A North-South Model of Structural Change and Growth

María Aristizábal-Ramírez * John Leahy † Linda L. Tesar‡

July 2, 2021

Preliminary and incomplete

Abstract

Our paper is motivated by a set of cross-country observations on economic growth, structural transformation, and investment rates in a large sample of countries. We observe a hump-shaped relationship between a country's investment rate and its level of development, both within countries over time and across countries. Advanced economies reach their investment peak at a higher level of income and at an earlier point in time relative to emerging markets. We also observe the familiar patterns of structural change (a decline in the agricultural share and an increase in the services share, both relative to manufacturing). The pace of change observed in the 1960 to 1980 period in advanced economies is remarkably similar to that in emerging markets since 1995. Motivated by these facts, we develop a two-region model of the world economy that captures the dynamics of investment and structural change. The regions are isolated from each other up to the point of capital market liberalization in the early 1990s. At that point, capital flows from advanced economies to emerging markets and accelerates the process of structural change in emerging markets. Both regions gain from the liberalization of financial markets, but the majority of the gains accrue to the emerging economies. The overall magnitude of gains depends on the date of liberalization, the relative sizes of the two regions and the degree of asymmetry between the two regions at the point of liberalization. Finally, we consider the impact of a "second wave" of liberalization when China fully opens its economy to capital inflows.

Keywords:

*Department of Economics, University of Michigan

†Department of Economics and Ford School of Public Policy, University of Michigan and NBER

‡Department of Economics, University of Michigan, NBER, and CEPR

§We would like to thank seminar participants at The University of North Carolina at Chapel Hill, North Carolina State University and University College Dublin

1 Introduction

Our paper is motivated by a set of cross-country observations on economic growth, structural transformation, and investment rates in a large sample of countries. We observe a hump-shaped relationship between a country's investment rate and its level of development, both within countries over time and across countries. Investment rates peak at around 26 percent of GDP in advanced economies as well as emerging markets. A key difference, however, is that the peak investment rate in advanced economies occurs at a level of PPP-adjusted per capita income that is roughly three times larger than the corresponding per capita income at the peak investment rate in emerging markets. Thus, advanced economies reach their investment peak at a higher level of income and at an earlier point in time relative to emerging markets. We also observe the familiar patterns of structural change (a decline in the agricultural share and an increase in the services share, both relative to manufacturing). Like the peak in investment, structural change occurs earlier in time and at a higher level of income in emerging economies. The pace of change observed in the 1960 to 1980 period in advanced economies is remarkably similar to that in emerging markets since 1995.

We develop a two-region model of the world economy that captures the dynamics of investment and structural change. The regions are isolated from each other up to the point of capital market liberalization in the early 1990s. At that point, capital flows from advanced economies to emerging markets and accelerates the process of structural change in emerging markets. The model can explain the pattern and relative timing of investment and structural change in the two regions. Both regions gain from the liberalization of financial markets, but the majority of the gains accrue to the emerging economies. The overall magnitude of gains depends on the date of liberalization, the relative sizes of the two regions and the degree of asymmetry between the two regions at the point of liberalization.

We use the model to investigate two counterfactuals. First, we study the welfare effects of varying the date of capital market liberalization. We find that the emerging economies gain most regardless of the date of liberalization, and that, while both countries generally prefer earlier liberalization, developing nations gain most from early liberalization. The second experiment is to consider the effect of China fully integrating into global capital markets. Here we find that the advanced economies gain much more than do the emerging economies. The reason is that the opening of China increases investment opportunities and raises the world interest rate. This benefits advanced economies since they are net creditors and huts emerging economies since they are net debtors.

Related literature

A key contribution of our study is to develop a quantitative model that is consistent with the dynamics of saving, capital accumulation, and sectoral shares within countries, as well as with the global allocation of investment in emerging and advanced economics. Our model builds off the work of Echevarria (1997), one of the earliest quantitative models of structural transformation in a closed economy. Her model combines the two mechanisms that have proved important in the subsequent literature. The first mechanism works on the demand side by assuming that preferences are non-homothetic. Non-homothetic preferences help explain patterns of expenditure as income rises, in particular the shift in spending from agricultural goods to manufacturing and services. Such preferences take many forms. Kongsamut et al. (2001) and Moro (2015) use Stone-Geary preferences, Foellmi and Zweimüller (2008) use hierarchical preferences, and Comin et al. (2015) use generalized CES preferences. Boppart (2014) uses the class of price independent generalized linearity preferences. We follow Echevarria (1997) and use preferences that converge to a constant growth path.

The second mechanism works on the supply side. Echeverria allows for differences across sectors in the rate of technological progress and factor intensity in production. Both of these mechanisms can lead to trends in relative prices that can, in turn, shift demand across sectors. Both supply-side and demand-side mechanisms can generate hump-shaped dynamics in the share of manufacturing production in output. Ngai and Pissarides (2007) emphasize differences across sectors in TFP growth, while Acemoglu and Guerrieri (2008) explore differences in factor utilization. Alvarez-Cuadrado et al. (2017) consider differences in substitutability between capital and labor. Herrendorf et al. (2015) fit a model with all three supply-side mechanisms to US data. We follow Echevarria and include both differences in TFP growth and differences in factor intensity.

The literature on structural change and economic growth is large (see Herrendorf et al. (2015) for a review) and much of the work on growth has tended to treat each country as a closed economy or, if open, where trade is assumed to be balanced. Our contribution is to study growth and structural change in an environment with integrated financial markets. Seminal work in this area includes Ventura (1997) and Matsuyama (2009), who construct theoretical models that illustrate how structural transformation in open economies may differ from structural transformation in closed economies. Much of the recent work has focused on explaining the sustained growth of East Asian economies, in particular Korea (Uy et al., 2013; Cai et al., 2015) Many of these papers assume balanced trade and abstract from capital accumulation (Uy et al., 2013; Świkecki, 2017; Sposi, 2019).

Recently, Kehoe et al. (2018) develop a global model of structural change with non-homothetic preferences, and multiple sectors to explain the decline of the US employment decline in manufacturing.

Capital flows are the main mechanism linking regions in our model. Opening financial markets allows capital to seek higher returns thereby promoting growth and accelerating the process of structural change. Technological progress is exogenous in our model. One can also imagine growth and structural change being driven by technology transfer. Fujiwara and Matsuyama (2020) explore such a model. In their model, there is no trade. Growth and structural changes arise as emerging economies adopt technologies developed by advanced economies.

The facts that motivate our study have predecessors elsewhere. The pattern of structural change is well known. The hump-shaped pattern in the investment rate has been noted by Echevarria (1997), Acemoglu and Guerrieri (2008), and Garcia-Santana et al. (2016). Rodrik (2016) and Fujiwara and Matsuyama (2020) argue that many emerging economies industrialize and de-industrialize at lower levels of GDP per capita than did advanced economies. What is new is our attempt to deal with all of these observations in a single setting and to explain the role of capital market integration on long-run growth paths.

2 Four Facts describing Investment, Economic Growth and Structural Change

In this section we establish four key facts describing the process of economic growth and structural transformation in a large sample of countries over the 1950 to 2017 period. We will return to these four facts in Section 6 to evaluate how well our model performs in explaining growth and sectoral change over time and across countries.

Our sample includes 34 countries. Together, these countries account for 82 percent of world GDP and 95 percent of world investment in 1960. We draw information from the Penn World Table 9.1, the World Development indicators, and the Federal Reserve Bank of St. Louis (FRED).

While we have data on a number of countries, our model has only two regions. This raises the question how to assign countries to regions and how we aggregate economic activity within regions. Our general rule is to assign richer countries to Block A and poorer countries to Block B where rich and poor are defined by per capita income at the beginning of our sample in 1950. The exception to this rule is Japan, which was relatively poor following WWII, but grew very quickly thereafter. As Japan looks more like a rich country for most of the sample, we include it in Block A. Where appropriate we discuss the sensitivity of our results to the assignment of countries to the two Blocks. The main place that this matters is in the welfare results of Section 7. Much of the welfare gains to integration appear to accrue to Ireland, Greece, Portugal and Spain, so that assigning these countries to Block A has the effect of eliminating the welfare gains to Block B.

Block A includes a set of advanced economies: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States. These economies are often referred to as the "North" in North-South models of economic growth and development. Block B (the "South") includes the following emerging markets: Argentina, Brazil, Chile, Greece, India, Indonesia, Ireland, Malaysia, Mexico, Poland, Portugal, South Korea, Spain, Taiwan, Thailand, and Turkey. China is the most important country missing from this list. China plays a small role in the global economy at the beginning of the sample, but a larger role recently. In section 8, we consider adding China to the model.

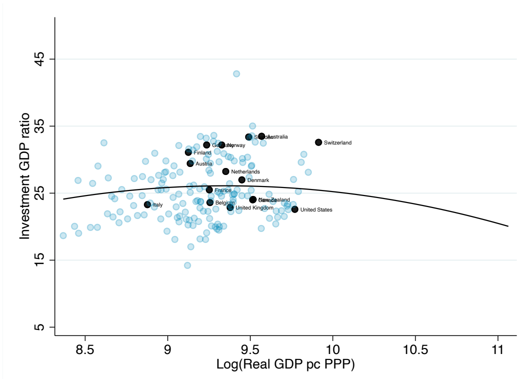
Where possible we define region level variables as the sums or averages of country level variables. Missing observations occasionally create complications. Details regarding the aggregation of country level observations to the block level are contained in Appendix A.

