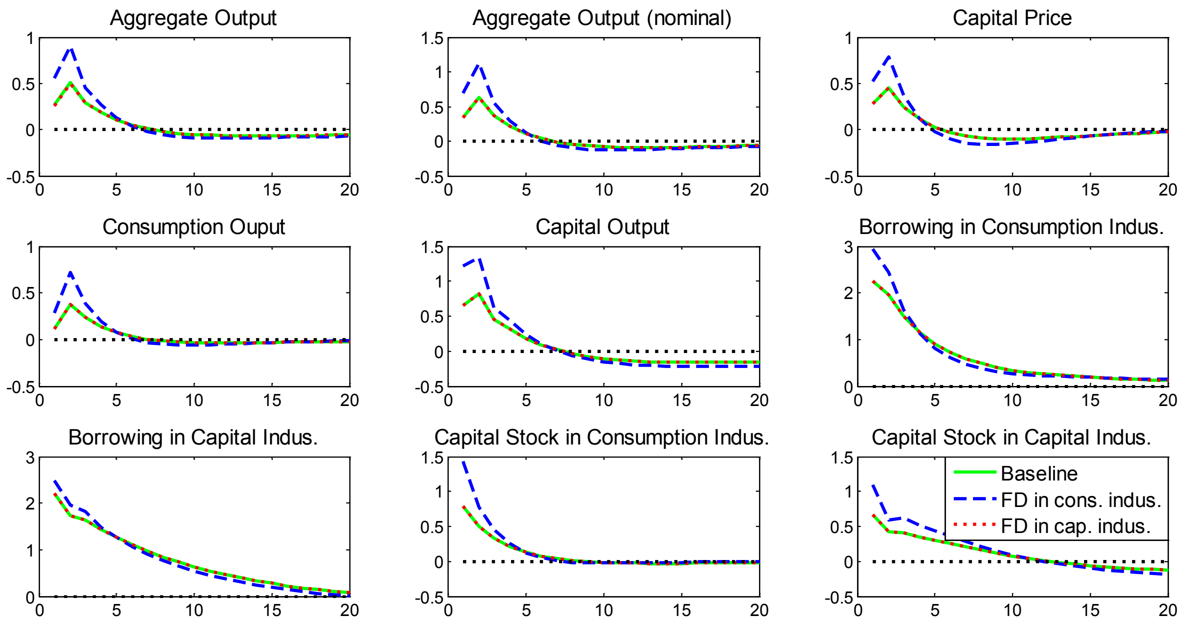
Figure 3.1: **Impulse responses to 0.5% positive TFP shock**



Note: All variables are expressed as percentage deviation from the steady state.

3.4.2.2 LTV ratio shock

Figure 3.2: **Impulse responses to 1% positive LTV ratio shock**



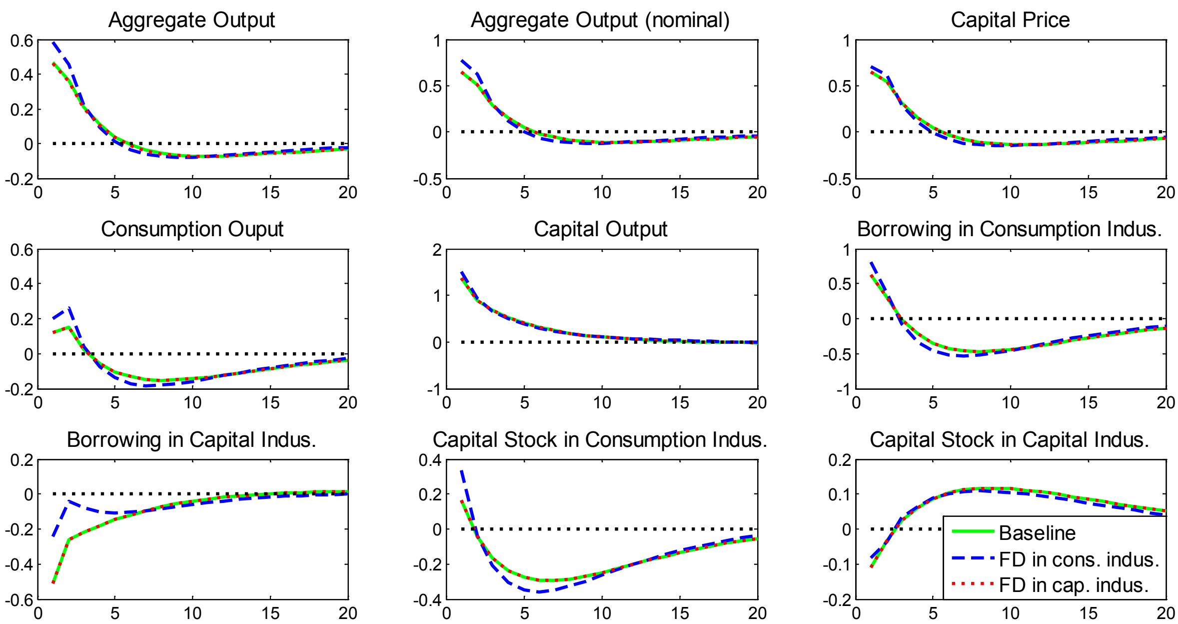
Note: All variables are expressed as percentage deviation from the steady state.

After one positive LTV ratio shock (Figure 3.2), the constrained firms suddenly have more ability to borrow money. Thus the borrowing, capital investment, production and capital price are all substantially enhanced in the first several periods. Some periods later, the borrowing constraint gets tighter as the LTV ratio decreases along with the extinction of shock. Thus we observe that the sectoral and aggregate output are slightly below the steady state levels, during some periods before the macroeconomy completely returns back to the steady state.

3.4.2.3 House demand shock

One positive house demand shock (Figure 3.3) pushes up the household's desire to purchase house (which is the physical capital from the persepective of firms). Then household rebates lending in order to procure some houses from the production sectors. Consequently the borrowing and capital stock in two industries both decline temporarily. To satisfy the risen capital demand, the output of capital industry grows. In constrast the output of consumption goods sector is relatively lower. The total output as the sum of two sectors increases during the initial periods but is then slightly below the steady state level for a while, as the consumption goods production is low.

