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Abstract

Lucas (1990) argues that the neoclassical adjustment process fails to explain the relative paucity of FDI inflows from rich to poor countries. In this paper we consider a natural experiment: using China as the treated country and India as the control, we show that the dynamics of the relative FDI flows subsequent to the implementation of China's one-child policy, as seen in the data, are consistent with neoclassical fundamentals. In particular, following the introduction of the one-child policy in China, the capital-labor (K/L) ratio of China increased relative to that of India, and, simultaneously, relative FDI inflows into China vs. India declined. These observations are explained in the context of a simple neoclassical OLG paradigm. The adjustment mechanism works as follows: the reduction in the (urban) labor force due to the one-child policy increases the savings per capita. This increases the K/L ratio and reduces the marginal product of capital (MPK). The reduction in MPK (relative to India) reduces the relative attractiveness of investment in China and is thus associated with lower FDI/GDP ratios. Our paper contributes to the nascent literature exploring demographic transitions and their effects on FDI flows.

Keywords: Lucas paradox, capital-labor ratio, FDI-intensity, one-child policy

JEL Classification: F11, F21, J11, O11, E13

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1. Introduction

In an influential paper Lucas (1990) argued that the neoclassical adjustment process (capital flowing to its highest rate of return use) fails to explain the relative paucity of foreign direct investment (FDI) inflows to poor countries from rich ones, compared to flows among rich countries themselves.[1] In this context the expressions "rich" and "poor" refer to countries with high and low capital-labor (K/L) ratios, with the latter generating higher capital returns. A country may be "poor" in terms of GDP per capita yet relatively "rich" in terms of its K/L ratio. For the neoclassical adjustment process it is the latter identification that matters.

In this paper we revisit the Lucas (1990) paradox in the context of a natural experiment: the imposition, in 1982, of China's mandatory one-child policy. Keeping India, (where an incentivized but voluntary two-child policy was largely ineffective) as the control, we compare macroeconomic data from the two countries and find that post 1982 the FDI/GDP ratio has been increasing in both countries but declining in China relative to India. We show these observations to be consistent with a neoclassical adjustment process by replicating them in a two-country (and rest of the world) overlapping generations (OLG) model with neoclassical fundamentals.

A key feature of the analysis is differential population (labor-force) growth rates and, in particular, a sudden, exogenous decline in the growth rate in one of the countries. This results in the national savings of the older generation accruing to a smaller younger generation. The resulting higher capital-labor ratio in turn leads to lower capital returns, discouraging FDI investment. If capital adjustment costs are present, the same phenomena are observed for a prolonged time. Consistent with the model's implications, we see that the trajectory of

[1] Alfaro et al. (2008, Figure 1, p. 352) support the Lucas (1990) paradox, using data from 23 developed and 75 developing countries.

the capital growth differences between India and China closely tracks the difference in their respective population growth rates.[2]

Differences in the evolution of the K/L and FDI/GDP ratios in China vs. India may have non-demographic origins. Within the context of the model we consider, differences in the labor productivity growth rate could have similar effects. We net out this possibility by computing labor productivity growth in China and India for the periods preceding and following the 1982 one-child policy intervention.[3] We find the productivity differences to have been very small, allowing us to focus on the effects caused by the exogenous intervention on the population growth rate of China.[4]

The broad message of the paper is two fold. First, relative population dynamics play a first order role in determining cross country FDI flows.[5] Second, accounting for these dynamics suggests that the post 1982 macroeconomic observations from India and China are consistent with neoclassical theory.[6]

[2] Our model's mechanism requires that saving rates do not drop more than the rate at which savings per young worker increase. Choukhmane et al. (2007) document a sharp rise in the Chinese saving rate after the policy had been implemented, giving empirical support to the model's mechanism.

[3] Rosenzweig and Zhang (2009) find a modest impact of the one-child policy on human capital (in the "child-quality" sense). This finding supports that the one-child policy has not led to other neglected factor-accumulation effects that may bias our results on the dynamics of physical-capital accumulation in this paper.

[4] The similarities in productivity differences between China and India are also supported by Hsieh and Klenow (2009), and Bollard, Klenow and Sharma (2013).

[5] A cogent reason to focus on determinants of FDI, such as population dynamics, is that for many countries FDI is one of the ways out of poverty traps: see, for example, deMello (1997, Table 3), for an early survey of the positive relationship between FDI and growth (including some Granger causality tests), and also Basu and Guariglia (2007) for further evidence from 119 countries, confirming this positive channel. For an essay on poverty traps and FDI see Azariadis (1996, pp. 464-5).

[6] Specifically, our analysis suggests that that the dynamic FDI paradigm employed in McGrattan and Prescott (2009, 2010) and Holmes, McGrattan and Prescott (2015) may fruitfully be extended to accommodate different cross-country population growth rates. The support we find in favor of neoclassical theory contributes to the unresolved debate on ideas vs factor accumulation (see, for example, Klenow and Rodriguez-Clare, 1997, and Klenow, 1998). According to this debate, it is difficult to decide which venue to use for models of development: neoclassical production functions, or models of innovation, expanding variety of intermediate and final goods, or technology adoption? A notable study explaining why this comparison is difficult is Hall and Jones (1999, Table 1, p. 91).

2. The Model

We construct a parsimonious OLG model of two countries, 1 and 2, and the rest of the world (ROW). We assume that countries 1 and 2 are price takers in international capital markets, where the 'world interest rate', denoted by r^*, is constant. For simplicity, we focus on FDI from ROW to these two countries. Our key simplifying assumptions are:

- Capital flows from ROW to countries 1 and 2, but there are no capital flows between countries 1 and 2.
- The labor force of each country cannot move to other countries.
- There is no international trade in final goods.[7]

None of these assumptions compromise the generality of our main results.

2.1 Production

Aggregate domestic production in country $i \in \{1, 2\}$ in period t is characterized by the production technology,

$$Y_{i,t} = Y_{i,t}^{i} + Y_{i,t}^{r} \ , \tag{1}$$

where,

$$Y_{i,t}^{i} = \left(K_{i,t}^{i}\right)^{\alpha_i} \left(A_{i,t}^{i} L_{i,t}^{i}\right)^{1-\alpha_i} \ , \qquad \alpha_i \in (0,1) \tag{2}$$

and

$$Y_{i,t}^{r} = \left(FDI_{i,t}^{r}\right)^{\alpha_i} \left(A_{i,t}^{r} L_{i,t}^{r}\right)^{1-\alpha_i} \ . \tag{3}$$

[7] This is a simplifying assumption, following Backus, Kehoe, and Kydland (1992) and Holmes, McGrattan and Prescott (2015). While there are plausible reasons to assume that FDI may be more focused on selling in a local market rather than as a base for exports (see the discussion in Holmes, McGrattan and Prescott, 2015, p. 1159), this assumption is not critical for the qualitative conclusions implied by the model. Assuming a fully integrated final-goods market would add more arbitrage conditions but would not eliminate the key arbitrage conditions behind the K/L ratio dynamics studied here. Our empirical application focuses on China and India, two countries that have, historically, faced both geographical and political barriers to capital flows and trade.

Subscripts denote the location of productive activity and superscripts denote the investing country. Accordingly, $K^i_{i,t}$ is the period t capital of country i invested by domestic firms, while $FDI^r_{i,t}$ is the stock of FDI capital invested by ROW firms in country i. $L^i_{i,t}$ is the part of the workforce of country i working in firms using capital financed by country i, while $L^r_{i,t}$ denotes workers of country i that work for ROW companies using FDI. The common depreciation rate for capital $K^i_{i,t}$ and $FDI^r_{i,t}$ is $\delta \in (0,1]$, for $i \in \{1,2\}$. The exogenous labor productivity levels in the two sectors are denoted by $A^i_{i,t}$ and $A^r_{i,t}$. The symbol $A^r_{i,t}$ allows us to consider that productivity may be either location-specific or firm-specific. Factors such as the extent of bureaucracy, infrastructure, political instability, etc., may cause the productivity of a foreign firm to be location-specific. Furthermore, technology transfer (as, e.g., in Holmes, McGrattan and Prescott, 2015), which we do not explicitly model, could cause productivity to be firm-specific. In each country i, we postulate a large number of identical firms operating the technologies described by equations (2) and (3).

Based on our assumption of no cross country labor force mobility, and assuming full employment in each country,

$$L_{i,t} = L^i_{i,t} + L^r_{i,t} \ , \tag{4}$$

where $L_{i,t}$ is the total workforce (population) in country $i \in \{1,2\}$. We assume that population growth is exogenously given by,

$$\frac{L_{i,t+1}}{L_{i,t}} = e^{g_{L,i,t+1}} \ , \ \ t = 0, 1, \dots \ . \tag{5}$$

Our production structure is a simplified version of the one in McGrattan and Prescott (2009, 2010) and Holmes et al. (2015), with some modifications to the role of labor in production.[8]

[8] The McGrattan and Prescott (2009, 2010) models assume that total population, $L_{i,t}$, enters the production function of both companies relying on domestic capital and of companies relying on FDI. Using the

2.2 Efficient factor allocation

The representative firm, i or r, located in country $i \in \{1, 2\}$, is profit maximizing in an environment of perfectly-competitive factor markets. Accordingly, factor demands are driven by equating marginal products to factor prices. In addition, since firm production functions exhibit constant returns to scale and factor flows within a country are frictionless, the competitive equilibrium efficiently allocates factor inputs $\left(K^i_{i,t}, FDI^r_{i,t}, L^i_{i,t}, L^r_{i,t}\right)$ in each country to maximizing domestic production (see also McGrattan and Prescott, 2009, 2010).

The intra-temporal conditions for the efficient allocation of factor inputs, $\left(K^i_{i,t}, FDI^r_{i,t}, L^i_{i,t}, L^r_{i,t}\right)$, in order to maximize $Y_{i,t}$, subject to,

$$K_{i,t} = K^i_{i,t} + FDI^r_{i,t} \ , \ \text{and} \quad L_{i,t} = L^i_{i,t} + L^r_{i,t} \ , \tag{6}$$

where $K_{i,t}$ is total country i capital and $L_{i,t}$ total country i labor, are,

$$MPK^i_{i,t} = MPK^r_{i,t} \ , \tag{7}$$

and,

$$MPL^i_{i,t} = MPL^r_{i,t} \ . \tag{8}$$

Here "MPK" and "MPL" signify the marginal product of capital and marginal product of labor respectively.