The first feature of the data we wish to highlight is the hump-shaped pattern in investment rates, both within countries over time and across countries. Figures 1a throught 1d illustrate the evolution of the investment rate in Block A as real per capita income (PPP adjusted) rises over time. Each dot corresponds to an investment rate for a single country i in year t. Figure 1a shows investment rates for the early part of our sample (the decade 1950 to 1960), with the last observation of the decade as the darker dot, identified with a country label. This decade captures an increase in investment rates along with the increase in real per capita income. Figures 1b, 1c, and 1d extend the sample through 1980, 2000 and 2017 respectively. The dots are darker with each decade over time, and the darkest dots depict the last observation. The investment rates trace out a parabola that peaks in 1968 at a real per capita income of $16,000 (in PPP adjusted terms). This nonlinear relationship between investment rates and income rising at low levels of income and then declining at higher levels of income has been noted in other studies (see, for example, Echevarria (1997), Acemoglu and Guerrieri (2008), and Garcia-Santana et al. (2016)).

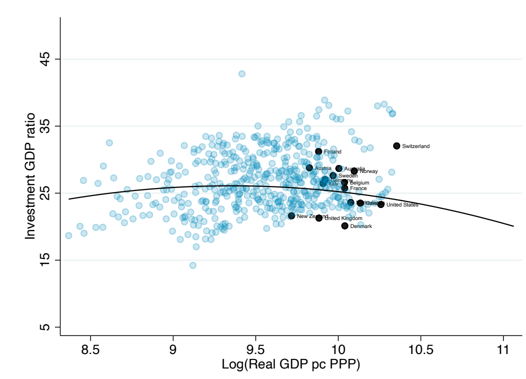
The hump-shaped pattern in investment rates observed for Block A is also observed in Block B. Figure 2 plots the investment rate for each region against per capita (PPP adjusted) income. Each dot is the investment rate in a given year for each block. Block A is depicted in blue (the solid line) and Block B in red (the dotted line). Each region has a hump-shaped pattern in investment. An important difference, however, and the second fact we wish to emphasize, is that the peak occurs at a higher level of per capita income in Block A than in Block B. The curves have the same shape and peak at the same investment rate, but

Figure 1: Evolution of the investment rate in Block A

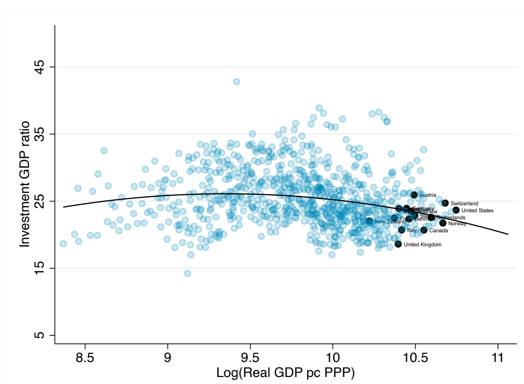
(a) 1950-1960



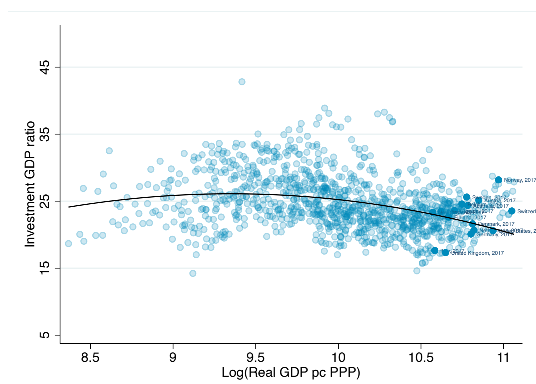
(b) 1950-1980



(c) 1950-2000



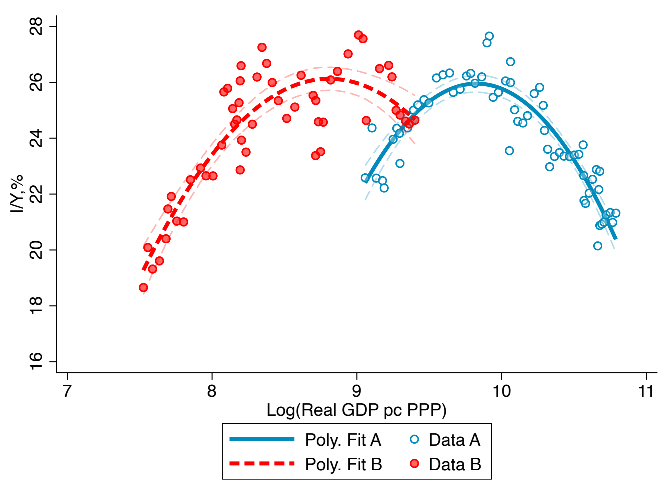
(d) All sample



Note: Each dot corresponds to a country in Block A in year t. Data Source: PWT9.1. The solid Lines corresponds to the fitted value of: $\frac{I_{iAt}}{Y_{iAt}} = \beta_0 + \beta_1 \log(GDP_{iAt}) + \beta_2 \log(GD_{iAt})^2 + \epsilon_{iAt}$

Block B's curve is shifted to the left of Block A along the x-axis corresponding to a lower level of real per capita income. This is suggestive that the two groups of countries follow a similar investment trajectory as they grow, but they start different points in time and with a different initial level of capital.

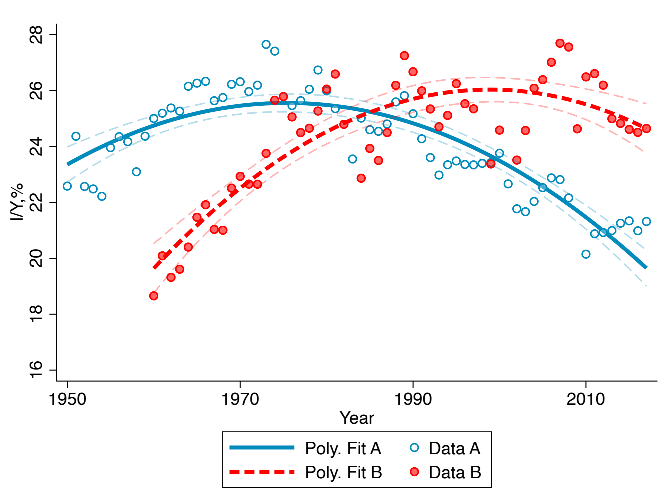
Figure 2: Investment rate for each region against per capita (PPP adjusted) income



Note: Each dot corresponds to an observation in Block j in year t. We compute the investment ratio as total investment over total GDP in all countries in Block j, and GDP per capital as total GDP over total population in Block j. We use data from 1950-2017 for Block A and from 1960-2017 fro Block B. We exclude years of sudden-stop recessions using the methodology in Calvo et al. (2006) (1975, 1982 and 2009 for Block A, and 1983, 1998, and 2001 for Block B). Data Source: PWT9.1. Dotted lines correspond 95% robust confidence intervals: $I_{jt}/Yjt = \beta_0 + \beta_1 \log(GDP_{jt}) + \beta_2 \log(GD_{jt})^2 + \epsilon_{jt}$

Figure 3 plots the same investment rates, but now against time. The investment rate peaks in the late 1960s in Block A (the solid line), while in Block B (the dotted line) it peaks after 2000. The lines are the results of estimating investment rates as a quadratic function of time, with the dotted lines indicating 95 percent confidence intervals. The observed investment rates seem to migrate away from the fitted parabola toward the end of the sample, particularly for Block B. We will argue below that the shift in investment rates in Block B in the last part of the sample is consistent with capital inflows that occurred with financial liberalization. Table 1 provides summary statistics on investment and income in the two regions. The first three columns of Table 1 confirm that the investment rate peaks at around 26 percent in each region, though Block A reaches the peak at a higher level of per capita income and much earlier in time. The last three columns show the estimated coefficients from fitting a parabola to the investment rate in each region. Given the standard errors, one cannot reject the hypothesis that the linear and quadratic terms are the same and that only the constant, related to the timing, of the investment path differs between the two regions.