Figure 3.3: **Impulse responses to 5% positive house demand shock**



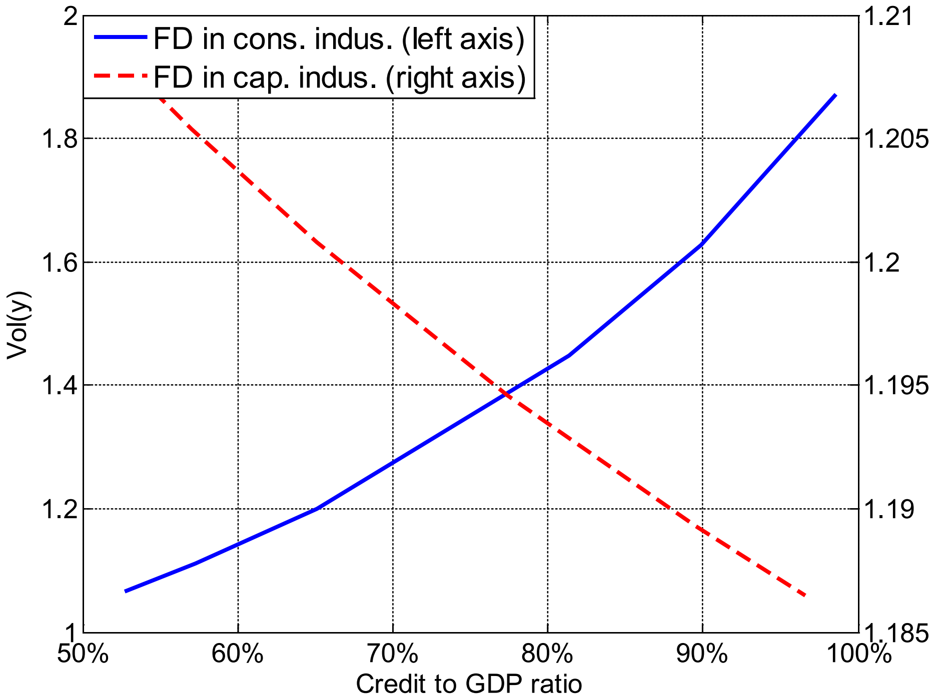
Note: All variables are expressed as percentage deviation from the steady state.

3.4.3 Quantitative analysis

In this subsection we quantify the influence of financial development on output volatility. We first document our quantitative result from model simulation, and explain the underlying mechanism and economic intuition afterwards.

First let us have a look back at the impulse response figures in Section 3.4.2. Paying particular attention to the quantitative difference among green, blue and red cuves, the key findings can be summarized as follows. (1) The larger credit access in consumption goods industry (displayed by blue dashed curves) makes the response of output to economic shocks stronger; while the higher credit access in capital goods industry (displayed by red dotted curves) has tiny effect on volatility. (2) That phenomenon is prevalent, no matter which kind of shock hits the economy. Thus it is straightforward to expect that if only consumption industry obtains enlarged credit access the output volatility will be larger, and if only capital industry obtains larger borrowing credit the volatility is barely changed.

Figure 3.4: **Output volatility vs. credit to GDP ratio**



This expectation is confirmed by Figure 3.4, which plots the relationship between simulated output volatility and credit to GDP ratio in our model economy. The output volatility is calculated by the standard deviation of HP-filtered (with smoothing parameter 1600) logarithmic output series from the model simulations. The blue solid curve is obtained by varying the degree of financial development in the consumption industry, while maintaining the LTV ratio in the capital industry at its baseline value. The red dashed curve is obtained by changing the LTV ratio only in the capital goods sector. The figure clearly demonstrates our core argument:

Industry heterogeneity matters in financial development and output volatility nexus. An overall measurement of "credit to GDP ratio" may have either positive or negative correlation with output volatility, depending on the certain industry where financial development occurs. If a higher credit ratio results from larger credit access in the capital industry, output volatility can decrease as shown by the red dashed curve. (The magnitude of volatility change along the red curve is much smaller compared to that along the blue curve. Hence in this figure we assign different scale to the left and right y-axis.) In contrast, larger credit access in the consumption industry results in a substantial expansion of output volatility as shown by the blue solid curve.[7]

3.4.3.1 Intuititive explanation

Given the complexity of our model, it is impossible to obtain an analytical expression on the relationship between financial development and output volatility. But we are still able to explain intuitively why industrial heterogeneity matters for the volatility effect of financial development. The interpretation is inspired by the idea of "input reallocation effect" of financial development as discussed in Cordoba and Ripoll (2004), Mendicino (2012), Pinheiro, Rivadeneyra and Teignier (2016).[8] First we notice that, with the financial amplification mechanism of the KM type borrowing constraint, the response of macroeconomic variables in the first several periods (especially the impact effect), is crucial to determine the size of output volatility. This can also be observed from the impulse responses in Figure 3.1, 3.2, 3.3. If an economic shock initially causes a large production reaction, the binding credit constraint plus the change of collateral asset price make the large deviation from the steady state persistent for several periods. The resulting output volatility is sizable.

The next step is to consider what factor drives the agents' initial production reactions. The answer is that the sensitivity of output to economic shocks crucially depends on the intensity of firms to adjust their production inputs, which relies on the marginal products of capital and labor. In the credit constrained economy, firms are always willing to expand the production as it is still profitable. They are restricted to do so, because the borrowing constraint is binding. The higher the marginal products of inputs are, the more profitable a potential production expansion is, and the more actively the firms will employ new inputs and produce if a positive shock makes the production expansion feasible. Consequently the output's deviation from its initial steady

[7] Based on our parameterization, the borrowing constraints in the model are always binding as long as the economic shocks are not too large. If we consider the possibility of "occasionally binding constraint", as in Jensen et al. (2017), Jensen, Ravn and Santoro (2016), the volatility along the blue curve may decrease in a certain region of high credit ratio. For simplicity we do not consider this possibility, because (1) the threshold of financial development, above which the "occasionally binding constraint" phenomenon is substantial, is probably quite high and most developing countries are far below that threshold; (2) taking into account the "occasionally binding constraint" does not alter the core argument of our paper that industrial heterogeneity matters.