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abstractions and notation of our model, domestic production in a McGrattan and Prescott (2009, 2010) type of model would be,

$$Y_{i,t} = \left[\left(K^i_{i,t}\right)^{\alpha_i} \left(A^i_{i,t}\right)^{1-\alpha_i} + \left(K^j_{i,t}\right)^{\alpha_i} \left(A^j_{i,t}\right)^{1-\alpha_i} \right] \left(L_{i,t}\right)^{1-\alpha_i} \ .$$

They motivate their formulation by the observed correlation between population size and FDI-location capacity. The McGrattan and Prescott (2009, 2010) formulation is convenient for obtaining an aggregate Cobb-Douglas domestic-production function. In this paper we suggest company-specific Cobb-Douglas production technologies and clearly distinguish those who work in FDI-related companies and those who work in domestically financed companies.

2.3 Households, domestic savings, and national capital

We use a variant of the overlapping-generations (OLG) model developed in Diamond (1965). Individuals live for two periods. Omitting subscript i, unless necessary, the following notation applies:

$c_{1,t} \equiv$ consumption of a young agent born at time t (t specifies the generation)

$c_{2,t} \equiv$ consumption when old at time $t+1$ of an individual born at time t

$L_t \equiv$ number of individuals born in period t and working in period t

$w_t \equiv$ wage received in period t

$r_{t+1} \equiv$ interest rate paid on savings held from period t to period $t+1$.

This notation implies that aggregate consumption in period $t+1$ is $L_t \cdot c_{2,t} + L_{t+1} \cdot c_{1,t+1}$ (See Table 1 below)

Table 1 – The evolution of consumption.

		Periods			
		t	$t+1$	$t+2$	$t+3$
Age Groups	**born in** t	$c_{1,t}$	$c_{2,t}$		
	born in $t+1$		$c_{1,t+1}$	$c_{2,t+1}$	
	born in $t+2$			$c_{1,t+2}$	$c_{2,t+2}$
	aggregating		$L_t \cdot c_{2,t}+$ $L_{t+1} \cdot c_{1,t+1}$	$L_{t+1} \cdot c_{2,t+1}+$ $L_{t+2} \cdot c_{1,t+2}$	

We further assume:

1. Within each cohort, individuals are identical. The utility function of a representative individual is given by,

$$U(c_{1,t}, c_{2,t}) = \log(c_{1,t}) + \beta \log(c_{2,t}) \ \text{, with discount factor} \quad \beta \in (0,1) \ . \tag{9}$$

2. Labor supply is completely inelastic and equal to one unit per period. Accordingly, the labor income of an individual when working in period t is w_t.

3. When young, individuals work, consume and accumulate capital (save). When old, individuals rent their capital to firms (in which the young generation works), consume, and die.

The consumption of generation t, when old (occurring in period $t+1$), is thus given by,

$$c_{2,t} = (1 + r_{t+1}) s_t \ , \tag{10}$$

where s_t denotes period t savings of a household. Since the only source of income when young is the wage income w_t, $s_t = w_t - c_{1,t}$, and (10) becomes,

$$c_{1,t} + \frac{c_{2,t}}{1 + r_{t+1}} = w_t \ . \tag{11}$$

Maximizing lifetime utility (9) subject to the lifetime constraint (11) yields,

$$s_t = \frac{\beta}{1+\beta} w_t \ . \tag{12}$$

Aggregate domestic savings of the young generation, $S_{i,t} = s_{i,t} L_{i,t}$, is equal to aggregate investment, which augments the national capital stock of the country in period t. Equation (12) then implies,

$$K^i_{i,t} = (1-\delta) K^i_{i,t-1} + \underbrace{\frac{\beta_i}{1+\beta_i} w_{i,t-1} L_{i,t-1}}_{\substack{\shortparallel \\ S_{i,t-1}}} \ , \quad i \in \{1,2\} \ . \tag{13}$$

In Appendix A we show that under one additional assumption,

$$A_{i,t}^{i} = A_{i,t}^{r} = A_{i,t} \ , \ \ t = 0, 1, ..., \tag{14}$$

production in both countries $i \in \{1, 2\}$ is given by an aggregated domestic production function of the form,

$$Y_{i,t} = K_{i,t}^{\alpha_i} \left(A_{i,t} L_{i,t}\right)^{1-\alpha_i} = \left(K_{i,t}^{i} + FDI_{i,t}^{r}\right)^{\alpha_i} \left(A_{i,t} L_{i,t}\right)^{1-\alpha_i} \ . \tag{15}$$

This special case allows the derivation of analytical results with direct empirical implications. Nevertheless, assuming $A_{i,t}^{i} \neq A_{i,t}^{j}$, and $A_{j,t}^{j} \neq A_{j,t}^{i}$, qualitatively gives the same empirical implications as described below, while depriving us of certain useful formulae that follow later in the paper. In what follows, we thus maintain assumption (14).[9]

2.4 Capital adjustment costs

In the absence of any capital adjustment cost, optimal investment is governed by,

$$r^{*} + \delta = MPK_{i,t} \ , \quad i \in \{1, 2\} \ . \tag{16}$$

With frictionless capital flows and unlimited capital availability at the world cost of capital r^{*}, steady state transitions due to underlying parameter changes will occur in one period which, in this model, corresponds to one-half of an adult lifetime. In order to better match the empirical duration of transitions we impose a capital adjustment cost on the dynamics implied by equations (13) and (16). In particular, we modify equation (16) to be of the form:

$$r^{*} + \delta = MPK_{i,t} + \psi\left(t, \bar{t}\right) \ , \quad i \in \{1, 2\} \ , \tag{17}$$

where,

$$\psi\left(t, \bar{t}\right) = \begin{cases} 0 & , \quad \text{if } \ t \leq \bar{t} \\ \eta \cdot \left(1 - \chi\right)^{t-\bar{t}-1} & , \quad \text{if } \ \bar{t} + 1 \leq t \end{cases} \ , \tag{18}$$

[9] We also assume that $A_{i,t}^{i} = A_{i,t}^{r}$ because we lack any data on labor productivity growth in foreign owned vs. domestically owned firms.

where $\eta > 0$, $\chi \in (0,1)$. The symbol $\bar{t} > 0$ denotes the period in which an exogenous intervention shocks equilibrium away from its steady-state path. For some periods after a transitional shock there is a loss of $\eta \cdot (1-\chi)^{t-\bar{t}-1}$ in capital returns, which we postulate as due either to costs of industrial relocation, or to institutional adjustments such as bureaucratic or political frictions.[10] These institutional adjustments are gradually smoothed out, and the capital-returns wedge, η, decays over time at rate χ.

2.5 Equilibrium

Equilibrium is characterized by a set of prices and quantities at which all firms maximize profits, all households maximize utility as price takers given these equilibrium prices and all domestic and international markets clear at these equilibrium prices and quantities.

In the model with adjustment costs, equilibrium in country $i \in \{1,2\}$ is characterized by conditions (13) and (17), with adjustment costs introducing long-lasting transitions in the capital labor ratio. In a steady state, adjustment costs are zero by construction.

In the next sections we study the effects of an exogenous demographic intervention on the K/L ratio and FDI. The intervention is characterized by a sudden decrease in population growth in one of the two countries, similar to the introduction of the one-child policy in China. This intervention puts a country in a transition characterized by changes in its K/L ratio and FDI flows. Specifically, following a drop in population growth, momentum in capital dynamics, exaggerated by capital-adjustment costs, increases the K/L ratio, which leads to a drop in the marginal product of capital, that, in turn, discourages FDI flows.

[10] The exogenous wedge that we impose upon condition (16) through equations (17) and (18) is similar to measured wedges that reflect deviations from the covered interest rate parity condition observed by Du, Tepper, and Verdelhan (2017) after the recent financial crisis. Du, Tepper, and Verdelhan (2017) attribute these deviations to costs through bank regulation. They can be seen as adjustment costs of moving from pre-crisis to post-crisis leverage ratios. For some countries, these covered interest rate parity deviations were stronger during the financial crisis crisis and then started fading away over time, as equation (18) implies (Du, Tepper, and Verdelhan, 2017, Figure 2).

To analyze these effects fully, we rely on specific relationships describing K/L ratio dynamics both along the transition path toward the steady-state growth path, and along the steady state growth path itself. These are presented below:

a) Transition Dynamics

Equation (17) implies,

$$\frac{K_{i,t}}{A_{i,t}L_{i,t}} = \left[\frac{\alpha_i}{r^* + \delta - \psi\left(t, \bar{t}\right)}\right]^{\frac{1}{1-\alpha_i}} \quad . \tag{19}$$

In turn, equation (19) implies that the growth rates of capital, labor and labor productivity are jointly related according to

$$g_{K,i,t} \equiv \ln\left(K_{i,t}\right) - \ln\left(K_{i,t-1}\right) = \frac{1}{1-\alpha_i} \ln\left[\frac{r^* + \delta - \psi\left(t-1, \bar{t}\right)}{r^* + \delta - \psi\left(t, \bar{t}\right)}\right] + g_{A,i,t} + g_{L,i,t} \ . \tag{20}$$

From equation (20) we see that an exogenous demographic intervention that reduces population growth from a constant rate $g_{L,i}$ to a lower constant rate $\bar{g}_{L,i}$, will also cause a drop in the growth rate of domestic capital, absent any other changes in labor productivity growth.

b) Steady State Growth Dynamics ($\psi\left(t, \bar{t}\right) = 0$)

We maintain our assumption that population growth is constant and further assume that productivity growth is also constant over time in country $i \in \{1, 2\}$, i.e.,

$$\frac{L_{i,t+1}}{L_{i,t}} = e^{g_{L,i}} \ , \quad \frac{A_{i,t+1}}{A_{i,t}} = e^{g_{A,i}} \ . \tag{21}$$