Figure 3: Investment rate for each region against time



Note: Each dot corresponds to an observation in Block j in year t. We compute the investment ratio as total investment over total GDP in all countries in Block j, and GDP per capital as total GDP over total population in Block j. We use data from 1950-2017 for Block A and from 1960-2017 fro Block B. Data Source: PWT9.1. Doted Lines correspond 95% robust confidence intervals: $\frac{I_t}{Y_t} = \beta_0 + \beta_1 Year + \beta_2 Year^2 + \epsilon_t$

Table 1: Summary Statistics: Fitted parabola for each region

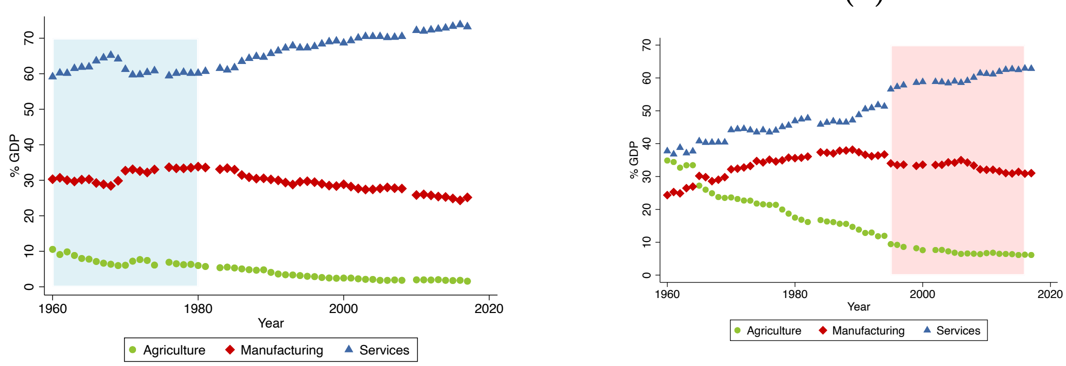
	$\max \hat{I/Y}\%$	*Real GDP*	$Year$	β_0	β_1	β_2
Block A	25.9	16535	1968	-415.9	91.0	-4.7
	(0.2)			(76.2)	(15.0)	(0.7)
Block B	25.9	6760	2004	-270.6	67.2	-3.8
	(0.3)			(40.00)	(9.5)	(0.6)

Note: SUR standard errors in parenthesis. Data Source: PWT9.1. $^{\circ}$ Real GDP *per capita* in PPP Expenditure side (2011 US dollars). Columns 4-6 correspond to the estimated coefficients of the $I_{jt}/Yjt = \beta_0 + \beta_1 \log(GDP_{jt}) + \beta_2 \log(GD_{jt})^2 + \epsilon_{jt}$

The third feature of the data that we highlight is the change in sectoral shares with economic development. Figure 4 plots the shares of agriculture, manufacturing and services in GDP for Blocks A and B over the 1960 to 2017 period. The figure captures the familiar increase in the service sector as a share of GDP over time and the decline in agriculture. In Block A the manufacturing share rises until until 1980 and declines thereafter. In Block B the manufacturing share rises and then declines slightly. It is instructive to compare Block A at an earlier stage of structural transformation (the shaded area in the figure to the left for the interval 1960 to 1980) with Block B in the years 1995 to 2017 (the shaded area in the figure to the right). To make the comparison easier, Figure 5a plots the sectoral shares on the same developmental time scale with time 0 at 1960 for Block A and time 0 at 1995 for Block B. The sectoral shares are almost identical, suggestive that the two regions are on a similar growth path, with Block B starting about three decades later than Block A. Figure 5b shows the fitted investment rate for each region over the same time intervals - the 1960 to 1980 period for Block A and 1995 to 2017 for Block B. The two curves are almost identical, with investment peaking just a bit higher in B than in A.

Figure 4: Shares of agriculture, manufacturing and services in GDP

(a) Block A **(b)** Block B

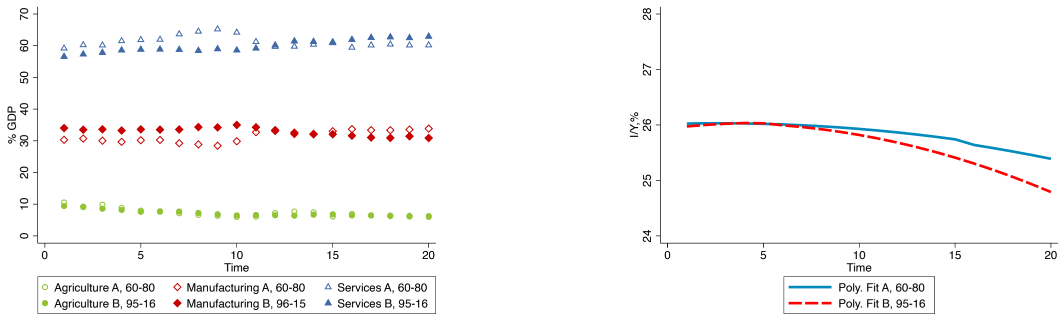


Note: Data Source WDI. Agriculture includes ISIC 1-5, Manufacturing includes ISIC 10-45, and Services includes ISIC 50-99, Excluding mining and wholesale trade. We normalize the data such that the shares add to one. For years 1960-1970 we impute the services share in Block A using the other two sectors.

Finally, a fourth feature of the data is the surge in private capital flows from Block A to Block B in the mid- to late-1990s. Figure 6 plots FDI inflows as a share of GDP (dark line, right axis) and the volume of direct and portfolio investment flows into Asia, Emerging Europe and Latin America (bars, left axis). As a consequence of the general liberalization of financial markets and the reduction in barriers to capital flow, Block B economies experienced a large increase in private foreign investment. In Section 6, we will show that this investment shifted the growth path of Block B economies, initially increasing the investment rate but

Figure 5: Comparing blocks: Block A 1960-1980, and Block B 1995-2017

(a) Sectoral Shares **(b)** Investment Ratio

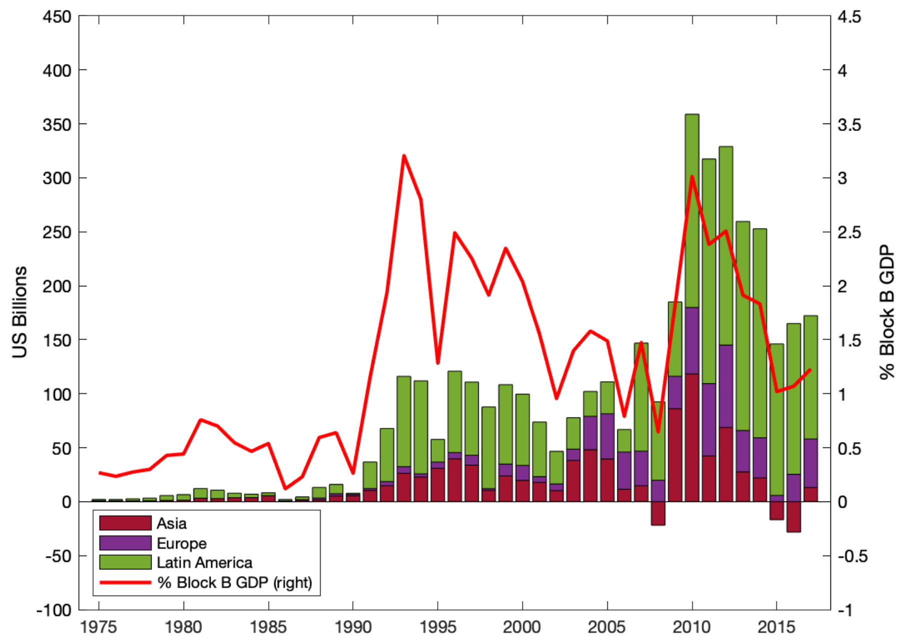


Note: Data Source WDI. Agriculture includes ISIC 1-5, Manufacturing includes ISIC 10-45, and Services includes ISIC 50-99, Excluding mining and wholesale trade. Data for Block A corresponds to years 1960-1980, and data for Block B corresponds to years 1995-2017

requiring a higher level of manufacturing output in the long run to service its external debt.

To summarize, the four facts we want to explain are (i) investment rates exhibit a hump-shaped pattern, over time and with real income, (ii) investment peaks at a later date and at a lower level of real per capita income in Block B relative to Block A, (iii) both blocks experience structural transformation with a decline in the agricultural share roughly offset by an increases in the services share, and this transformation occurs later in Block B relative to Block A, and (iv) Block B experiences a surge of private investment from Block A prior to its investment peak.

Figure 6: FDI inflows over GDP and flows of direct and portfolio investment into Block B



Note: Data Source WDI. Direct + Portfolio investment inflow is defined as net incurrence of direct investment and portfolio investment liabilities. Asia: India, Indonesia, South Korea, Malaysia, Taiwan, and Thailand. Europe: Greece, Ireland, Poland, Spain, Portugal and Turkey. Latin America and the Caribbean: Argentina, Brazil, Chile, Mexico.

3 Model

We construct a model of growth and structural transformation that is consistent with the data both within and across countries, and captures the shifts in investment that occur with capital market integration. The global economy is comprised of two regional economies, corresponding to the two Blocks in the previous section. Each regional economy has three sectors: agriculture, manufacturing, and services. Agents in each region choose consumption of the three goods, the allocation of capital and labor across the three sectors, and total capital investment to maximize the present value of utility. Structural transformation is generated in two ways: total factor productivity in each sector grows at a different rate and preferences are non-homothetic. In the latter we follow Echevarria (1997) and add additional terms to an otherwise homothetic utility function. We parameterize these terms so that the model convergences to a balanced growth path in the long run.

The two regions differ in four ways. To capture the fact that structural transformation and the peak of the investment hump in Block A occur earlier in time, we assume that Region A is further along in the development process in the sense that its productivity is higher and its preferences are closer to the long-run balanced growth path. Second, each region has a different initial capital stock. This allows us to match the data at the beginning of our sample in 1960. Third, labor is less productive in Block B. This will help the model match the fact that structural transformation and the peak of the investment hump in Block B occur at a lower level of per capita GDP. Finally, the two regions differ in their size. Relative size will affect the way in which the impact of financial liberalization is distributed across the two Blocks. In all other aspects the two regions are identical.