[8] But our explanation is quite different, though our paper and these studies have the same focus on the allocation of inputs. (1) They work on the allocation between different firms in a homogenous industry while we discuss different firms in two heterogenous industries. (2) The economy-wide capital expansion effect does not stand out in their models as they do not feature an independent capital production sector. (3) The change of firms' output shares caused by financial development plays a key role in their models, but is not important in our economy.

state level will be larger. Therefore, we need to inspect how financial development changes the marginal benefit of employing new inputs. Financial development increases the labor marginal product, but alters the overall capital marginal product in an ambiguous way.

In the context of our two-sector economy, the key point is that financial development induces two effects on capital dynamics: *inter-industry capital reallocation*, and *economy-wide capital expansion*. The *capital reallocation effect* means that as the two industries compete in the input market, the larger credit access in one sector increases its share of capital holding, decreases its own capital marginal product but increases the marginal product in the other sector. The *capital expansion effect* means that financial development stimulates a larger demand of capital and encourages capital producers to produce more, which finally increases the total capital abundance and decreases the capital marginal product in all sectors. Since the consumption goods industry does not produce capital, it can only procure that from the capital goods industry. Thus the *capital reallocation effect* plays its role and barely alters the overall capital marginal product, if larger credit access occurs in consumption industry. In contrast, an expanded production in capital goods sector renders more capital available for both industries. Hence the *capital expansion effect* dominates and decreases the overall capital marginal product, if credit expansion occurs in investment industry. Taking into account the increase of labor marginal product no matter financial development takes place in which sector, the sensitivity of output to economic shocks crucially depends on how financial development alters the overall capital marginal product. This mechanism explains why industrial heterogeneity is crucial, in order to analyze the effect of financial development on aggregate output volatility.

3.4.3.2 Quantitative formalization

Next we formalize our intuitive explanation. We use E_{YZ} to denote the elasticity of output Y to exogenous economic shock Z. This elasticity is directly linked to output volatility, measured by the standard deviation of output percentage deviation. In our economy aggregate output is the sum of consumption sector output Y_1 and capital sector output QY_2 i.e. $Y = Y_1 + QY_2$. Then the elasticity E_{YZ} can be approximated as the weighted average of output elasticities in two sectors:

$$E_{YZ} \approx s_1 E_{Y_1 Z} + (1 - s_1) E_{Y_2 Z}$$

where s_1 is the share of consumption goods sector's output in aggregate GDP. (In this equation the capital price Q does not appear because it was already cancelled out.) At this stage we have seen that the effect of financial development depends on how it influences two factors: one is the industrial output share s_1, and another is the industrial output elasticities to shocks ($E_{Y_1 Z}$, $E_{Y_2 Z}$). Next we further decompose the term $E_{Y_1 Z}$ and $E_{Y_2 Z}$.

The production uses capital stock and labor as inputs. Thus for the consumption sector we can write $E_{Y_1 Z} = E_{Y_1 K_1} E_{K_1 Z} + E_{Y_1 L_1} E_{L_1 Z}$ where the definitions of elasticities $E_{Y_1 K_1}$, $E_{K_1 Z}$, $E_{Y_1 L_1}$, $E_{L_1 Z}$ are self-explanatory. As we assume Cobb-Douglas production functions, we know

$E_{Y_1K_1} = \alpha_1$ and $E_{Y_1L_1} = 1 - \alpha_1$. As a consequence, we have:

$$E_{Y_1Z} = \alpha_1 E_{K_1Z} + (1 - \alpha_1) E_{L_1Z}$$

Likewise, for the capital production we obtain:

$$E_{Y_2Z} = \alpha_2 E_{K_2Z} + (1 - \alpha_2) E_{L_2Z}$$

Since the parameters α_1 and α_2 are constant, what we concern is how financial development affects the the elasticity terms E_{K_1Z}, E_{L_1Z}, E_{K_2Z}, E_{L_2Z}. These terms reflect the strength of input employment response to shocks. Obviously, the more productive the production inputs are, the more profitable the entrepreneurs' employment of these inputs is, and the larger demand for these inputs the firms have. That is linked to the larger values of those elasticity terms. In other words, the elasticity terms crucially depend on the marginal products of the correpsonding production inputs: MPK_1, MPL_1, MPK_2, MPL_2.

Overall, the financial development changes the intensity of output response to shocks because it alters the industrial output share s_1 and inputs' marginal products (MPK_1, MPL_1, MPK_2, MPL_2). We write this relationship, in an unrigorous manner, in equation (3.29):

$$E_{YZ} = F\left(s_1, MPK_1, MPL_1, MPK_2, MPL_2; \alpha_1, \alpha_2\right) \tag{3.29}$$