In conjunction with (17) and (18), equation (15) yields,

$$r^* + \delta = \frac{\partial Y_{i,t}}{\partial K_{i,t}} \equiv MPK_{i,t} = MPK_{i,t}^{i} = MPK_{i,t}^{r} \ , \quad i \in \{1, 2\} \ . \tag{22}$$

In Appendix B we show that the steady state growth path in economy i is characterized by equations,

$$\frac{Y_{i,t}^{ss}}{L_{i,t}} = \left(\frac{\alpha_i}{r^* + \delta}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{i,t} \ , \tag{23}$$

$$\frac{\left(K_{i,t}^{i}\right)^{ss}}{L_{i,t}} = \frac{\beta_i\left(1-\alpha_i\right)}{\left(1+\beta_i\right)\left(e^{g_{A,i}+g_{L,i}}+\delta-1\right)}\left(\frac{\alpha_i}{r^*+\delta}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{i,t} \ , \tag{24}$$

and,

$$\frac{\left(FDI_{i,t}^{r}\right)^{ss}}{Y_{i,t}^{ss}} = \frac{\alpha_i}{r^*+\delta} - \frac{\beta_i\left(1-\alpha_i\right)}{\left(1+\beta_i\right)\left(e^{g_{A,i}+g_{L,i}}+\delta-1\right)} \ . \tag{25}$$

Equation (24) implies that an exogenous demographic intervention that reduces population growth from a constant rate $g_{L,i}$ to another lower constant rate $\bar{g}_{L,i}$, will permanently increase national capital per worker. This permanent increase in $\left(K_{i,t}^{i}\right)^{ss}/L_{i,t}$ reduces capital returns. By equation (25), the crowding out of FDI will also cause a drop in the long run steady-state level of the FDI/GDP ratio.[11] Equations (19) - (25), all of which are neoclassical in origin, form the backbone of the analysis to follow.

In the next section we first detail the empirical behavior of K, L, and K/L in China and India before and after China's one-child policy implementation, and then demonstrate that a reasonably parameterized version of the present model replicates this behavior.

2.6 Comparative population policies in China and India

The two countries with the largest populations in the world, China and India, offer a unique contrast regarding population policy. Both countries initiated public policies to control population growth. In India a two-child birth regulation policy was voluntary and ineffective. In contrast, China's one-child policy was mandatory and effective.

[11]The expression 'crowding out' implies that the lower capital returns which follow on higher K/L ratios reduce the incentives for foreign firms to undertake FDI.

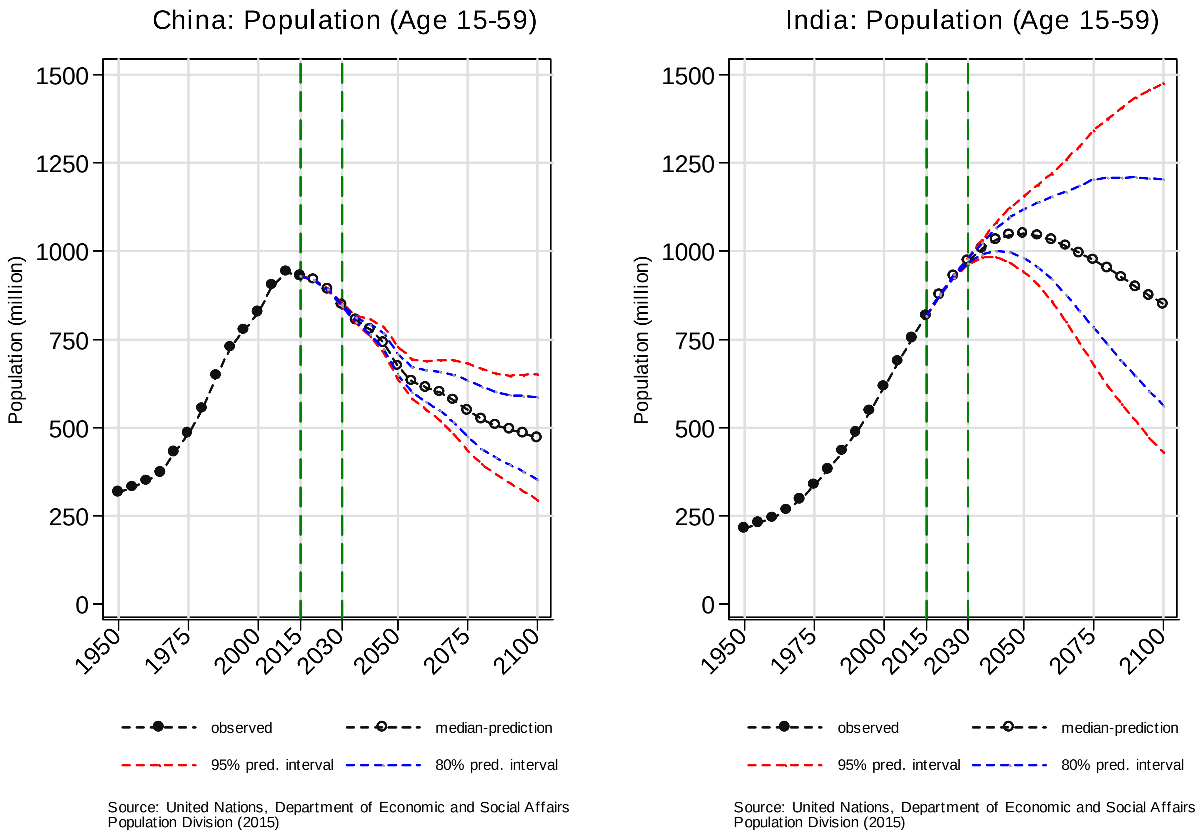

Figure 1 – Population dynamics in China and India. The two green lines indicate that, until 2030, predictions of working population dynamics are robust to any population-growth scenario.

Figure 1 demonstrates the scope of this major exogenous demographic policy intervention, which qualifies as a natural experiment. It depicts actual and predicted population dynamics according to various population growth scenarios and confidence intervals obtained through a Bayesian averaging method. Both data and population projection scenarios in Figure 1 are obtained from the United Nations Population division. Computations are done using an open source package described in Raftery et al. (2012) and Gerland et al. (2014). Three key observations result:

1. In China, an absolute decline in the working population (aged 15-59) began in 2010 and is predicted to continue under all reasonable scenarios.

2. In India the working population is predicted to continue growing at least until 2030.

3. After 2025, the working-aged population in India will exceed that of China.

These three points show that China's policy intervention was not only effective almost immediately after implementation but also that its effects on population dynamics are expected to persist beyond one generation.[12] The anticipation of these persistent policy effects is crucial for investment decisions because investors are forward-looking and major investments are typically long-lived. The combination of contemporaneous and expected future effects of the one-child policy on these comparative population dynamics strengthens the impact of the natural experiment. Furthermore, we show in Table 2 that crucial growth-performance features, such as productivity growth and GDP growth, were similar in China and India before and, most especially, after the exogenous demographic intervention. This similarity allows us to plausibly attribute trend differences between China and India solely to the exogenous demographic intervention in China.

As shown in Table 2, both China and India experienced very similar rapid GDP growth in the period after the implementation of the one-child policy in China. (see the two columns under "g_Y" in Table 2). Based on the production function given in (15), the two columns under "g_A", labor productivity growth, have been calculated using the corresponding formula $g_A = (g_Y - \alpha g_K) / (1 - \alpha) - g_L$ (we have assumed that the capital intensity parameter, $\alpha = 1/3$ in both China and India). Note that productivity growth, g_A was also similar in

[12]The recently introduced two-children policy in China is likely to alter the anticipated population dynamics in China, depicted in the left panel of Figure 1, after 2030. Nevertheless, predictions about population dynamics 15 years ahead will not be affected. These predictions are captured later in the time interval bracketed by the vertical dashed lines.

China and India both in Period 1, and even more so in Period 2 while increasing in both. The capital stock grew more rapidly in China in the latter period, while the dramatic labor force growth slowdown in China is clearly evident in the "g_L" column.

Table 2 Growth rates of macro aggregates. Annual rates (%).

	(i)		*(ii)*		*(iii)*		*(iv)*	
	g_L		g_K		g_Y		g_A	
	China	India	China	India	China	India	China	India
Period 1 (1960-1981)	2.05	2.27	7.89	3.52	5.11	4.14	1.69	2.17
Period 2 (1982-2014)	0.82	1.99	13.97	12.42	9.14	9.28	5.94	5.74

Source: Penn World Tables and United Nations.

g_L- growth rate of labor

g_K- growth rate of capital

g_Y- growth rate of GDP

g_A- growth rate of labor productivity

Let $\Delta g_{x,t} \equiv g_{x,1,t} - g_{x,2,t}$, with country 1 being China and country 2 being India. Figure 2 plots the empirical $\Delta g_{L,t}$ (red line) and $\Delta g_{K,t}$ (blue line), and identifies the date when the one-child policy was implemented (1982). Solid lines are the Hodrick-Prescott filtered series. Only a few years after 1982, $\Delta g_{L,t}$ takes on negative values and decreases over time (right axis in Figure 2), demonstrating that there has been a strong exogenous demographic intervention in China relative to India.

A key feature of Figure 2 is the simultaneity in the reversal of the trajectory of $\Delta g_{L,t}$ and the reversal of the trajectory of $\Delta g_{K,t}$ after 1982. It supports our hypothesis that China's exogenous demographic intervention has played a crucial role in explaining the differential capital-accumulation dynamics in the two countries after 1982.

That $\Delta g_{K,t}$ is positive after 1982 is not a surprise, as Δg_A rose from -0.48% before 1982 to 0.20% after 1982 (see Table 2). This rise in Δg_A is not, however, strong enough to mask the impact of population growth on capital growth.