We allow for interactions between the two regions. We assume the manufactured good is traded but agriculture and services are produced and consumed locally. This is consistent with the fact that most trade between Block A and Block B is in manufactured goods.[1] Because there is a single manufactured good in the model, all trade is intertemporal trade. In the beginning of the sample, capital markets are closed so, in effect, each region functions as a closed economy. When capital markets in Block B liberalize, capital flows from Block A to Block B. The model incorporates adjustment costs in the accumulation of capital and in the accumulation of debt in order to slow the flow of capital between A and B.

We now present the model in detail.

[1] Appendix B shows that 70% of trade between blocks A and B during 2000-2014 occurs in the manufacturing sector. Block A exports 1.8 % of GDP to Block B, and imports 1.4% in manufacturing, while Block B exports 5.8% of GDP to Block A and imports 7.4% in manufacturing.

3.1 The regional economies

Time is discrete and indexed by $t = \{0, 1, 2, \dots\}$. There are two regions labeled $i = \{A, B\}$ There are three sectors by $j \in \{a, m, s\}$ where a is agriculture, m is manufacturing and s is services. Each good is produced with capital and labor. Capital is produced by the manufacturing sector. The production functions are:

$$\begin{aligned} Y^i_{at} &= A\mu^{t-\bar{t}_i}(K^i_{at})^{\theta}(E^i L^i_{at})^{1-\theta} \\ Y^i_{mt} &= B\lambda^{(t-\bar{t}_i)(1-\gamma)}(K^i_{mt})^{\gamma}(E^i L^i_{mt})^{1-\gamma} \\ Y^i_{st} &= C\nu^{t-\bar{t}_i}(K^i_{st})^{\phi}(E^i L^i_{st})^{1-\phi} \end{aligned}$$

There are several things to note about these functions. First, they incorporate two of the main supply side mechanisms for structural transformation. Productivity growth is sector specific as in Ngai and Pissarides (2007), and factor intensity is sector specific and in Acemoglu and Guerrieri (2008). While these parameters differ across sectors, we assume that they are the same across the two regions. Second, the level of productivity may differ across regions. This is captured by the exponent $t - \bar{t}_i$. One can think of $\bar{t}_i$ as the date at which the region began the development process. A lower $\bar{t}_i$ means that that the region has been growing for longer. Third, labor productivity may differ across regions. This is the role played by E^i.

Given the total supply of capital and labor in the economy, firms in each sector employ capital and labor to maximize profit. As there are no state variables in the firm's problem, profit maximization is static. Let P^i_{jt} denote the price of good j in region i at date t. We will take the manufacturing good to be the numeraire, $P^i_{mt} = 1$. Let W^i_t and R^i_t denote the real wage and the real rental price of capital respectively. The firm's problem for agriculture becomes

$$\max_{K^i_{at}, L^i_{at}} P^i_{at} Y^i_{at} - W^i_t L^i_{at} - R^i_t K^i_{at}.$$

The problems for manufacturing and services take similar forms.

There is a representative consumer that receives utility from the consumption of three goods. The consumer maximizes the present discounted value of utility $\sum_t \beta^t U^i_t$ where β is the discount factor and the period utility U^i_t is:

$$U^i_t = \sum_{j \in \{a,m,s\}} \alpha_j \ln(C^i_{jt}) - \eta \left(\frac{g_j}{C^i_{jt}} \right)^{\rho_j (t - \bar{t}_i)}$$

The second term generates the non-homotheticity in consumption, one of the drivers of sectoral change in the model. The parameters g_i are chosen so that the economy has a balanced growth path: $g_a = \lambda^\theta \mu$, $g_c = \lambda$, and $g_m = \lambda^\phi \nu$.[2] Tying utility to sectoral production growth is non-standard.[3] In reality both utility and sectoral production are likely to be both a function of time and income. This formulation captures this dependence while maintaining the nice steady state properties of a model with a balanced growth path. The cost of this formulation is that it is difficult to interpret comparative statics with regard to the growth rate of sectoral prodution. Fortunately such comparative statics are not the focus of our study.

The consumer owns the capital stock. The consumer's budget constraint is

$$\sum_{j\in\{a,m,s\}} P^i_{jt}C^i_{jt} + K^i_{t+1} + \frac{D^i_{t+1}}{1+r_t} = W^i_t L^i_t - R^i_t K^i_t + (1-\delta)K^i_t - G(K^i_{t+1}, K^i_t) - D^i_t - H(D^i_{t+1}, D^i_t)$$

There are several things to note about this budget constraint. Investment is equal to $K^i_{t+1} - (1-\delta)K^i_t$ and has a price equal to one since it is in terms of the manufactured good. The function $G(K^i_{t+1}, K^i_t)$ is the capital adjustment cost. D is foreign debt and takes the form of a one period pure discount bond. r_t is the world interest rate (also in terms of the manufactured good). Note the interest rate r_t is related to the rental rate R_t by:

$$r_t = (1 + G_1)(R_t - \delta) - G_2(1 + H_1) - H_2(1 + G_1) + H_1 - G_1$$

. H is the portfolio adjustment cost. Initially D_t is zero when there is no trade. In later periods D_t is a choice variable.

The adjustment costs take the following forms :

$$\begin{aligned} G(K^i_{t+1}, K^i_t) &= \frac{\psi}{2}\frac{\left(K^i_{t+1} - K^i_t\right)^2}{K^i_t} \\ H(D^i_{t+1}, D^i_t) &= \frac{\psi_2}{2}\frac{\left(D^i_{t+1} - D^i_t\right)^2}{K^i_t} \end{aligned}$$

The market clearing conditions are the usual ones. Since agriculture and services are non-traded,

$$C^i_{jt} = Y^i_{jt} \qquad j \in \{a, s\} \text{ and } i \in \{A, B\}$$

[2]The utility function used by Echevarria (1997) is a special case of our utility function with the $g_j = 1$. The advantage of our specification is that the model has a well defined steady state, which makes it easier to solve for the transition dynamics.

[3]Kongsamut et al. (2001) also tie parameters of preferences and technology to generate a generalized balanced growth path in which aggregate variables grow at constant rates whereas sectoral shares shift over time.

Market clearing for manufactured goods takes the form

$$C^i_{mt} + K^i_{t+1} - (1-\delta)K^i_t + G(K^i_{t+1}, K^i_t) + H(D^i_{t+1}, D^i_t) = Y^i_{mt} \qquad i \in \{A, B\}$$

when there is no trade, and

$$\sum_{i \in \{A,B\}} C^i_{mt} + K^i_{t+1} - (1-\delta)K^i_t + G(K^i_{t+1}, K^i_t) + H(D^i_{t+1}, D^i_t) = \sum_i Y^i_{mt}$$

when trade is allowed. Note here that we assume that the adjustment costs are paid in terms of the manufactured good. The debt market clears

$$D^A_t + D^B_t = 0$$

Factor markets clear

$$\begin{aligned} \sum_{j \in \{a,m,s\}} K^i_{jt} &= K^i_t \qquad i \in \{A, B\} \\ \sum_{j \in \{a,m,s\}} L^i_{jt} &= 1 \qquad i \in \{A, B\} \end{aligned}$$

An equilibrium is a sequence of prices $\{r_t, P^A_{at}, P^A_{mt}, P^B_{at}, P^B_{mt}, W^A_t, R^A_t, W^B_t, R^B_t\}$, consumptions $\{C^A_{at}, C^A_{mt}, C^A_{st}, C^B_{at}, C^B_{mt}, C^B_{st}\}$, capital allocations $\{K^A_{at}, K^A_{mt}, K^A_{st}, K^B_{at}, K^B_{mt}, K^B_{st}\}$, and labor allocations $\{L^A_{at}, L^A_{mt}, L^A_{st}, L^B_{at}, L^B_{mt}, L^B_{st}\}$ such that firms and consumers maximize and markets clear.

3.2 Solution

The model as written is non-stationary, with growing output and unstable consumption shares. The model can be transformed into a stationary model through the appropriate transformation. Specifically, define

$$
\begin{aligned}
k_t^i &= \frac{K_t^i}{\lambda^t} \\
k_{jt}^i &= \frac{K_{jt}^i}{\lambda^t} \\
i_t^i &= \frac{I_t}{\lambda^t} = \lambda k_{t+1}^i - (1-\delta) k_t^i \\
d_t^i &= \frac{D_t^i}{\lambda^t} \\
c_{at}^i &= \frac{C_{at}^i}{\lambda^{\theta t}\mu^t} \\
c_{mt}^i &= \frac{C_{mt}^i}{\lambda^t} \\
c_{st}^i &= \frac{C_{st}^i}{\lambda^{\phi t}\nu^t} \\
w_t^i &= \frac{W_t^i}{\lambda^t} \\
p_{at}^i &= \lambda^{(\theta-1)t}\mu^t P_{at}^i \\
p_{st}^i &= \lambda^{(\phi-1)t}\nu^t P_{st}^i
\end{aligned}
$$

With this normalization the period utility functions become

$$U_t = \sum_{j\in\{a,m,s\}} \alpha_j \ln(c_{jt}) - \eta \left(\frac{1}{c_{jt}}\right)^{\rho_j}$$

where we have omitted terms that are independent of optimization. The budget constraint becomes

$$p_{at}^i c_{at}^i + c_{mt}^i + p_{st}^i c_{st}^i + k_{t+1}^i + \frac{\lambda d_{t+1}^i}{1+r_t} = w_t^i L_t^i - R_t^i k_t^i + (1-\delta)k_t^i - G(\lambda k_{t+1}^i, k_t^i) - d_t^i - H(\lambda d_{t+1}^i, d_t^i)$$

The production functions and market clearing conditions also become stationary.[4]

We solve for the steady state in the transformed economy, and for the transition dynamics to that steady state. One complication is to find the equilibrium debt dynamics, we guess an interest rate path, solve the model and then adjust the interest rate path until we find the equilibrium.