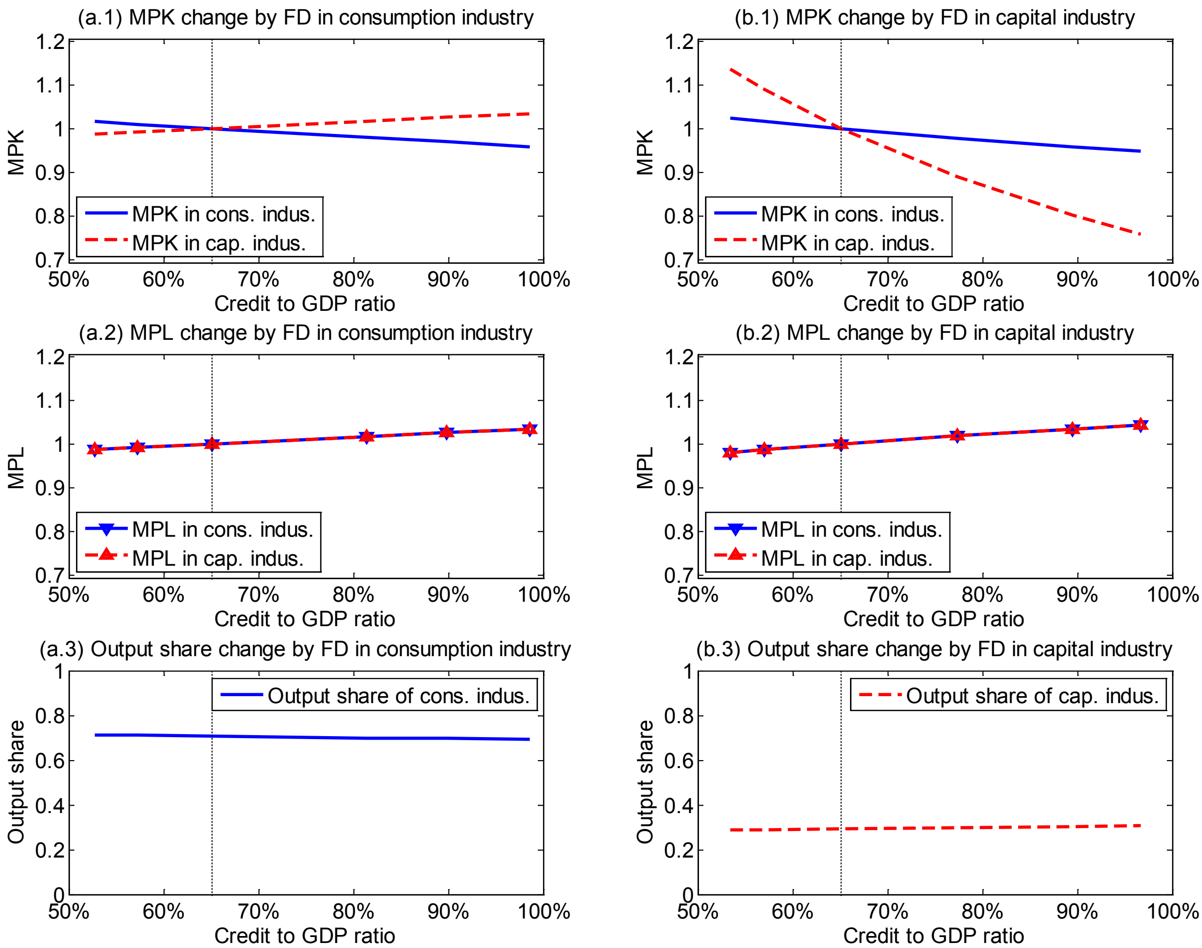
where $F(\cdot; \alpha_1, \alpha_2)$ is a nonlinear function. It depends on the industrial output share s_1 as weight, and is increasing with the marginal products (MPK_1, MPL_1, MPK_2, MPL_2).[9] This logic enables us to understand why financial development in distinct industries have different effects. Below we conduct a quantitative comparison based on our model.

[9] In the previous literature review on the existing theoretical models, we summarized that the "Aggregate Output Responsiveness" depends on the size of "$MPK \cdot \Delta K \cdot Weight$" (see Section 3.2.2). Our equation (3.29) is in fact consistent with that idea. (i) The output share s_1 corresponds to "*Weight*". (ii) The parameters (α_1, α_2) measure the output effect of additional production input using the concept of elasticity, while "*MPK*" directly measures the level. (iii) The terms (MPK_1, MPL_1, MPK_2, MPL_2) affect the firms' responsiveness of employing new inputs. This responsiveness is captured directly by "ΔK". Although equation (3.29) is conceptually similar to the expression of "$MPK \cdot \Delta K \cdot Weight$", we do not use that instead. This is because the marginal product of input also affects the volume of input redistribution in our two-sector model. Thus we cannot separate the components "*MPK*" and "ΔK".

3.4.3.3 Quantitative comparison

Figure 3.5 demonstrates the relative intensity of potential input reallocation effect versus capital expansion effect under different financial development levels. The curves in the figure show the steady state values of several variables contained in equation (3.29).

Figure 3.5: **The intensity of input reallocation effect vs. capital expansion effect**



Note: (i) The black dotted vertical line corresponds to the baseline case of credit ratio at 65%. (ii) In subfigure (a.1) - (b.2) the MPKs and MPLs at different financial development stages, are displayed as the ratios to the steady state levels in baseline model. This facilitates our comparision of different cases, as the benchmark marginal product level is unit.

(1) We first look at the left panel which corresponds to the case of raised LTV ratio only in consumption goods industry. (a) The financial development greatly raises the demand for capital in consumption sector. Thus, compared to the baseline economy in steady state a larger share of capital is held by consumption goods sector. Then the marginal production of capital MPK_1 in consumption industry declines as its capital stock increases; the MPK_2 in capital industry increases as its capital to output ratio declines. As demonstrated by subfigure (a.1), the size of MPK_1's increase and MPK_2's decrease are similar. Hence by *inter-industry capital reallocation* the changes of capital marginal product in two sectors offset each other. (b) As

displayed by subfigure (a.2), the marginal product of labor MPL_1 and MPL_2 increase in both industries. This is because the capital stock is increased while the total supply of labor is barely affected by financial development. In the figure the curves of MPL_1 and MPL_2 are mutually overlapped. The strong correlation of MPL_1 and MPL_2 is a natural result of the full mobility of labor, as they are tightly linked to the economy-wide wage. (c) The subfigure (a.3) indicates that financial development does not largely change the output share s_1 of the industry. In sum, we find in an economy with higer financial development in consumption industry compared to the baseline case, the changes of MPK_1 and MPK_2 offset each other, MPL_1 and MPL_2 both increase, and output share s_1 is almost unchanged. According to equation (3.29), the output response intensity E_{YZ} increases. That makes the output dynamics after shocks more volatile. In a nutshell, if higher access to credit only occurs in consumption goods sector, the *inter-industry capital reallocation effect* plays its role as the two industries compete in the production input market.