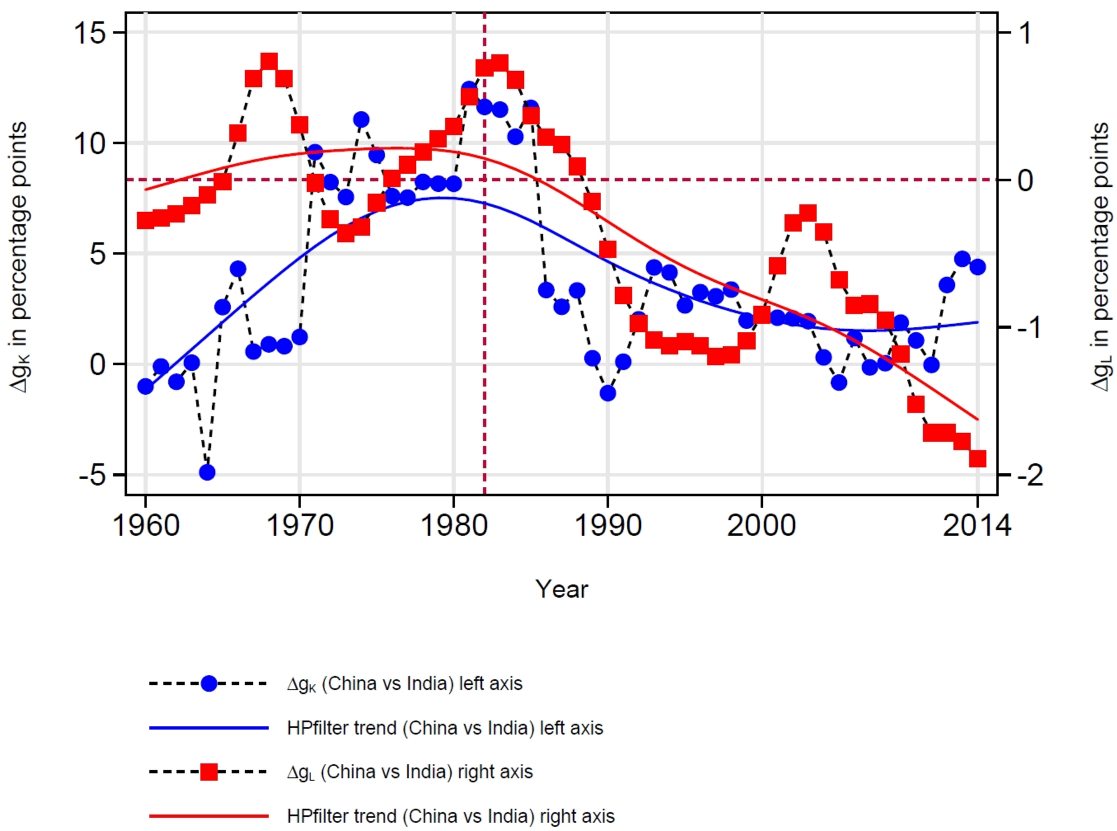

Figure 2 - Differential growth rates of capital and labor: China vs India.

To demonstrate the mechanics of our model we provide a numerical example of a country where an exogenous demographic intervention occurs in period 10. All model parameter values are given by Table 3.[13] The drop in population growth rate due to the intervention is similar to that of the one-child policy in China. The chosen value for δ is taken from Klenow and Rodriguez-Clare (1997, p. 76), while the value of r^* is in accordance with estimates in Holston, Laubach, and Williams (2017).

Table 3 - Parameter values.

	Parameters	
T	Length of period	25
$(1-\beta)/\beta$	Annual rate of time preference	6%
g_A	Annual labor productivity growth rate	4%
g_L	Annual population growth rate	2%
g_{L_1}	Annual population growth rate after intervention	-1.0%
α	Output elasticity of capital	1/3
r^*	Annual world interest rate	3%
δ	Annual depreciation rate	3%
η	Wedge on world capital return (annual)%	0.5%
χ	Rate of decay of the world-interest rate wedge	30%

Since India's demographic-control policies were broadly ineffective and it was exposed to the same extant globalization factors as China (especially in the mid-1990s), we postulate that India remained close to a steady-state path, and examine the difference in the capital growth rate between the two countries. In particular, equation (20) can be re-written as,

$$\Delta g_{K,t} = \frac{1}{1-\alpha_1} \ln \left[\frac{r^* + \delta - \psi\,(t-1,\bar{t})}{r^* + \delta - \psi\,(t,\bar{t})} \right] + \Delta g_{L,t} + \Delta g_{A,t} \ , \tag{26}$$

where $\Delta g_{x,t} \equiv g_{x,1,t} - g_{x,2,t}$, with country 1 being China and country 2 being India. Equation (26) governs the capital-labor (K/L) ratio dynamics depicted in Figure 3, and offers a first model test regarding the one-child policy in China and its comparison with India. If neoclassical K/L ratio mechanics are indeed present in China and India then the effect

[13]Both economies in our analysis share the common parameter values of Table 3 except for g_L which, for the treated country only (China), changes from g_L to g_{L_1}.

of the one-child policy in China is captured by an exogenous drop in $\Delta g_{L,t}$, which, in turn causes a drop in $\Delta g_{K,t}$. In accordance with equation (26), if we observe that the dynamics of $\Delta g_{K,t}$ track the dynamics of $\Delta g_{L,t}$, then the neoclassical K/L ratio mechanics implied by our parsimonious model are supported. Figure 3 presents the difference between one country experiencing an exogenous demographic intervention (the treated country), and a country on its steady-state path (the control country).[14]

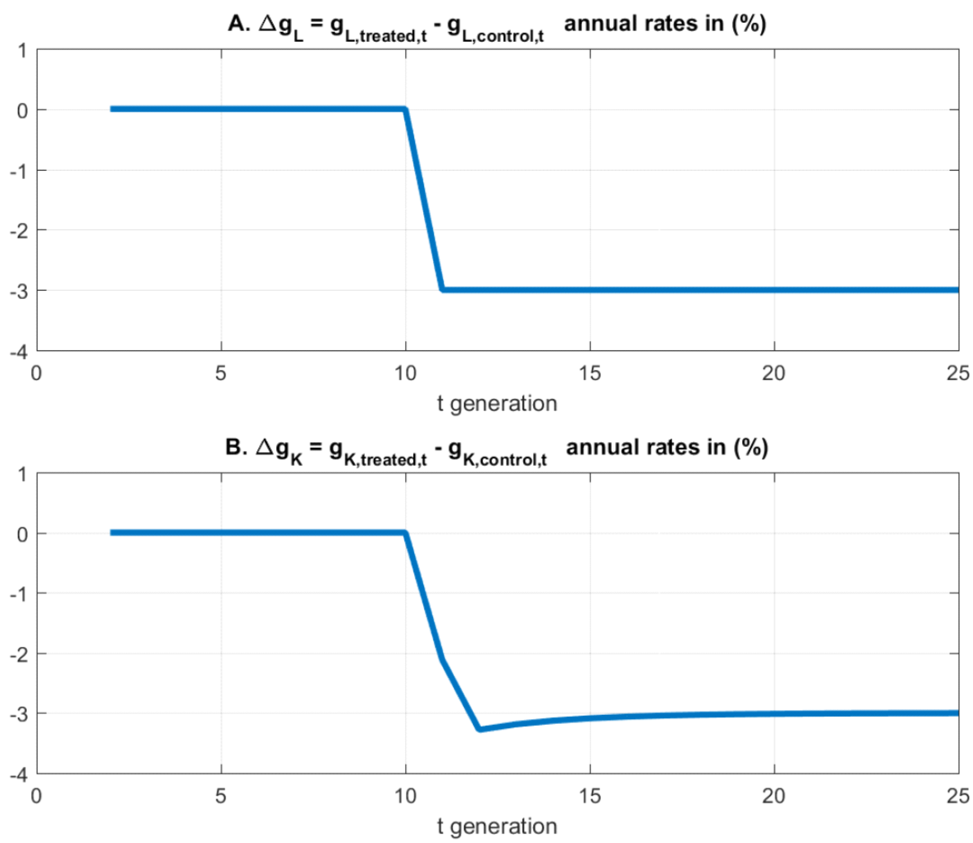

Figure 3 – The effect of demographic intervention on the difference in the capital growth rate for the two economies parameterized as per Table 3, around the time of the demographic intervention (treatment for one country only).

[14]Note that the control country is initially identical to its treated counterpart even with regards to the level of labor productivity.

Figure 3 shows that the natural experiment of the one-child policy is consistent with the effects predicted by a neoclassical model. Specifically, Figure 2 lends empirical support to the theoretical implications depicted in Figure 3.

3. The impact of an exogenous demographic intervention on relative FDI dynamics: theory and empirics

In this section we focus on FDI, specifically the trajectories of capital inflows from ROW. Using Table 3 parameter values, Figure 4 depicts model-generated differences between one country experiencing an exogenous period-10 demographic intervention (treated country), and a country on its steady-state path (control country). Both countries are identical as regards their initial K/L ratio and have identical labor productivity growth rates before and after the intervention. Panels A, C and E describe the consequences for the treated country alone while Panels B, D and F compare its response to the intervention with the same quantity in the control country. To more fully assess the implications of Figure 4, observe that if we consider two time series, x_t and z_t, and plot $\log(x_t) - \log(z_t)$ over time, then an upward-sloping $\log(x_t) - \log(z_t)$ implies that x_t grows faster than z_t.

First consider Panels A and B of Figure 4. Following the demographic intervention, the K/L ratio of the treated country spikes up (Panel A) before returning to its long run steady state value.[15] As a result, the K/L ratio in the treated country increases relative to the control country as captured in Panel B.[16] After some generations, the effect disappears, with the K/L ratio in both countries identical once again (Panel B). The K/L ratio effects are directly reflected in the corresponding MPK values: the abrupt increase in the treated

[15] As stressed above, in equation (19), capital in efficiency units, $K/(AL)$, is tied to the world interest rate, r^*. In order to better understand the dynamics of K/L ratios we need to control for changes in the dynamics of labor productivity, A, which we plot in Panel A of Figure 4 as $K/(AL)$.