Note that the consumption shares of the transformed economy are the same as the consumption shares of the original economy. For example, the consumption share of agricultural

[4]Note $\frac{G(K_{t+1}^i, K_t^i)}{\lambda^t} = G(\lambda k_{t+1}^i, k_t^i)$. Similarly for H.

goods is

$$\frac{\bar{p}^i_{at}c^i_{at}}{p^i_{at}c^i_{at}+c^i_{mt}+p^i_{st}c^i_{st}} = \frac{\lambda^{(\theta-1)t}\mu^t P^i_{at}\frac{C^i_{at}}{\lambda^{\theta t}\mu^t}}{\lambda^{(\theta-1)t}\mu^t P^i_{jt}\frac{C^i_{at}}{\lambda^{\theta t}\mu^t}+\frac{C^i_{mt}}{\lambda^t}+\lambda^{(\phi-1)t}\nu^t P^i_{st}\frac{C^i_{st}}{\lambda^{\phi t}\nu^t}} = \frac{P^i_{at}C^i_{at}}{P^i_{at}C^i_{at}+C^i_{mt}+P^i_{st}C^i_{st}}$$

This implies that the when the transformed economy is in steady state the consumption share in the original economy are constant.

4 Computation

Our solution method consists in first solving the stationary version of the model and then recovering the results for the growing economy. In this sense, our solution is similar to Echevarria (1997). However, since we have an open economy, we require a shooting algorithm to find the long-run level of debt such that all of the restrictions in our model – including the transversality condition – are satisfied.

The algorithm proceeds as follows. We make a guess for the steady state trade balance of Block A, tb_{Ass} and solve the perfect foresight model using this guess and initial conditions k_{A0} , k_{B0}, d_0. Using this solution we verify if the transversality condition is satisfied. If the debt position condition is satisfied, our guess satisfies all the constraints and we have found a solution. If not, then we adjust our guess of the steady state trade balance appropriately. For example, if Block A has too much savings. We therefore increase our guess for final debt position of Block A (Increase d_{ss}).

5 Calibration

We calibrate the economy using data for Block A.[5] We assume that the group of advanced economies was in steady state in 2017. The only differences between both blocks are the efficiency of the labor force, the initial capital stock, and the stage of the development process. Our calibration strategy follows three steps, first we calibrate capital shares (θ, γ, φ), sectoral growth rates(μ, λ, μ), and depreciation (δ) to match the long run characteristics of Block A. Second, we calibrate preferences (α_j, η_j, ρ_j), adjustment costs (Ψ_1, Ψ_2), and the initial efficiency parameters (A,B,C) to match the initial and final points of the sectoral shares in Block A, and Investment to GDP to this same block. Third, we calibrate the differences between blocks using the initial GDP in each block to calibrate

[5] Block A: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States

$bart_i$, and the average population and aggregate TFP difference between blocks to calibrate L and E.

The only parameters that we calibrate from Block B are parameters related to the relative size of the Block and its initial stage of development in 1960. These include the relative size of the labor force, the relative productivity of labor, the initial capital stock, and $\bar{t}_i$. The evolution of the capital stock and structural change in Block B are all unmatched moments.

5.1 Long-run parameters

5.1.1 Production Functions

To calibrate the capital shares (θ, γ, φ), the growth rates of total factor productivity in agriculture and services (μ, ν), and labor augmenting total factor productivity in manufacturing λ, we use data from the WIOD from 2000 to 2014 for countries in Block A in local currency units. In particular we use data on sectoral wages, total hours, number of workers, and total output per sector and year in local currency units. We define our three sectors aggregating SIC sub sectors as follows: agriculture in the model corresponds to agriculture and mining in the data SIC 01-14; manufacturing includes manufacturing and construction SIC 15-39; and services includes SIC 40-97.

We define the capital share as one minus the labor share, averaged over time and across countries. Table 11 in the Appendix shows the summary statistics by country in Block A. To aggregate, we first take the average per year over all countries to generate Block A and then we calculate average over all years. Table 2 shows the summary statistics for these parameters. According to the data agriculture is the most capital intensive sector and manufacturing is the least capital intensive sector.

Table 2: Summary Statistics: Capital Shares

		Mean	**Std. Dev**	**Min**	**Max**
Agriculture	θ	0.54	0.21	0.14	0.87
Manufacturing	γ	0.36	0.06	0.23	0.48
Services	φ	0.39	0.04	0.34	0.46

Note: Agriculture and Mining SIC 01-14; Manufacturing and Construction SIC 15-39; Services SIC 40-97.

To calculate the growth rates of total factor productivity in agriculture and services (μ, ν), and the growth rate of labor augmenting TFP in manufacturing λ, we first compute the TFP for each country of Block A in years 2000 and 2014, using data on sectoral output, capital, labor and the capital shares calculated above.

Table 12 in the Appendix shows the summary statistics per country in Block A between 2000-2014. We define the Block's A rate of technical progress in sector j as the average growth rate per country i in sector j, as defined in the following equation

$$g_j = \frac{1}{N}\sum_{i=1}^{N}\Big(\frac{\log(TFP_{j,2014}) - \log(TFP_{j,2000})}{14}\Big)$$

where θ, γ, and φ are the capital shares per sector. Then we define $\mu = \exp(g_{jA} - (1-\theta)n)$ as the growth rate in agriculture, $\nu = \exp(g_{jC} - (1-\varphi)n)$ as the growth rate in services, and $\lambda = \exp(\frac{g_M}{\gamma} - n)$ as the growth rate in manufacturing. Where n is average population growth rate in the US between 1960 and 2017, which is equal to $n = 0.98\%$. Recall, that λ is labor augmenting, while μ and ν are not.

Table 3 summarizes these results, with the calibrated parameters corresponding to the first column. Productivity growth is highest in manufacturing. Productivity growth is roughly equal in agriculture and services.

Table 3: Summary Statistics: Total Factor Productivity Growth

		Mean	**Std. Dev**	**Min**	**Max**
Agriculture	μ	1.00	0.05	0.93	1.10
Manufacturing	λ	1.02	0.03	0.96	1.07
Services	ν	1.00	0.02	0.96	1.02

Note: Agriculture and Mining SIC 01-14; Manufacturing and Construction SIC 15-39; "Services SIC 40-97.

5.1.2 Depreciation and Discount Factor

To calibrate the depreciation rate, δ, we use data from Penn World Table 9.1 from 1960 to 2017. Following the same pattern of aggregation, we first calculate the average depreciation rate per year across countries to generate Block A, and then the average per year. Table 4 summarizes these results, with the calibrated parameter corresponds to the first column.

To calibrate the discount factor, β, we use the debt Euler equation in steady state (Eq. 23) and set interest rate in steady state to be equal to 5.1%. This condition implies a discount factor $\beta = 0.9671$.

5.2 Preferences

We calibrate the utility parameters (α_j, η_j, ρ_j for $j = \{A, M, S\}$) to minimize the squared distance between the sectoral output shares in 2017 and 1970 in the model and the data

Table 4: Summary Statistics: Depreciation Rate

		Mean	Std. Dev	Min	Max
Depreciation (%)	δ	3.7	0.2	3.5	4.2

Note: Using data from Penn World Table 9.1 the table shows summary statistics for the depreciation rate of Block A between 1960-2017. We compute Block's A depreciation rate as the average depreciation rate by year of all countries in Block A.

for Block A, as well as the investment share in 2017. To calibrate these parameters we use production sectoral shares, and the investment share, real consumptions per capita and prices[6], and investment in the data. In addition we use, the calibrated capital shares, and TFP growth rates from the model. We allow for each moment to have different weights $w_1, \dots, w_7$.[7]

We use data on consumption from the International Comparison program in 1975 and 2017, first and last release of the data correspondingly. We use as consumption the real per capita expenditure per sector. Following Echevarria (1997) we classify expenditure in three sectors. First, agriculture (Cat. 03-04) includes food and non-alcoholic beverages, alcoholic beverages, tobacco, non-alcoholic beverages, and alcoholic beverages, tobacco and narcotics; manufacturing (Cat 05-07) includes clothing and footwear, actual housing, water, electricity, gas and other fuels, furnishings, household equipment and routine household maintenance, purchase of vehicles, net purchases abroad, and collective consumption expenditure by government; finally, services (Cat. 08-14) include health, transport, communication, recreation and culture, education, restaurants and hotels, miscellaneous goods and services, and transport. Table 5 presents the summary statistics for consumption in 2017 and 1975 for Block A, and Table 13 in the Appendix shows the average consumption per country in Block A.