(2) The story differs if financial development only occurs in investment industry. The right panel shows the steady state consequences of capital industry financial development. (a) On the one hand, the capital industry produces more capital which decreases its own MPK_2. On the other hand, since more capital is available also for the consumption goods industry, the MPK_1 in that sector also declines. Therefore, in the case that financial development occurs in investment industry, the *economy-wide capital expansion effect* dominates over the *inter-industry capital reallocation effect* and induces an overall decline of capital marginal product. The situation is clear in subfigure (b.1). (b) However, the marginal product of labor MPL_1 and MPL_2 increase in both industries, as shown by subfigure (b.2). But the increase of labor marginal product does not exceed the magnitude of capital marginal product's decline. (c) The subfigure (b.3) exhibits that the output share of capital industry does not change a lot. As a whole, the lower capital marginal product, partly offset by the higher labor marginal product, along with a stable output share, results in a slightly decreased or roughly unchanged output response intensity E_{YZ} according to equation (3.29).

3.4.4 Robustness analysis

We conduct several robustness analyses as follows. (1) We change the value of capital share parameters (α_1, α_2) in production function. (2) We change the population share parameters (ω_1, ω_2, ω_3). (3) We change the working capital requirement parameter Ω. (4) We modify the shock processes. The robustness check results are shown by Figure 3.6. We see the core point of our paper is qualitatively unchanged. We describe our exercises briefly as below.

3.4.4.1 Production function

The production technique may be different across countries. That can be partly reflected by the values of capital share parameters (α_1, α_2). A change of their values also changes the steady state output share of the two industries. In subfigure 3.6(a), the output volatility is calculated by simulating a model with $\alpha_2 = 0.5$, rather than the baseline value of 0.3. Clearly the increase of output volatility after a credit expansion in consumption sector is still outstanding. The decrease of output volatility caused by a credit expansion in capital industry is slight. Setting other alternative values of (α_1, α_2) does not qualitatively alter our finding, whose result is not reported here.

3.4.4.2 Population share

The population share of different agent types may shape the relative size of sectors in the economy. In our baseline setup the values are $\omega_1 = 0.4$, $\omega_2 = 0.2$ and $\omega_3 = 0.4$. Now we follow most previous studies which assume an equal weight for all sectors, and set $\omega_1 = \omega_2 = \omega_3 = 1/3$. In subfigure 3.6(b), we do not see obvious change compared to our baseline result.

3.4.4.3 Working capital requirement

As discussed by Finocchiaro and Mendicino (2016) the assumption of working capital requirement in borrowing constraint is potentially important for the business cycle fluctuations, because it allows a direct interaction between financial friction and labor demand. In literature, there are alternative ways to set the working capital requirement. As an extreme example, Yépez (2017) assumes that the working capital is equal to the whole output value. In order to inspect whether our model is sensitive to the size of working capital requirement, we set $\Omega = 0$ instead of the baseline value $\Omega = 1$. Numerically we find that deleting the working capital component greatly reduces the volume of output volatility variation, especially when LTV ratio is high. However, as shown in subfigure 3.6(c) the main finding of our model has no essential change anyway.

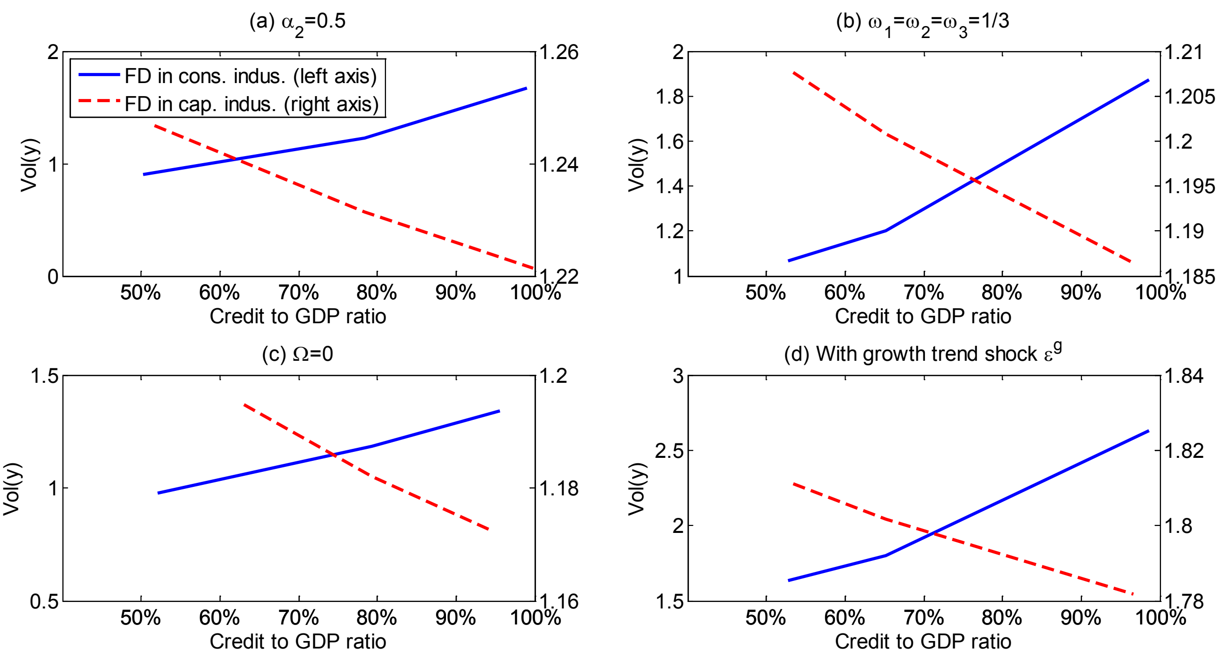
3.4.4.4 Shock process

Finally we modify the shock processes. We try several experiments. (i) In the first exercise, we no longer assume that the economic growth rate $g_t = g$ is constant as in equation (3.6). Instead, we introduce the growth trend shock such that:

$$g_t = (1-\rho_g)g + \rho_g g_{t-1} + \varepsilon_t^g$$

where $\varepsilon_t^g \overset{iid}{\sim} N(0, \sigma_g^2)$ with the persistence parameter $\rho_g = 0.9$ and standard deviation $\sigma_g = 5\%$. We see from subfigure 3.6(d) that though the exact size of output volatility depends on the assumed shock process, the financial development in the two industries always demonstrates difference. (ii) In the second exercise, we modify our previous assumption that the TFP shock ε_t^a and LTV ratio shock ε_t^γ are identical in both industries. Now we use ε_{1t}^a and ε_{2t}^a to replace ε_t^a in equation (3.5) and (3.14), and use ε_{1t}^γ and ε_{2t}^γ to replace ε_t^γ in equation (3.3) and (3.12), respectively. The correlation in the two sectors can be assumed relatively low such as $corr(\varepsilon_{1t}^a, \varepsilon_{2t}^a) = 0.3$ and $corr(\varepsilon_{1t}^\gamma, \varepsilon_{2t}^\gamma) = 0.3$. The simulation results are similar to our baseline model, and hence we do not report here. (iii) In the third experiment we change the relative size of different types of shocks. For instance we depress the relative importance of TFP shock by doubling the standard deviations of LTV and house demand shocks such that $\sigma_\gamma = 2\%$ and $\sigma_j = 10\%$. The alternative setup of shock process does not bring about any qualitative changes.

Figure 3.6: **Output volatility vs. credit to GDP ratio (robustness analysis)**



3.5 Conclusion

This paper argues that financial development can either exacerbate or dampen output volatility, depending on the type of industry whose borrowing constraint is relaxed. Using a two-sector real business cycle model augmented with the collateral constraint à la Kiyotaki and Moore (1997), we show that if domestic financial friction is reduced in the consumption goods sector, macroeconomic volatility will rise. On the contrary, if the borrowing constraint is lessened in the capital goods sector, output volatility may decline or be roughly unchanged. The key to understand the difference is the relative importance of the *inter-industry capital reallocation effect* versus the *economy-wide capital expansion effect* induced by financial development. The finding of our paper implies that an explicit discussion on the industrial heterogeneity is crucial, in order to analyze the effect of financial development on macroeconomic volatility.

The extension of our work can go along several promising directions. (1) A direct extension is to investigate how the industrial structure of a country influences the effects of financial development. Our model argues that consumption goods production sector and capital goods sector play different roles. Thus it is natural to ask, e.g. whether an economy with more output share of heavy industry performs dissimilarly from another country which produces higher share of final consumption goods. (2) Alternative possibility is to extend our model in a small open economy setup. Our closed economy model rules out the connection with international borrowing and international trade. In many developing countries the open economic connection plays a substantial role in macroeconomic dynamics. But obviously a small open economy setup will heavily complicate our analysis, especially considering that agents can lend and borrow both domestically and overseas. Actually we feel it tricky to separate the impact of international financial liberalization from domestic financial development. (3) Another potential is to differentiate credit in other ways, such as household-firm credit, tradable-nontradable firm credit, or even private-government credit. For example, Bahadir and Gumus (2016) employ a small open economy model matched to Turkey, and show that the change in household credit is more correlated with major macroeconomic variables than tradable and nontradable firm credit. This will inspire us to consider whether household credit is also more relevant to macroeconomic volatility. We leave this question in the future work.

Appendix

Appendix 3.A. On the industrial heterogeneity of financial development level

Here we discuss the industrial heterogeneity of financial development level from three aspects: firm size, closeness to government, and external financing dependence.

3.A.1. Firm size

The industrial characteristics (e.g. production technology, economies of scale, market competitiveness) make the average firm size largely varies across industries. In some network industries like transportation and telecommunication the firm size is usually huge. In the retail, food, clothing industries there exist a great amount of small enterprises. Kumar, Rajan and Zingales (2011) find that "capital-intensive industries, high wage industries, and industries that do a lot of R&D have larger firms". It is not unreasonable to conjecture that the industries consist of mainly large firm possibly have better credit access than others, taking into account the finding by firm-level studies that small and medium enterprises (SMEs) often face difficulty in borrowing. The situation in China could be marked. The SMEs in China face large challenges in accessing bank credit (Tsai, 2016). These SMEs are mostly located in the consumption goods sector. The lack of bank loan pushes many of them to resort to informal financial sector, which proceeds along another path disparate from the official financial development.

The credit expansion effect of financial development is uneven, conditional on the firm size. O'Toole and Newman (2017) find that in Vietnam financial development reduces financing constraints for small firms, and has no effect on medium firms. Based on a cross-country study, Arellano, Bai and Zhang (2012) find that as financial development improves, the leverage difference between small and large firm rises (where small firms have lower leverage). Thus, we may guess an economy-wide financial development probably causes uneven credit expansion across industries.

3.A.2. Closeness to government

The closeness to government may facilitate the acquirement of loan for some industries. A remarkable example is the state-owned enterprise (SOE) sector. In many countries the SOEs remain significant in the aggregate economy, and they are increasingly concentrated in a few "strategic" sectors such as the infrastructure industries of transportation, water and energy. (See Christiansen (2011) for a review on the SOEs in OECD countries, and a lot of studies on the Chinese case.) The industries mostly occupied by the SOEs are often in the category of investment goods industry. Benefiting from a good relationship with the government, those

SOEs are often less constrained for bank credit access. (One reason is that the banking system is largely controlled by the government.) In the case that bank loan is not readily available, the government may provide some other financing aids. Some industries' closeness to government may even impair the financing availability for the others. For example, O'Toole and Newman (2017) find that in Vietnam the financing constraint of private firms is increasing in the use of finance by SOEs.