[16] Following the identification mentioned in the preceding paragraph, the K/L ratio in the treated country grew relative to its equivalent in the control country.

country's K/L ratio has its counterpart in an absolute reduction in its MPK (Panel C), and a relative MPK reduction vis-a-vis the control country (Panel D). Following equation (18), adjustment costs of industrial relocation, and institutional adjustments such as bureaucratic or political frictions are manifested through a temporary drop in capital returns, driven by the capital-returns wedge $\psi(t, \bar{t}) = \eta \cdot (1-\chi)^{t-\bar{t}-1}$, that decays over time. Our choice of parameter η is an annual rate of 0.5%, and the decay parameter $\chi = 30\%$ implies that the half-life of this interest-rate wedge η is about 50 years, which corresponds to two generations of young workers, as the length of each period is 25 years. These values of η and χ are capable of reproducing empirically plausible K/L ratio dynamics.

Panels E and F detail the consequences of the intervention for the FDI/GDP ratio of the treated country. As evident in equation (25), the steady state FDI/GDP ratio of country i is positively related to its population growth rate $g_{L,i}$. Accordingly, a reduction in the treated country's $g_{L,i}$ reduces its FDI/GDP ratio, an effect manifested in Panel E. Relative to the control country, its FDI/GDP ratio declines as well (Panel F). Although the K/L ratio of the treated country eventually returns to its pre-intervention values (Panel A), the composition of its ownership of its capital stock has changed in favor of proportionately less FDI. We summarize these model implications as follows: a permanent decline in the population growth rate of the treated country leads to, (i) a temporary (though prolonged) increase (both absolute and comparative) in the K/L ratio above its steady state value, and (ii) a permanent reduction in its FDI/GDP ratio both absolutely and relative to its control counterpart. In summary, Figure 4 portrays the model implied consequences of a sudden reduction in the treated country's population growth rate on its K/L and FDI/GDP dynamics: the K/L ratio grows and the FDI/GDP ratio declines, both absolutely and relative to the control.

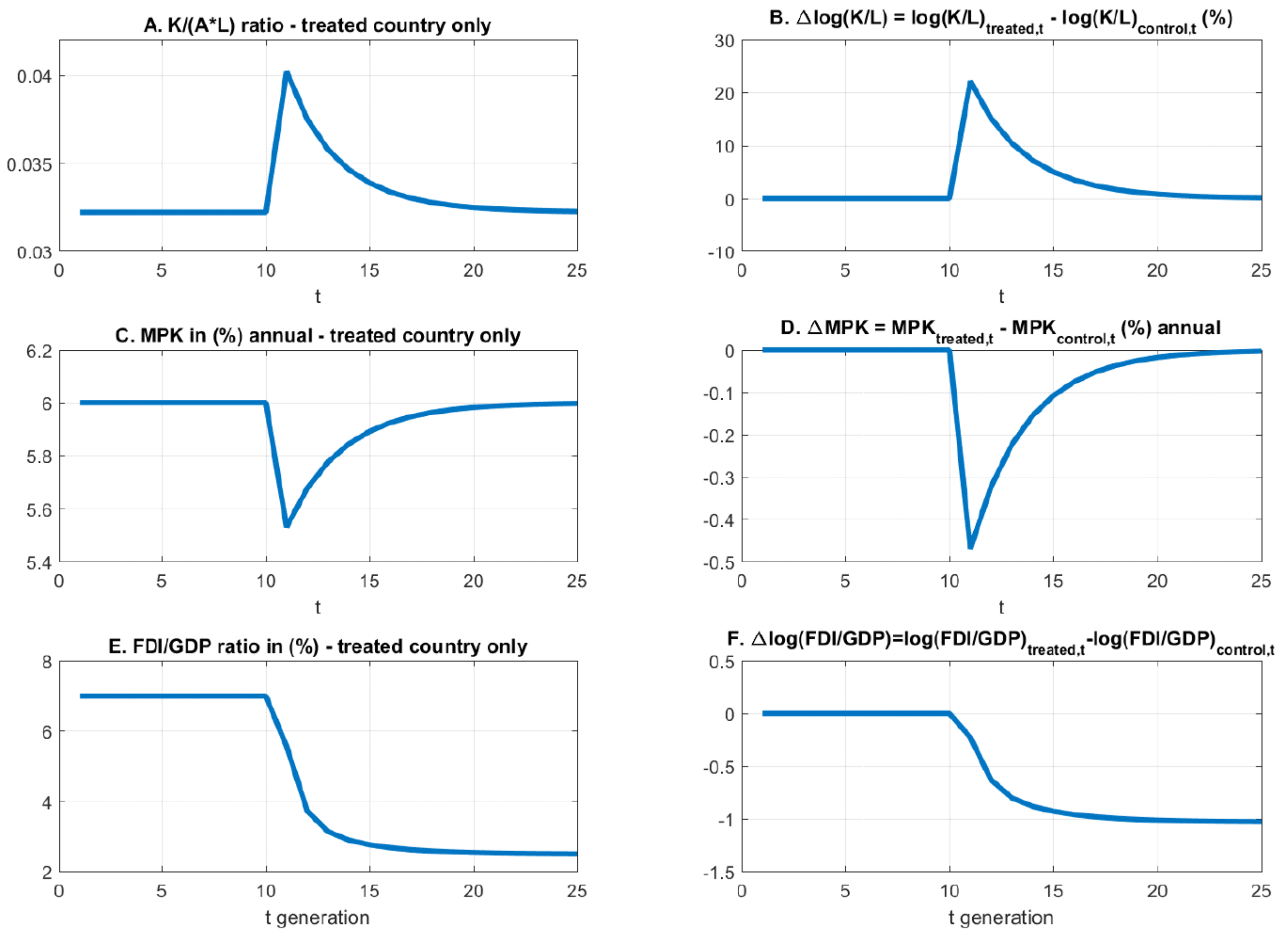

Figure 4 – Comparative time paths of K/L, MPK and FDI/GDP, for the two economies parameterized as per Table 3, around the time of the demographic intervention (treatment for one country only).

We next examine the question of whether these effects are in accordance with data. Figure 5 explores the empirical consistency of the one-child policy intervention in China.

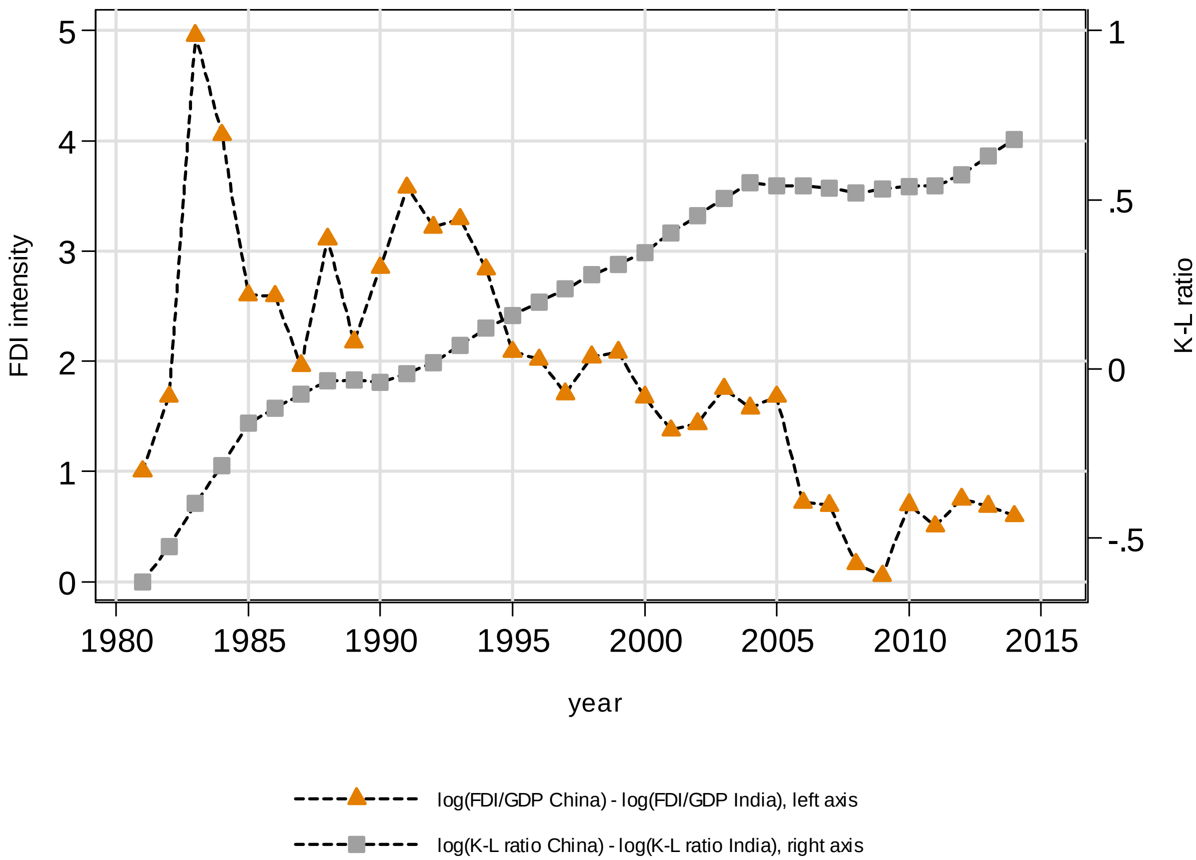

Figure 5 - Differential growth rates of FDI/GDP and K/L: China vs India.

In particular, post the 1982 demographic intervention, the K/L ratio of China grew more rapidly than that of India. This empirical observation is in accordance with our model's implication in Panel B of Figure 4. During the same period, FDI intensity (measured by FDI as a share of GDP) grew faster in India than in China. In 1990, the intensity of FDI in China was about 30 times larger than that of India, but by 2014, the intensity of FDI in China was less than 2 times that of India.[17] This empirical observation agrees with our model's implication as depicted in Panel E of Figure 4.

[17]In Appendix C we document the data used in Figure 5 and offer a robustness check focusing on K/L trends of the non-agricultural workforce in both countries (see Figure A.6 and Table A.1 in the Appendix). It is important to note that FDI in China and India during the period examined did not represent the purchase of existing domestic capital by foreign entities; rather observed FDI data predominantly describes the formation of new capital.