We use sectorial output shares from WDI for years 1975 and 2017, and investment share from PWT 9.1. Table 6 shows these values in percentages. Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Manufacturing corresponds to ISIC divisions 10-45, including mining, and services correspond to ISIC divisions 50-99. Since in our model production of manufacturing includes investment and capital adjustment costs, we define I_{ty} as the investment share times output from the ICP.

[6]We use data from ICP in 1975

[7]In our preferred specification $w_1 = 6$, $w_3 = 8$, and the remaining weights are all equal to one.

Table 5: Summary Statistics: Consumption and Prices 2017 and 1975

	Mean	**Std. Dev**	**Min**	**Max**
Consumption in Agriculture	3.1	1.7	0.8	5.2
Consumption in Manufacturing	8.4	6.3	0.2	16.5
Consumption in Services	14.4	11.0	0.2	31.4

Note: Units in thousand dollars, 2011. Agriculture (Cat. 03-04) includes food and non-alcoholic beverages, alcoholic beverages, tobacco, non-alcoholic beverages, and alcoholic beverages, tobacco and narcotics; Manufacturing (Cat 05-07) includes clothing and footwear, actual housing, water, electricity, gas and other fuels, furnishings, household equipment and routine household maintenance, purchase of vehicles, net purchases abroad, and collective consumption expenditure by government; Services (Cat. 08-14) include health, transport, communication, recreation and culture, education, restaurants and hotels, miscellaneous goods and services, and transport.

Table 6: Sectorial Output Shares for Block A,%

Year	ay_t	my_t	sy_t	iy_t
1975	6.9	33.3	59.8	24.4
2017	1.6	25.2	73.2	21.3

Note: Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Manufacturing corresponds to ISIC divisions 10-45. Services correspond to ISIC divisions 50-99

5.3 Efficiency Parameters and Adjustment Costs

We calibrate the Investment Adjustment Costs (Ψ), Portfolio Adjustment Costs (Ψ_2) to minimize the distance between the peak I/Y and $Log(GDP)$ in Block A between the model and the data.

To calibrate the Initial Efficiency Parameters -A,B,C- we use data from the ICP in 2017 on sectoral relative prices and real GDP *per capita* in PPP for Block A from PWT 9.1. We compute relative prices in agriculture and services as the deflator per sector, that is nominal expenditure to real expenditure, to the corresponding price in manufacturing. We classify each sector using the same criteria as we do for the preferences parameters.

Using these data and our parameters we solve for the steady state of the stationary closed economy.

5.4 Differences between Blocks

Finally, we calibrate three sources of parameters that differ between Blocks A and B. We start by defining the difference in labor productivity between blocks. To do so, we set the labor productivity of Block A to be equal to one. Then, we use data from WIOD from 2000-

Table 7: Summary Statistics: Relative Prices in Block A 2017

	Mean	**Std. Dev**	**Min**	**Max**
Agriculture	0.9	0.1	0.7	1.1
Services	1.1	0.1	0.9	1.4

Note: Agriculture (Cat. 03-04) includes food and non-alcoholic beverages, alcoholic beverages, tobacco, non-alcoholic beverages, and alcoholic beverages, tobacco and narcotics; Manufacturing (Cat 05-07) includes clothing and footwear, actual housing, water, electricity, gas and other fuels, furnishings, household equipment and routine household maintenance, purchase of vehicles, net purchases abroad, and collective consumption expenditure by government; Services (Cat. 08-14) include health, transport, communication, recreation and culture, education, restaurants and hotels, miscellaneous goods and services, and transport.

2011 to compute the average aggregate TFP per Block. Using these residuals we compute the average ratio during this period as the difference in labor productivity between blocks. Table 8 summarizes this ratio. On average Block B TFP is 35% of Block A's, and we interpret this difference in our model as $E_B = 0.35$.

Table 8: Summary Statistics: Relative TFP

	Mean	**Std. Dev**	**Min**	**Max**
TFP_B/TFP_A	0.39	0.16	0.20	0.77
L_B/L_A	1.9	.4	1.2	2.5

Note: Summary Statistics for the relative aggregate TFP and relative population size between blocks

Second, we allow for differences in population size between blocks. Again we normalize population in Block A to one. Then using data from PWT9.1 we compute the average relative population of B to A as the labor size for Block B. On average, Block B has 87% more population than Block A, as shown in the second line of table 8.

Third, we initialize the development process. This involves both the parameter $\bar{t}_i$ and the initial capital stocks. It is important to notice that according to our model, all economies are following the same development process, and differences in GDP can be interpreted economies being at different points on this path. In this sense, we solve for an arbitrary closed economy with an initial capital stock close to zero[8], and define that each Block is in the period that minimizes the distance between the real GDP per capita in 1960 and the GDP implied by this path. We find that Block A in 1960 was on its 27th year of the development path, while Block B was in the 14th year of the development path, and use as the initial capital stock the implied level by $\bar{t}_A = 30$ and $\bar{t}_B = 14$

Table 9 presents all the parameters in the calibrated model.

[8]The minimum possible capital stock to obtain a solution for the model corresponds to $10 US in PPP 2011

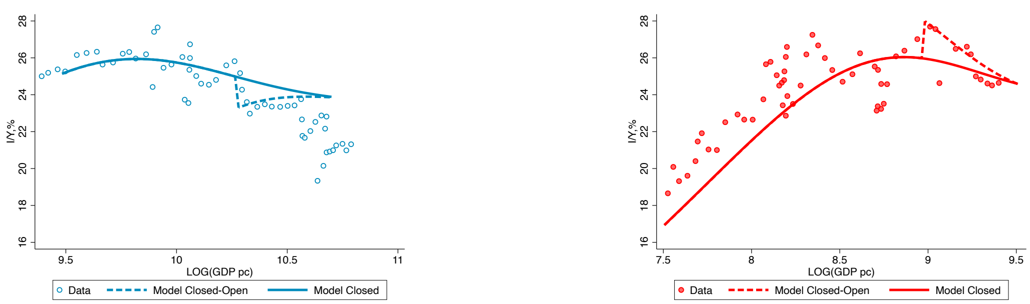
Table 9: Parameters

Preferences								
$\alpha_1 = 0.12$	$\alpha_2 = 0.33$	$\alpha_3 = 0.54$	$\eta_1 = 0.03$	$\eta_2 = 0.0288$	$\eta_3 = 9.38$	$\rho_1 = 1.20$	$\rho_2 = 0.35$	$\rho_3 = 0.23$
Production								
$A = 0.60$	$B = 0.65$	$C = 0.58$	$\mu = 1.00$	$\lambda = 1.02$	$\nu = 1.00$	$\theta = 0.49$	$\gamma = 0.37$	$\phi = 0.40$
Other								
$\beta = 0.97$	$\delta = 0.04$	$\Psi = 3.87$	$\Psi_2 = 0.2$	$E_B = 0.37$	$L_A = 1$	$L_B = 2.7$	$t_{1A} = 30$	$t_{1B} = 14$

6 Comparing the Model to the Data

Figure 7: The simulated paths of the investment rate relative to real per capita GDP for both Blocks A and B

(a) Block A **(b)** Block B



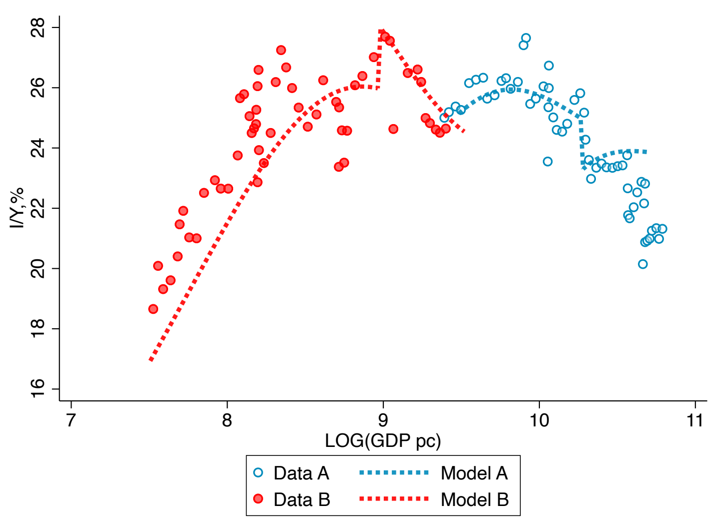
Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The solid line corresponds to the simulated results of the closed economy, and the dashed line corresponds to the open economy opening in 1990.

Given the calibrated parameters, we simulate the model assuming financial markets open in 1990. Prior to 1990, both regions are effectively closed. After 1990, they engage in intertemporal trade. The opening of financial markets is unanticipated. We start by comparing the simulated paths for the investment rate as a function of real per capita income in the data and in the model (Figure 7). The dots in the figure are data and correspond to the dots in Figure 2. The solid line in the figure shows the path of investment for each block under the assumption that both blocks remain closed through the full sample. The light dotted line shows the perturbation to investment in both regions when the economies open to capital flows.

There are several points to emphasize in the figure. First, the investment rates produced by the model exhibit the hump shape in the data. This was fact 1. Second, the investment rate peaks at a lower level of per capita income in Block A than in Block B. This was fact 2. The final observation is that when capital market liberalization occurs, the investment rate drops in Block A and increases in Block B. The increase in B is larger because it is expressed as a share of GDP, which is lower in Block B. In both cases the open-economy path fits the data somewhat better than the closed-economy path. The improvement in fit is even more evident in Figure 8 where the two investment curves are plotted together. Block B peaks at a lower level of per capita income and openness accelerates the increase in investment.