3.A.3. External financing dependence

Different indusries show dissimilar dependence on external financing. Typically, the more capital or technology intensive industries are more reliant on access to external borrowing. Suppose that one economy enhances the bank loan availability, from a stage with universally low financial development level for all industries. Then some industries would significantly benefit from this kind of financial development, while some industries are unaffected because they seldomly rely on external financing. Since some industries may benefit more than others from financial services, even though the financial development does not discriminate on industries *ex ante*, the influence on different industries may differ *ex post*. For example, Ilyina and Samaniego (2011) show that "well-functioning financial markets direct resources toward industries where growth is driven by R&D".

Appendix 3.B. List of relevant empirical literature

Table 3.3 is a non-exhaustive list for the relevant empirical literature about the effect of financial development on output volatility. In order to focus on the recent studies and experience, we only document the literature published after year 2000.

Table 3.3: **List of relevant empirical literature about the effect of financial development on output volatility**

Literature	**Sample countries**	**Sample period**	**-/+ effect of financial development on vol(y)**	**Definition of output volatility**	**Definition of financial development**	**Econometric method**
Acemoglu et al. (2003)	61 ctr.	1970-1997	insignificant	overall or 5Y SD of pc y gr	(log of) the ratio of real M2 to GDP	2SLS
Alatrash et al. (2014)	103 ctr.	1981-2010	+/- (inverse-U-shaped) for ctr. with high-quality fin. sectors; insignificant for ctr. with low-quality fin. sectors	5Y SD of pc y gr	private credit to GDP ratio	difference GMM
Beck, Degryse and Kneer (2014)	77 ctr.	1980-2007	insignificant	overall or 5Y SD of pc y gr	intermediation: log(credit to GDP ratio); size: value added share of the financial industry in GDP	OLS
Beck, Lundberg and Majnoni (2006)	63 ctr.	1960-1997	insignificant (depends on type of shock)	13Y or 9Y SD of pc y gr	private credit to GDP ratio	OLS
Dabla-Norris and Srivisal (2013)	110 ctr.	1974-2008	- (only up to a threshold)	5Y SD of pc y gr (Robust: HP-filtered)	private credit by deposit bank and other fin. inst. (Robust: total liquid liability; deposit bank asset; total deposit)	system GMM

Note: (1) Besides the effect of financial development on output volatility, some literature also studies other contents (e.g. the effect on consumption volatility, effect of international financial openness). Here, in the table we only report the part of research where we are interested in. (2) In order to save space we use some abbreviations: ctr. (countries), fin. (financial), Y (year), SD (standard deviation), pc (per capita), y (output), gr (growth rate).

Table 3.3 (cont.): **List of relevant empirical literature about the effect of financial development on output volatility**

Literature	Sample countries	Sample period	-/+ effect of financial development on vol(y)	Definition of output volatility	Definition of financial development	Econometric method
Denizer, Iyigun and Owen (2002)	70 ctr.	1956-1998	-	9Y SD of pc y gr	4 measures: M2/GDP, claims on the nonfinancial private sector/GDP; nonfinancial private sector credit/total domestic credit; deposit money bank domestic assets/(itself + central bank domestic assets)	FE
Dodonov (2009)	24 EU ctr. (construction and manufacturing firms)	2000-2005	+	overall SD of firm-level sale gr	market capitalization as % of GDP; IMF's index of financial markets	IV
Easterly, Islam and Stiglitz (2000)	74 ctr.	1960-1997	-/+ (U-shaped)	SD of pc y gr over two periods: 1960-1978, 1979-1997	credit to private sector/GDP	IV
Ferreira da Silva (2002)	40 ctr.	1960-1997	-	overall SD of band-pass filtered y	4 measures: liquid liabilities/GDP; total assets of deposit money banks/financial intermediary system; non-financial private sector credit/total domestic credit; non-financial private sector credit/GDP	GMM
Ferreira Tiryaki (2003)	40 ctr.	1960-1997	insignificant	6Y SD of band-pass filtered y	as the same as Ferreira da Silva (2002)	GMM
Fidrmuc and Scharler (2013)	20 OECD ctr.	1995-2005	insignificant (by bank sector development, - by stock market)	log abs. value of pc y gr excluding time and country FEs	(log of) total credit by banks/GDP, bank assets/GDP	system GMM

Note: (1) Besides the effect of financial development on output volatility, some literature also studies other contents (e.g. the effect on consumption volatility, effect of international financial openness). Here, in the table we only report the part of research where we are interested in. (2) In order to save space we use some abbreviations: ctr. (countries), fin. (financial), Y (year), SD (standard deviation), pc (per capita), y (output), gr (growth rate).

Table 3.3 (cont.): **List of relevant empirical literature about the effect of financial development on output volatility**

Literature	Sample countries	Sample period	-/+ effect of financial development on vol(y)	Definition of output volatility	Definition of financial development	Econometric method
Hahn (2003)	22 OECD ctr.	1970-2000	insignificant (depends on type of shock)	5Y or 10Y SD or abs. diff. b/w max. and min. of y gap (Robust: SD of pc y gr)	stock market development; a conglomerate index of financial structure by Demirgüc et al. (2001)	IV, FE
Ibrahim and Alagidede (2016)	23 Sub-Saharan African ctr.	1980-2014	-/+ (U-shaped) for business-cycle vol.; insignificant for long-run vol.	square root of calculated variance of pc y using spectral method	private credit to GDP ratio	PMG (pooled mean group); MG
Kunieda (2008)	90 ctr.	1971-2000	+/- (inverse-U-shaped)	5Y SD of pc y gr	private credit to GDP ratio	GMM
Larrain (2006)	59 ctr. (industry-level data)	1963-1999	-	overall SD of BK filtered industrial y	private credit by deposit money banks to GDP ratio	OLS, IV
Levchenko, Rancière and Thoenig (2009)	56 ctr. (industry-level data for manufacturing)	1970-1999	insignificant	10Y SD of industrial y gr	private credit to GDP ratio	DID
Mallick (2014)	114 ctr. (27 high-, 49 middle-, 38 low-income)	1980-2004	- for business-cycle vol.; insignificant for long-run vol.	square root of calculated variance of pc y using spectral method	(log of) credit to the private sector by banks and other fin. inst. (Robust: stock market capitalization to GDP ratio)	OLS
Manganelli and Popov (2015)	28 OECD ctr.	1970-2007	- (through the channel of sectoral reallocation)	economy's convergence toward the benchmark MVE-implied industrial composition	value of total credits by financial intermediaries to the private sector/GDP (Robust: equity market size; bond market size; various measures of financial integration)	GMM

Note: (1) Besides the effect of financial development on output volatility, some literature also studies other contents (e.g. the effect on consumption volatility, effect of international financial openness). Here, in the table we only report the part of research where we are interested in. (2) In order to save space we use some abbreviations: ctr. (countries), fin. (financial), Y (year), SD (standard deviation), pc (per capita), y (output), gr (growth rate).