The results depicted in Figure 5 do not contradict the Lucas paradox per se: FDI/GDP and K/L were higher in China compared to India throughout the entire sample period.[18] It suggests, however, that the search for neoclassical fundamentals underlying FDI flows may be more productively undertaken by exploring cross-country *relative* rather than absolute FDI dynamics.[19]

4. Relationship to the existing literature

The neoclassical foundation for dynamic FDI analysis was first articulated in McGrattan and Prescott (2009, 2010), and Holmes, McGrattan and Prescott (2015). These three studies introduce international capital flows in a fashion similar to the present model. The paradigms they consider assume that both population growth rates and labor-productivity growth rates are equal across countries (see McGrattan and Prescott, 2010, p. 1503, and Holmes, McGrattan and Prescott, 2015, p. 1172), an assumption necessary for the existence of steady states in their formulations.[20] In these papers both developed and developing countries have the

[18]The present model is also able to replicate the Lucas (1990) paradox as a potential competitive equilibrium outcome. To see this, first note that by equation (24), the level of labor productivity, A_i, influences the K/L ratio. By equation (25), however, the level of labor productivity has no influence on the steady state FDI/GDP ratio. Imagine two countries, one with a lower β_i, a higher level of capital intensity α_i, and higher labor force and labor productivity growth rate. By equation (25) this country will have the higher steady-state FDI/GDP ratio (r^* and δ being common to both countries). If this country simultaneously enjoys labor productivity A_i dramatically above its counterpart, this high FDI/GDP ratio country will also have a higher (K/L). Accordingly, more capital flows from the ROW to the richer of the two countries, where we measure wealth in terms of capital per worker. This is one version of the Lucas (1990) paradox in our neoclassical setting.

In fact, the high FDI/GDP, high A country described above resembles the USA in many respects: a country with a high absolute TFP level, high TFP growth by developed world standards, a high income share to capital and low savings (low β).

[19]Notably, this natural experiment could not showcase these mechanics back in 1990, when the Lucas-paradox paper was written.

[20]To see why this paradigm does not allow for steady states with heterogeneous rates of population growth across countries, consider an intertemporal Euler equation relating the growth rate of consumption to a constant world interest rate, r^*. With constant relative risk aversion γ, this Euler equation is given by $c_{t+1}^i/c_t^i = [\beta(1+r^*)]^{1/\gamma}$, with c_t^i being consumption in country i. With $\hat{c}_t^i$ denoting consumption in efficiency units for a model with constant exogenous population growth rate, $g_{L,i}$, and constant exogenous labor productivity growth, $g_{A,i}$, $\hat{c}_{t+1}^i/\hat{c}_t^i = e^{-g_{L,i}-g_{A,i}}[\beta(1+r^*)]^{1/\gamma}$. A steady state in which $\hat{c}_{t+1}^i = \hat{c}_t^i$ in efficiency units is impossible for all countries if population growth rates are heterogeneous. Other steady states are

same population growth, suggesting that developing countries catch up with the world production frontier mainly through capital deepening. Alternatively, the concept of "technology transfer" in McGrattan and Prescott (2009, 2010), and Holmes, McGrattan and Prescott (2015) represents another appropriate technique for analyzing, e.g., the post-World-War II transition of southern European economies toward the EU frontier.

In our analysis, the one-child policy in China and its effect on population growth plays the central role. Since cross-country heterogeneity of population growth is crucial for the present model, we have used a simple OLG context. For emerging markets, real-world transitional dynamics which are far from the steady state, can be quite complicated, suggesting that the assumption of household perfect foresight may be too strong. The "myopia" (beyond an adult's life span of, e.g., 50-60 years) of an OLG model however, is perhaps the more appropriate starting point for capturing the rules of thumb used by savers in emerging economies.

5. Conclusion

The message of our paper is that demographics matter for explaining FDI transitions. It represents a first pass at introducing demographics into a formally articulated dynamic model of FDI. We use the mandatory one-child policy in China, contrasted with India's comparatively laissez faire approach as a natural experiment to test for the presence of neoclassical FDI dynamics. Our evidence and analysis support the hypothesis that neoclassical fundamentals do govern *relative* FDI flows.

More broadly, our work is a contribution to the nascent literature on the role of FDI and technology transfer in international markets in the context of integrated capital markets (see McGrattan and Prescott, (2009, 2010), and Holmes, McGrattan and Prescott,

impossible, as well.

(2015)). Specifically, we emphasize the effects of demographic events on FDI flows, a topic not previously addressed in that literature.

6. Appendix A – Proof of production aggregation

We omit time subscripts for simplicity. From equations (1), (2), (3), and (14), we obtain,

$$Y_i = A_i^{1-\alpha_i} \left(K_i^i\right)^{\alpha_i} \left(L_i^i\right)^{1-\alpha_i} \left[1 + \left(\frac{FDI_i^r}{K_i^i}\right)^{\alpha_i} \left(\frac{L_i^r}{L_i^i}\right)^{1-\alpha_i}\right] . \tag{27}$$

Assuming frictionless cross-country capital flows, condition (7) implies the equlibrium condition:

$$r^* + \delta = MPK_{1,t}^1 = MPK_{1,t}^r = MPK_{2,t}^2 = MPK_{2,t}^r . \tag{28}$$

Combining equations (28), (2), and (3), we obtain,

$$FDI_i^r \cdot L_i^i = K_i^i \cdot L_i^r . \tag{29}$$

Equation (27), combined with (29) and (4) becomes,

$$Y_i = A_i^{1-\alpha_i} \left(K_i^i\right)^{\alpha_i} \left(L_i^i\right)^{-\alpha_i} L_i . \tag{30}$$

Adding the term $K_i^i \cdot L_i^i$ to both sides of equation (29) leads to $(K_i^i + FDI_i^r) \cdot L_i^i = K_i^i \cdot (L_i^i + L_i^r)$, which implies,

$$\frac{K_i}{L_i} = \frac{K_i^i}{L_i^i} , \tag{31}$$

given (4), and given that $K_i = K_i^i + FDI_i^r$. Combining (30) with (31) we obtain

$$Y_i = A_i^{1-\alpha_i} \left(\frac{K_i}{L_i}\right)^{\alpha_i} L_i ,$$

which coincides with equation (15), proving the aggregation result. □

7. Appendix B - Proof of equations (23), (24), and (25)

Equation (22) implies $r^* + \delta = \alpha_i K_{i,t}^{\alpha_i - 1} \left(A_{i,t} L_{i,t}\right)^{1-\alpha_i}$, which gives,

$$K_{i,t} = \left(\frac{\alpha_i}{r^* + \delta}\right)^{\frac{1}{1-\alpha_i}} A_{i,t} L_{i,t} \ . \tag{32}$$

Substituting (32) into (15) gives equation (23).

To prove (24), notice that (13) and (15) give,

$$K_{i,t+1}^i = (1 - \delta) K_{i,t}^i + \frac{\beta_i (1 - \alpha_i)}{1 + \beta_i} Y_{i,t} \ . \tag{33}$$

Substituting (33) into (23) implies,

$$K_{i,t+1}^i = (1 - \delta) K_{i,t}^i + \frac{\beta_i (1 - \alpha_i)}{1 + \beta_i} \left(\frac{\alpha_i}{r^* + \delta}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{i,t} L_{i,t} \ . \tag{34}$$

Dividing both sides of equation (34) by $A_{i,t} L_{i,t}$, and considering constant exogenous growth rates for technology and population, $g_{A,i}$ and $g_{L,i}$, we obtain,

$$e^{g_{A,i} + g_{L,i}} \frac{K_{i,t+1}^i}{A_{i,t+1} L_{i,t+1}} = (1 - \delta) \frac{K_{i,t}^i}{A_{i,t} L_{i,t}} + \frac{\beta_i (1 - \alpha_i)}{1 + \beta_i} \left(\frac{\alpha_i}{r^* + \delta}\right)^{\frac{\alpha_i}{1-\alpha_i}} \ . \tag{35}$$

After placing domestic capital in efficiency units, $K_{i,t}^i / \left(A_{i,t} L_{i,t}\right)$, on a zero-growth steady-state path, so that $\left(K_{i,t}^i\right)^{ss} / \left(A_{i,t} L_{i,t}\right) = \left(K_{i,t+1}^i\right)^{ss} / \left(A_{i,t+1} L_{i,t+1}\right)$, equation (35) implies,

$$\left(K_{i,t}^i\right)^{ss} = \frac{\beta_i (1 - \alpha_i)}{(1 + \beta_i)\left(e^{g_{A,i} + g_{L,i}} + \delta - 1\right)} \underbrace{\left(\frac{\alpha_i}{r^* + \delta}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{i,t} L_{i,t}}_{\substack{\shortparallel \\ Y_{i,t}^{ss}}} , \tag{36}$$

proving equation (24).

For proving equation (25), observe that equation (22) implies,

$$\frac{K_{i,t}^{ss}}{Y_{i,t}^{ss}} = \frac{\alpha_i}{r^* + \delta} \ . \tag{37}$$

Equation (6) together with (37) gives,

$$\frac{\left(K_{i,t}^{i}\right)^{ss}}{Y_{i,t}^{ss}} + \frac{\left(FDI_{i,t}^{r}\right)^{ss}}{Y_{i,t}^{ss}} = \frac{\alpha_i}{r^* + \delta} \ . \tag{38}$$

Equation (36) combined with (23) implies,

$$\frac{\left(K_{i,t}^{i}\right)^{ss}}{Y_{i,t}^{ss}} = \frac{\beta_i \left(1 - \alpha_i\right)}{\left(1 + \beta_i\right)\left(e^{g_{A,i} + g_{L,i}} + \delta - 1\right)} \ . \tag{39}$$

Combining (38) and (39) proves equation (25). □

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Appendix C - Data Descriptions and Sources

Foreign Direct Investment[1]

We use four different data sources to cross-verify the FDI inflows and outflows of China and India.