Recall that the model is calibrated to match Block A. The only parameters chosen to match Block B are the initial capital stock, the level of labor productivity and the date at which development begins. In addition, the model abstracts from all financial crises, including the Asian Crisis and the Great Recession in 2008. In spite of all this, the model fits the evolution of investment in Block B remarkably well.

Figure 8: The simulated paths of the investment rate relative to real per capita GDP for both Blocks A and B

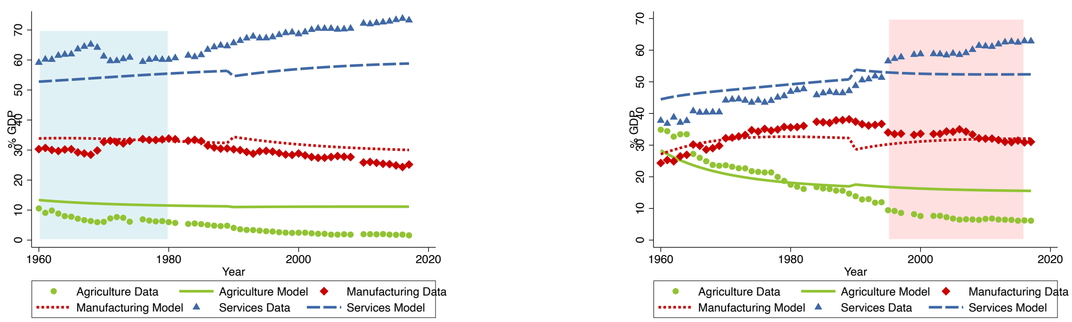


Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The dashed line corresponds to the simulated results of the model opening in 1990.

The model also produces time paths for production by sector that can be compared to data. Figure 9 provides this comparison for both Blocks A and B. The model (dotted lines) generates paths that are roughly consistent with the data - the general decline in agriculture and the increase in services - though the fit is better for Block A than for Block B. Recall that the model is calibrated to match Block A as closely as possible. Only the date at which development begins is chosen to match Block B. Our third fact states that structural transformation and investment in Block B from 1995 to 2017 is comparable to Block A from 1960 to 1980. Figure 10 repeats this exercise with the simulated data. The sectoral shares from the shaded areas of Figure 10a are remarkably similar. Figure 10b shows the investment rates over the same time intervals for Block A and Block B. The model produces a sharper decline in investment in Block A relative to Block B.

Figure 9: The simulated paths of the production by sector for both Blocks A and B

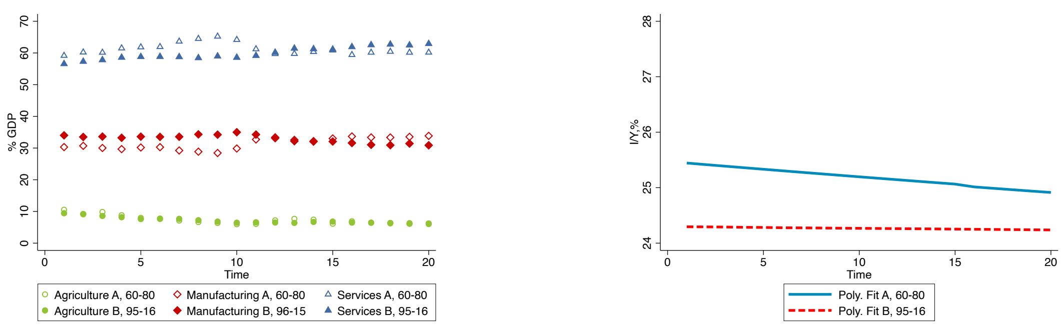
(a) Block A **(b)** Block B



Note: Data Source WDI. Agriculture includes ISIC 1-5, Manufacturing includes ISIC 10-45, and Services includes ISIC 50-99.Excluding mining and wholesale trade.

Figure 10: The simulated paths of the production by sector for both Blocks A and B

(a) Sectoral Shares **(b)** Investment Ratio

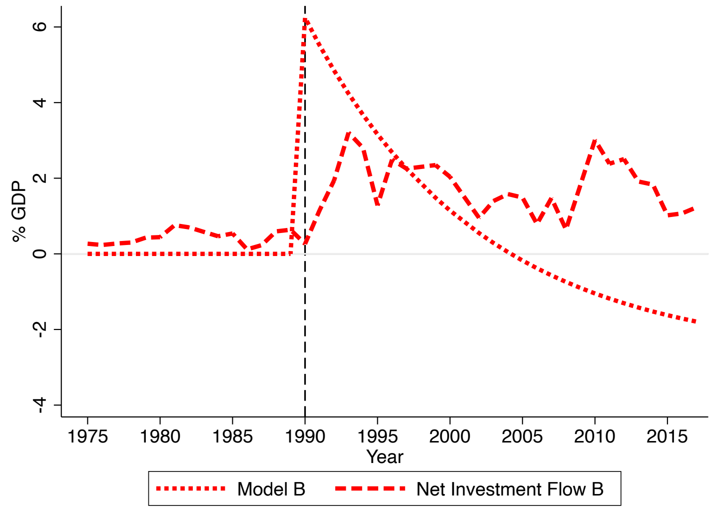


Note: Data Source WDI. Agriculture includes ISIC 1-5, Manufacturing includes ISIC 10-45, and Services includes ISIC 50-99, Excluding mining and wholesale trade.

Our fourth fact is that there was a surge in capital flows beginning around 1990. Figure 11 shows private capital flows from Block A to Block B in the model and the data. The initial date of liberalization is assumed to be 1990. The volume of capital flow shown in the figure is endogenously generated by the model. The surge in capital flows peaks at around 8 percent of Block B GDP, higher than in the data. However, it drops off quickly. The volume of capital flow from 1990-2005 in the model is 48.4% of GDP while it is 32.4% in the data.

The surge in capital flows causes both investment and consumption to rise in Block B and fall in Block A. Figure 12 plots each investment curve (model and data) relative to time. The vertical line shows the date of capital market liberalization. At that point, the two investment paths diverge, causing the investment rate to rise in Block B and fall in

Figure 11: The simulated paths of the private capital flows from Block A to Block B



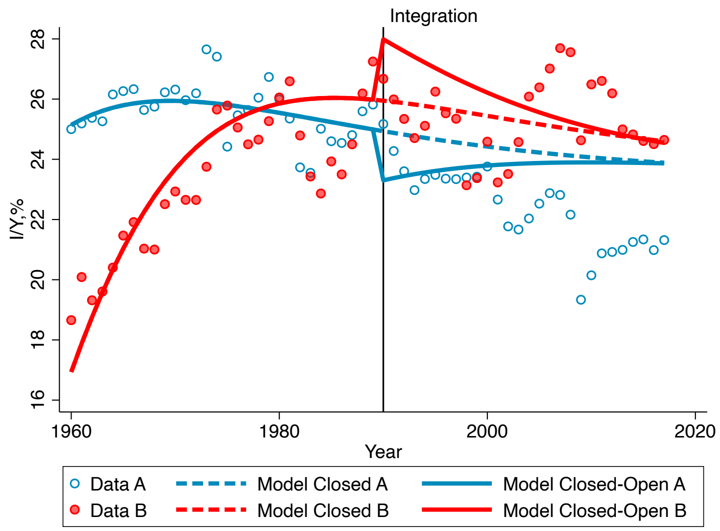
Note: Data Source WDI. Total Capital inflow is defined as net incurrence of liabilities excluding derivatives. Direct + Portfolio investment inflow is defined as net incurrence of direct investment and portfolio investment liabilities.

Block A. The investment rate in Block A then flattens relative to the closed-economy path. Because Block B has borrowed from Block A and must pay interest in terms of the traded manufacturing good, in the very long run B's investment rate is slightly above where it would have been as a closed economy, and in A it is slightly lower. (see Figure 22 in the Appendix.)

The rise in investment in Block B raises output and consumption. Figure 13 shows the impact of capital market liberalization on consumption of each of the three goods in Block A and Block B. The figure plots the time path of consumption relative to the path consumption would have followed if the economy had remain closed. Block B consumption rises on impact. Consumption of the manufacturing (the traded good) increases the most, while agriculture increases the least. This pattern is driven mainly by the non-homotheticity in preferences. The rise in consumption pushes Block B along the development path increasing consumption of manufacturing and services and reducing the consumption of agricultural goods. This effect through preferences dominates the effect through relative prices. The rise in investment increases the supply of capital and drives down the price of capital intensive goods such as agriculture. Note that consumption rises in the short run, but falls in the long run. In the long run Block B must pay for the capital it borrows in the short run.