Table 3.3 (cont.): **List of relevant empirical literature about the effect of financial development on output volatility**

Literature	Sample countries	Sample period	-/+ effect of financial development on vol(y)	Definition of output volatility	Definition of financial development	Econometric method
Raddatz (2006)	48 ctr. (industry-level data for manufacturing)	1981-1998	- (in sectors with high liquidity needs)	overall SD of industrial value added gr	private credit to GDP ratio (Robust: quality of accounting standards, stock market capitalization)	2SLS
Raheem, Bello Ajide and Adeniyi (2016)	71 ctr.	1996-2012	-	overall SD of pc y gr (Robust: 5Y SD, HP-filtered)	private sector credit/GDP; credit provided by the banking sector/GDP	system GMM
Tharavanij (2007)	44 ctr.	1975-2004	insignificant	(log) 5Y SD of pc y gr or CF band-pass filtered pc y	(log) private credit to GDP ratio (Robust: M3 to GDP ratio)	pooled OLS, RE, FE, IV
Xu (2009)	81 ctr.	1962-2000	-	overall SD of pc y gr	bank credits to private sector/GDP	GMM, Granger causality test
Yang and Liu (2016)	56 ctr. (24 developed, 32 developing)	1980-2009	-/+ (U-shaped)	5Y SD of pc y gr	private sector domestic credits/GDP	system GMM

Note: (1) Besides the effect of financial development on output volatility, some literature also studies other contents (e.g. the effect on consumption volatility, effect of international financial openness). Here, in the table we only report the part of research where we are interested in. (2) In order to save space we use some abbreviations: ctr. (countries), fin. (financial), Y (year), SD (standard deviation), pc (per capita), y (output), gr (growth rate).

Appendix 3.C. List of countries and data source

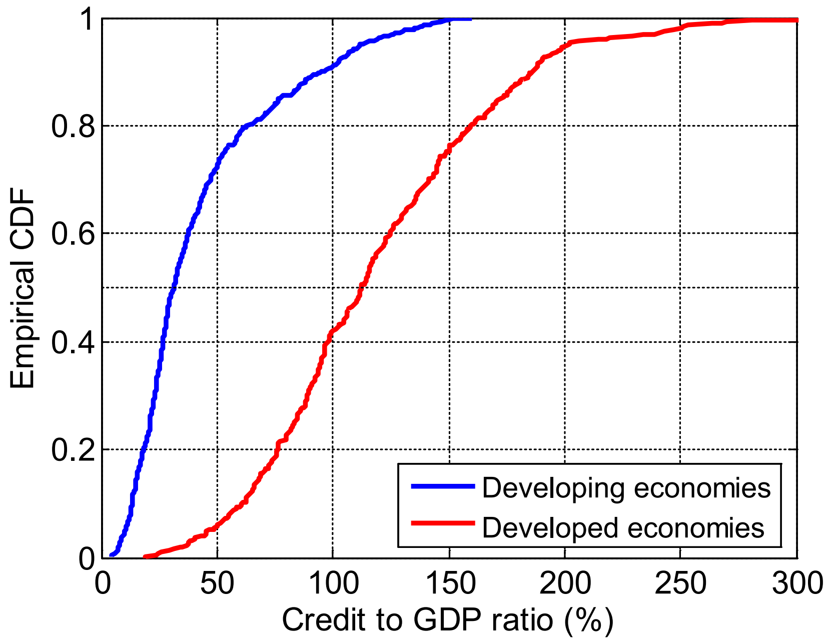
We check the private credit to GDP ratios in different countries. We take an unbalanced panel of 81 countries using the annual data between 2000 and 2014 from the World Development Indicators (WDI) database. This country set counts for more than 95% of world GDP and hence is representative of the world. The sample includes 50 developing countries and 31 developed economies, as listed in Table 3.4.

Table 3.4: **List of 50 developing and 31 developed economies in the sample**

50 developing economies:				
Argentina	Dominican Republic	Jamaica	Pakistan	Swaziland
Bangladesh	Ecuador	Kazakhstan	Panama	Thailand
Bolivia	El Salvador	Kyrgyz Republic	Paraguay	Tunisia
Brazil	Ethiopia	Lebanon	Peru	Turkey
Bulgaria	Georgia	Malaysia	Philippines	Uganda
Burkina Faso	Guatemala	Mauritius	Poland	Ukraine
Chile	Hungary	Mexico	Romania	Uruguay
China	India	Moldova	Russia	Venezuela
Colombia	Indonesia	Nicaragua	South Africa	Vietnam
Costa Rica	Iran	Nigeria	Sri Lanka	Zambia
31 developed economies:				
Australia	Finland	Israel	New Zealand	Switzerland
Austria	France	Italy	Norway	United Kingdom
Belgium	Germany	Japan	Portugal	United States
Canada	Greece	Korea, Rep.	Singapore	
Cyprus	Hong Kong, China	Latvia	Slovenia	
Czech Republic	Iceland	Malta	Spain	
Denmark	Ireland	Netherlands	Sweden	

In Figure 3.4 we plot the empirical CDF (cumulative distribution function) of "Domestic credit to private sector (% of GDP)" (code *FS.AST.PRVT.GD.ZS*) for the groups of developing and developed economies, respectively. Apparently, most developing countries have much lower levels of financial development.

Figure 3.7: **Empirical CDF of credit to GDP ratios in developing and developed economies**



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