1. OECD: 1990-2013. Historic time series from OECD FDI statistics to end-2013 (http://www.oecd.org/daf/inv/investment-policy/fdi-statistics-according-tobmd3.htm).
2. National Accounts: 1982 – 2014. National Bureau of Statistics China (NBS-China) provides FDI outflow and inflow information (http://data.stats.gov.cn/english/index.htm).
3. UNCTAD (United Nations Conference on Trade and Development): 1981-2013.The UNCTAD work program on FDI Statistics documents and analyzes global and regional trends in FDI.
4. DataStream: 1981-2016 (Quarterly). Thomson Reuters DataStream provides quarterly data on FDI inflows and outflows for China and India.[2]

Population Estimates and Forecasts: 1950-2100. United Nations: probabilistic population projections based on the world population prospects (the 2015 revision)[3].

GDP Series: 1990-2014, 2015-2018 (estimates). Work Bank, PPP adjusted at constant 2011 international USD.

Capital Stock -GDP ratio (K/Y ratio): PWT 9.0 (The Penn World Table).

FDI data come from four sources: (a) National Accounts, (b) OECD, (c) Datastream, and (d) UNCTAD. These sources cover different years, so we specify which we use in each context and document the correlation among these data sources. National account data for India is downloaded from the RBI website (https://rbi.org.in/Scripts/SDDSView.aspx) and it is identical to the data provided by OECD. So, we only report the OECD source.

[1] All FDI statistics from different sources use 2010 USD as the base dollar value.
[2] The quarterly data sources are composed by Oxford Economics (http://www.oxfordeconomics.com/).
[3] United Nations (2015). Probabilistic Population Projections based on the World Population Prospects: The 2015 Revision. Population Division, DESA. http://esa.un.org/unpd/ppp/.

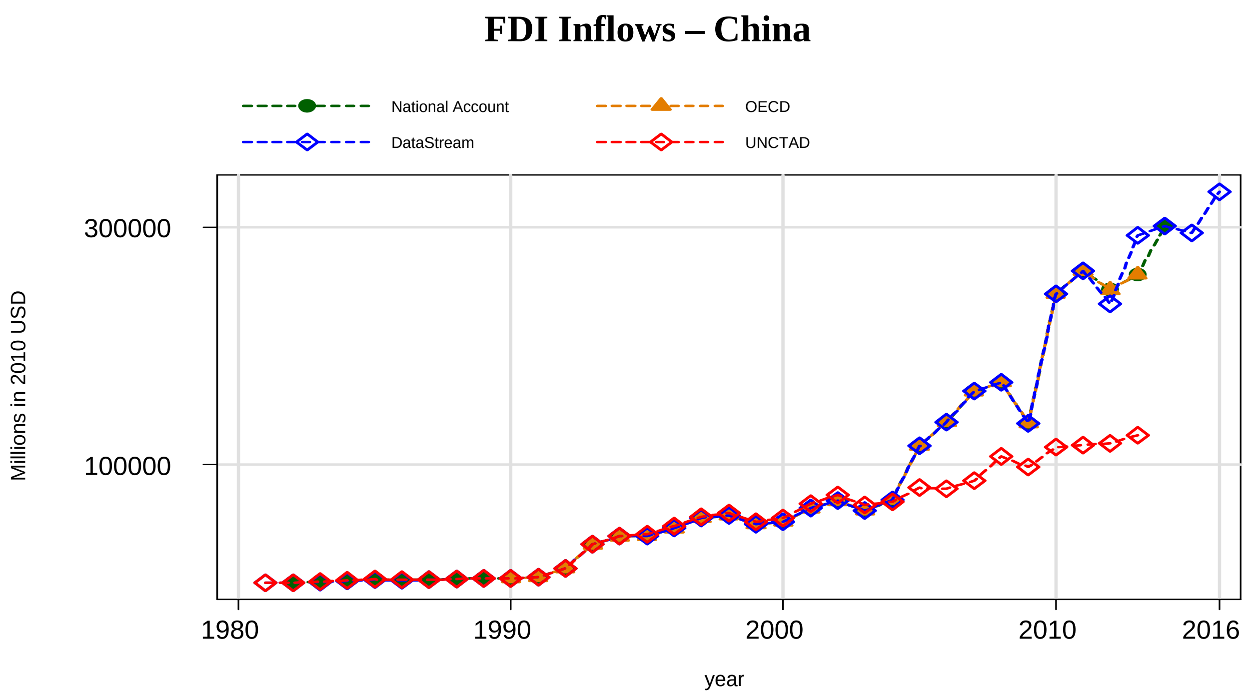

Figure A.1

The sources used in the paper are National-account data for the period 1982-2014 and Datastream data for years 2015-2016. National-account data and Datastream data overlap over the period 1982-2014 with a correlation coefficient of 99.79%.

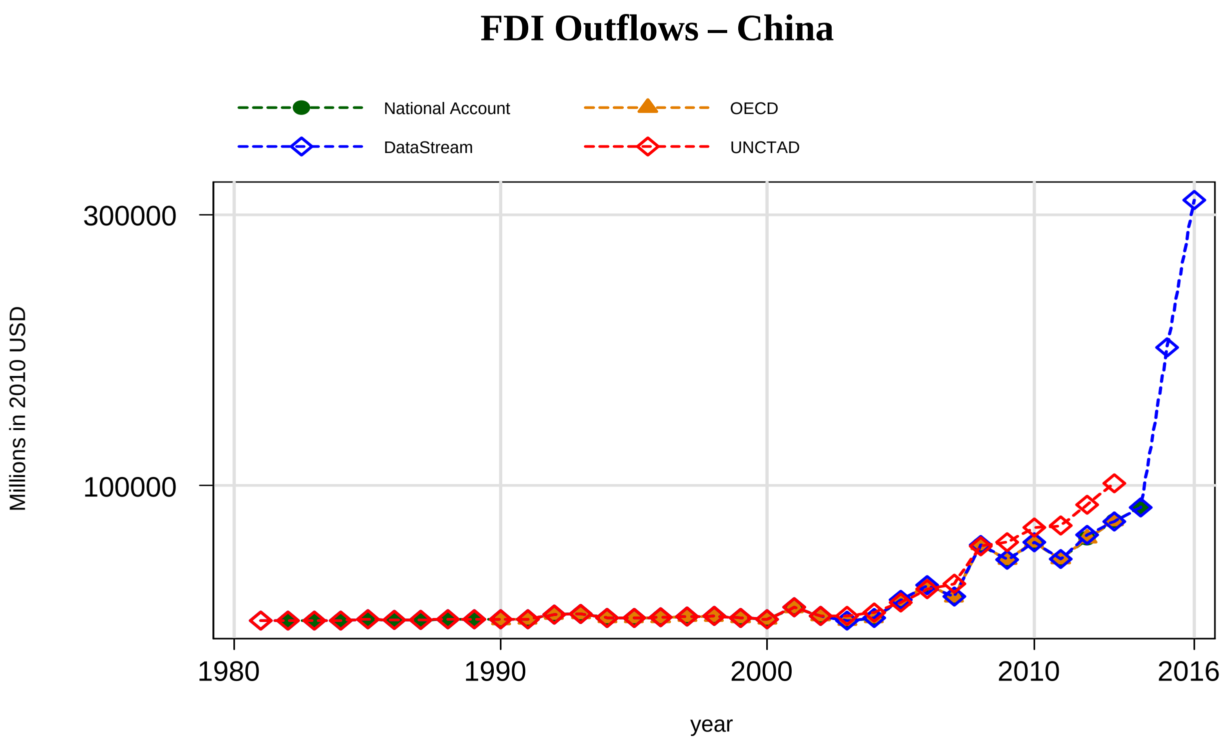

Figure A.2

The sources used in the paper are National-account data for the period 1982-2014 and Datastream data for years 2015-2016. National-account data and Datastream data overlap over the period 1982-2014 with a correlation coefficient 99.99%.

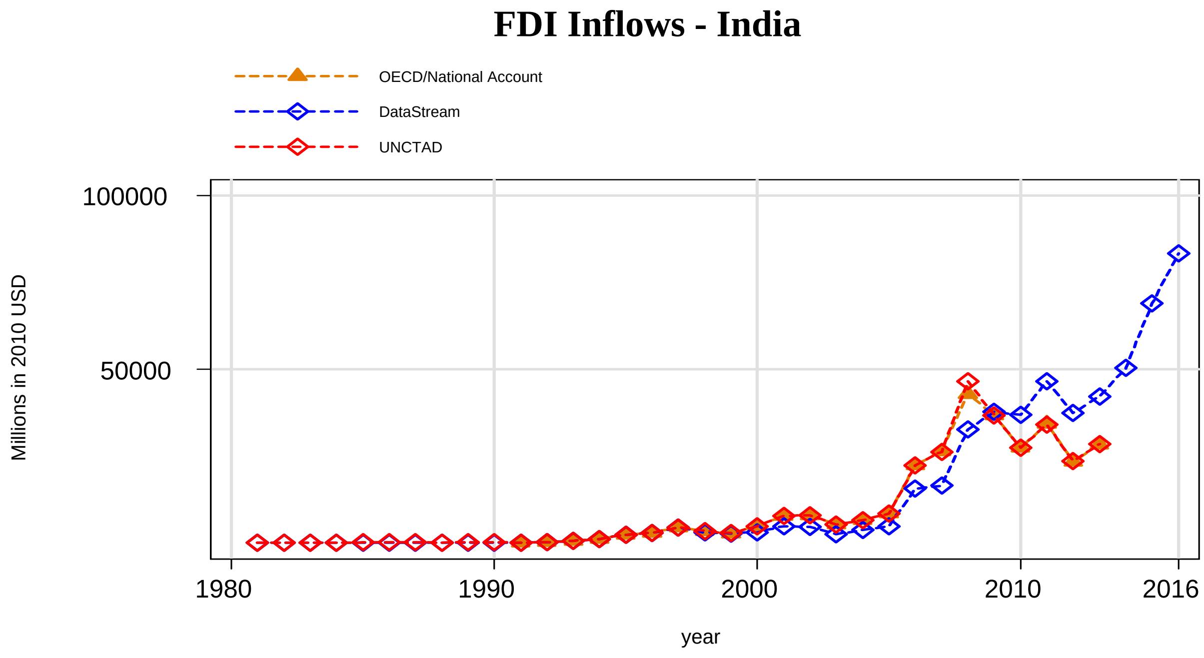

Figure A.3

The sources used in the paper are UNCTAD data for the period 1981-2013 and Datastream data for years 2014-2016. UNCTAD data and Datastream data overlap over the period 1981-2013 with a correlation coefficient of 92.56%. The reason we have chosen UNCTAD data for the period 1981-2013 is because, (a) for the period between 1981 and 1989 Datastream reports zero values (but not missing values), and (b) the two data sources overlap over the period 1991-2013 with a correlation coefficient of 99.87%.

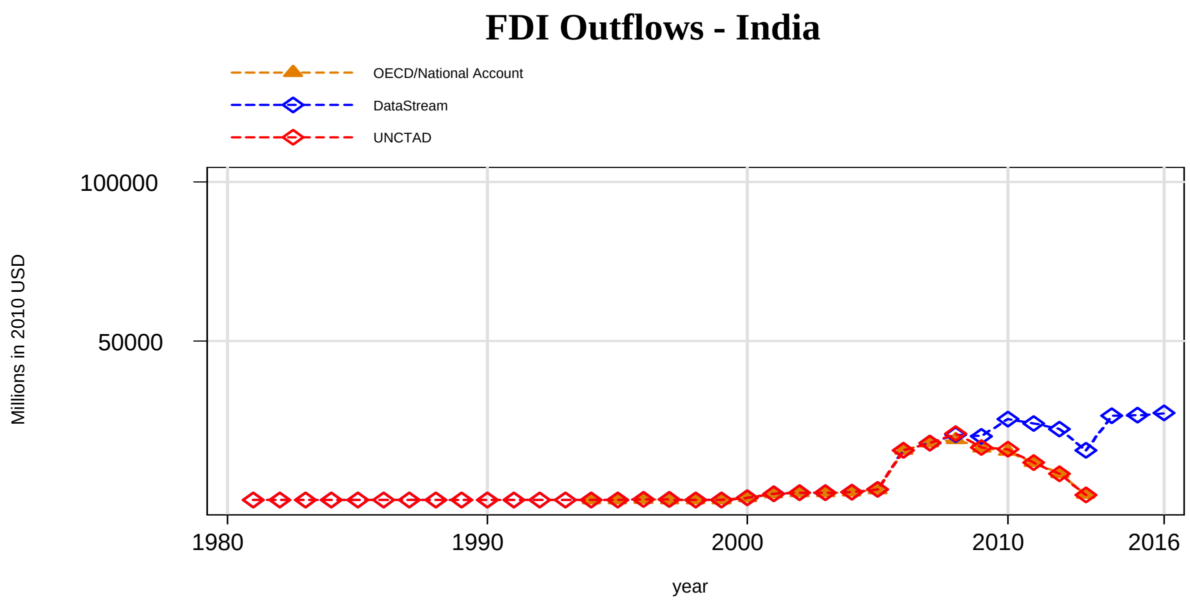

Figure A.4

The sources used in the paper are UNCTAD data for the period 1981-2013 and Datastream data for years 2014-2016. UNCTAD data and Datastream data overlap over the period 1981-2013 with a correlation coefficient of 89.32%. The reason we have chosen UNCTAD data for the period 1981-2013 is because, (a) for the period between 1981 and 1993 Datastream reports zero values (but not missing values), and (b) the two data sources overlap over the period 1994-2013 with a correlation coefficient of 99.86%.

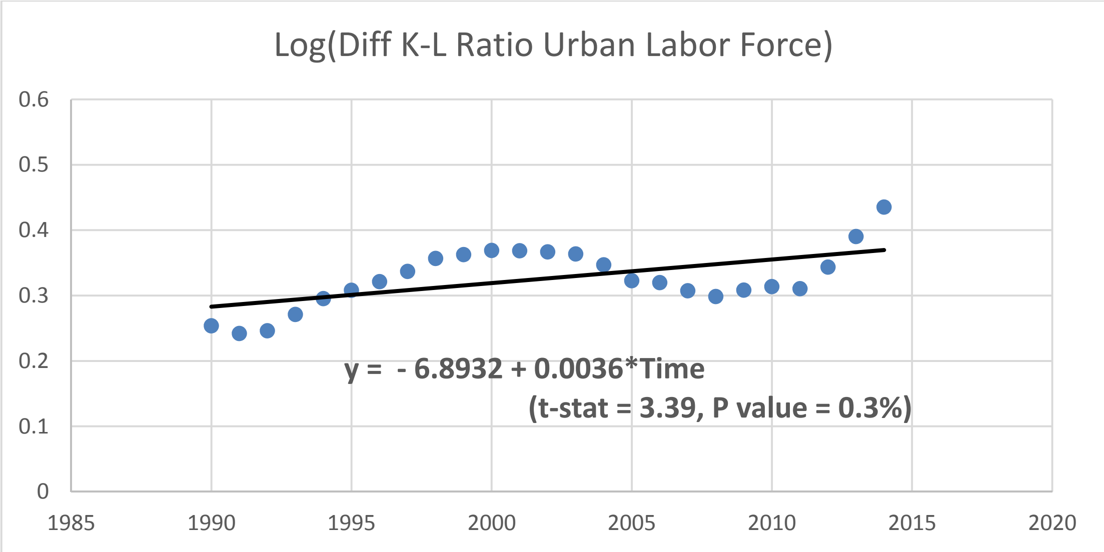

Figure A.5

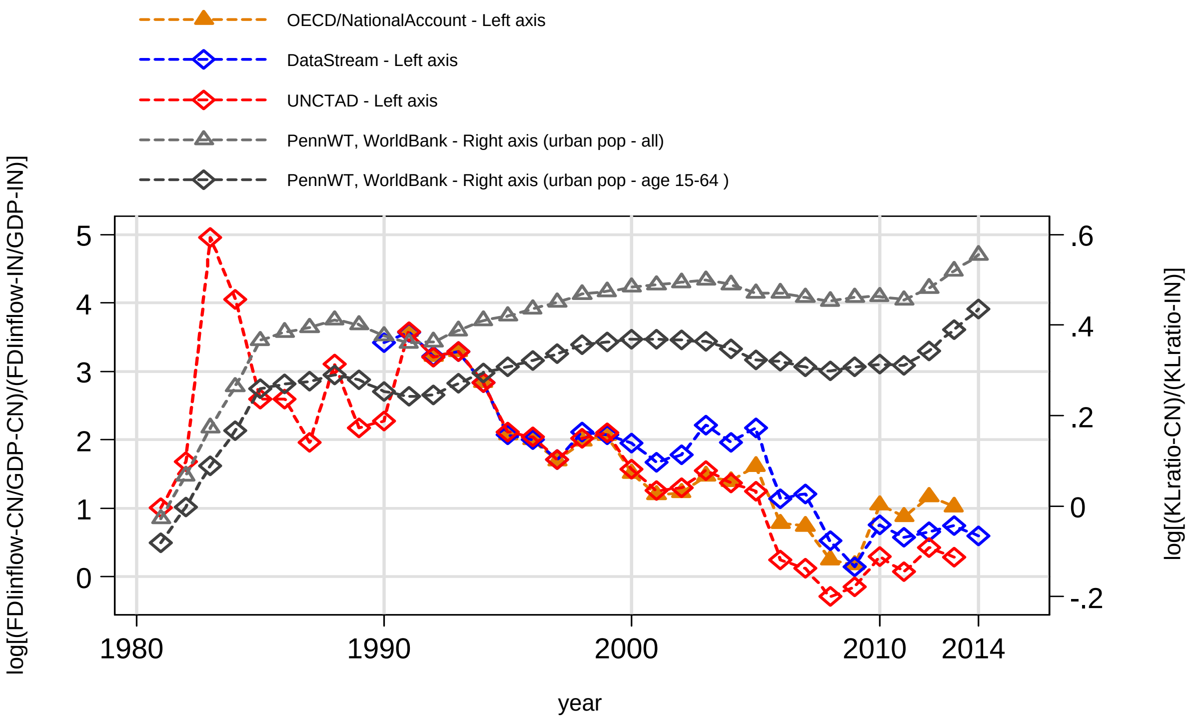

Figure A.6

To address the concern that large-scale internal migration in China would decrease the capital-labor ratio instead of increasing it, we use the urban population, restricted to ages 15-64 and perform a robustness check. Figure A.5 shows that the linear time trend coefficient (of the log K/L ratio of China over the K/L ratio of India) is positive and statistically significant (not equal to 0 with p-value at 0.3%). In Figure A.6 where we plot a similar data series as Figure 5 (in the paper) using this restricted sample, all the quantitative results remain.

The first two columns of Table A.1 provide the data appearing in Figure A.6 (without the logarithmic conversion of ratios). The last two columns of Table A.1 are the two new urban (working) population series appearing in Figure A.6.

year	Ratio_FDIY	Ratio_FullPop	Ratio_PopUrban	Ratio_PopUrbanWorking
1990	30.45	0.96	1.46	1.29
1991	35.73	0.99	1.43	1.27
1992	25.08	1.02	1.44	1.28
1993	26.94	1.07	1.47	1.31
1994	17.04	1.13	1.51	1.34
1995	7.96	1.17	1.52	1.36
1996	7.42	1.22	1.55	1.38
1997	5.54	1.27	1.57	1.40
1998	8.32	1.32	1.60	1.43
1999	7.95	1.36	1.61	1.44
2000	7.02	1.41	1.62	1.45
2001	5.33	1.50	1.63	1.45
2002	5.94	1.57	1.64	1.44
2003	9.19	1.66	1.65	1.44
2004	7.14	1.73	1.63	1.41
2005	8.79	1.72	1.60	1.38
2006	3.11	1.72	1.60	1.38
2007	3.36	1.71	1.59	1.36
2008	1.69	1.68	1.57	1.35
2009	1.16	1.70	1.59	1.36
2010	2.12	1.72	1.59	1.37
2011	1.77	1.72	1.58	1.36
2012	1.92	1.77	1.62	1.41
2013	2.11	1.87	1.68	1.48
2014	1.81	1.97	1.74	1.55

Table A.1