The response of consumption in Block A is the mirror image of the response of Block B. In the short run, consumption falls in Block A as the Block attempts to take advantage of profitable investment opportunities in Block B. Consumption falls most for manufacturing and services and least for agriculture. Again these sectoral shifts reflect mainly the impact of

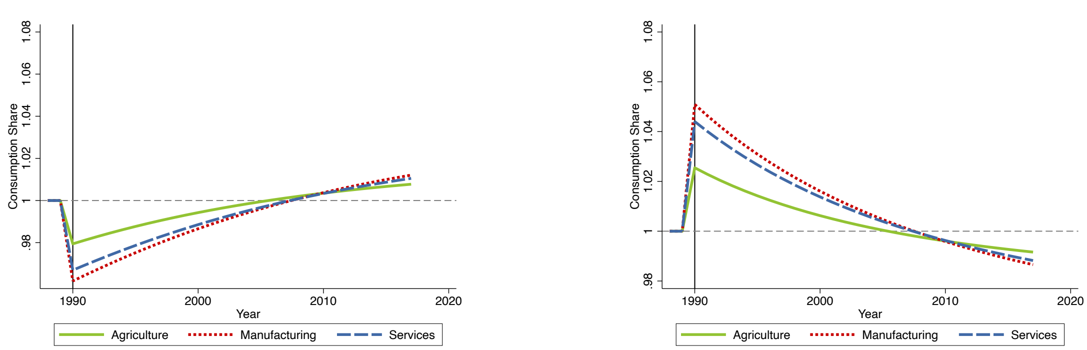
Figure 12: The simulated paths of the investment rate relative to time for both Blocks A and B



Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The solid line corresponds to the simulated results of the closed economy, and the dashed line corresponds to the open economy opening in 1990.

Figure 13: The impact of capital market liberalization on consumption of each of the three goods in Block A and Block B

(a) Block A **(b)** Block B



the level of consumption on preferences. In the long run Block A is able use its accumulated wealth to consume more than it would have had the economy remained closed.

We see the effects of financial liberalization on sectoral production in Figure 9. In Block A, the desire to export capital causes production to shift towards manufacturing. This shift comes mainly at the expense of services, as agricultural demand remains relatively strong. The response of Block B is the mirror image.

7 Welfare

In this section we use our model to evaluate the welfare effects of capital market liberalization. Who gains from liberalization? How does the timing of reform affect these gains? Not surprisingly we find that the welfare gains are larger if the two economies integrate earlier. We find that Block B gains more than Block A, and that Block B's gains are more sensitive to the timing of liberalization.

Evaluating the welfare effects of a policy change in a multi-good setting is not as straightforward as it is in a single-good economy. There is no natural numeraire good in a multi-good setting. Microeconomic theory has focused on two different measures of the welfare impact of a change in policy. These two measures agree on the sign of the welfare change, but, since they use different prices, they can differ in magnitude. The first is the *compensating variation*. The compensating variation takes as its starting point the post-reform equilibrium and the post-reform prices. It asks, "How much and in what direction must the present value of income change in order for agents to experience the pre-reform present-value utility a these post-reform prices?" In this sense, it reflects the compensation that would make agents living in the post-reform world indifferent to the reform (ignoring the general equilibrium feedback that actual compensation would naturally bring on). The *equivalent variation*, on the other hand, begins with the pre-reform equilibrium and the pre-reform prices, and asks "How much and in what direction must the present value of income change in order for agents to experience the post-reform present-value utility at the pre-reform prices?" The equivalent variation measures the wealth change that is equivalent to the policy reform from the pre-reform perspective.

Let $E_t(U_t, P_t)$ denote the expenditure in date t necessary to reach present value utility U_t given a price vector P_t. Note that P_t is a vector of the date-t prices of all goods in all periods $s \geq t$. We can write the compensating variation of a reform at date t as,

$$CV_t = E_t(U_t^{open}, P_t^{open}) - E_t(U_t^{closed}, P_t^{open})$$

Here U_t^{open} is the present value of utility if capital markets are opened in period t and U_t^{closed} is the present value of utility of capital markets remain closed forever. P_t^{open} is the price vector if capital markets are open. As noted above, the compensating variation uses post-reform prices to transform the change in utility into a change in expenditure. If $CV_t > 0$, the reform raises welfare. Similarly we can write the equivalent variation of a reform at date t as,

$$EV_t = E_t(U_t^{open}, P_t^{closed}) - E_t(U_t^{closed}, P_t^{closed})$$

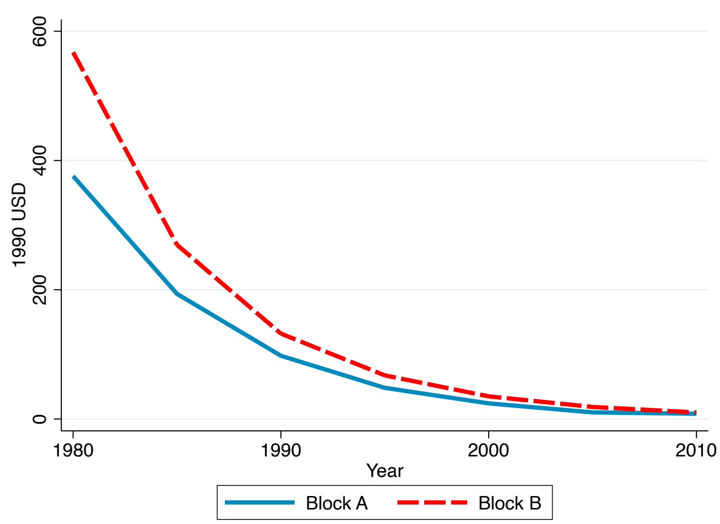
where the only change is that the equivalent variation uses P_t^{closed}, the price vector in the case that capital markets remain closed, to transform the change in utility in to a change in expenditure. Given that E_t is monotonically increasing in U_t, CV_t and EV_t are either both positive or both negative.

Using our model to calculate these quantities, we find liberalization in 1990 was welfare improving for both blocks, but that Block B gained more from liberalization than Block A.[9] The compensating variation to liberalization in 1990 is 0.01% of GDP for Block A and 0.06% of GDP for Block B. The equivalent variations are 0.011% for Block A and 0.058% for Block B. On a per capita basis the gains are more even. Because labor is less productive in Block B, the gain in GDP is distributed more widely. The per capita gains implied by the compensating variation in terms of 1990 US dollars are $91 in Block A and $132 in Block B.

We can also use the model to investigate the welfare effect of varying the date of liberalization. Figure 14 graphs the compensating variation as a function of the date of liberalization. One complication is that CV_t is calculated in terms of the numeraire at date t. In order to make all of the quantities comparable, we used the closed economy interest rate to transform all expenditure into 1990 dollars. Here we find that the gains the of Block A are relatively insensitive to the data of liberalization, whereas Block B has a clear preference for liberalizing earlier.

[9] Interestingly, which region gains is somewhat sensitive to how we allocate countries to Blocks A and B. For example, if Greece, Ireland, Portugal and Spain are assigned to Block A, then Block A gains significantly more from liberalization than does Block B.

Figure 14: The impact of capital market liberalization on welfare in Block A and Block B



Note: The x-axis shows different opening dates. The y-axis shows the per capita CV in 1990 closed economy prices. We compute the CV as the present discounted value of expenditure under the open economy since the opening date, minus the presented discounted value of the expenditure required to keep the closed economy utility with the new prices.

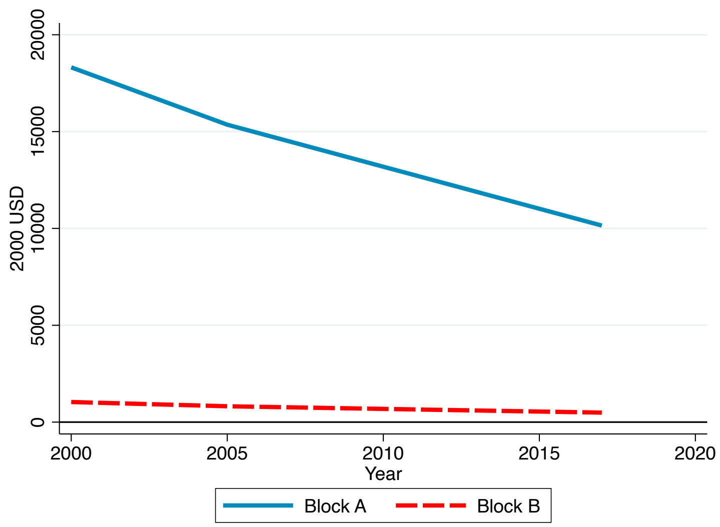
8 China's Integration

Our two-country model includes the North and the South but excludes China, which is becoming an increasing force in world markets. It is natural to ask how the investment patterns would change if we were to include China in the model. To date, China remains largely closed to private capital flows. It is very difficult for foreigners to invest in China and own Chinese companies. The question then becomes, "What would happen if China liberalized its capital markets?"

To answer this question, we consider a simple experiment. Rather than solve a three country model with three sectors, we model China as a new exogenous investment opportunity. In our experiment, we assume that China liberalizes to asset trade with Blocks A and B in 2017 (which is the end of our sample). We assume that both Blocks A and B can trade with China at an exogenous interest rate that mimics the path of the world interest rate after the integration of Blocks A and B. Otherwise the calibration of the model is the same. In effect, Blocks A and B are modeled as small open economies, facing an exogenously higher Chinese interest rate. This experiment should give a qualitative indication of the impact of Chinese liberalization.

Figure 15 shows the welfare impact of Chinese liberalization. The graph plots the compensating variation as function of potential integration dates. Block A gains much more than Block B irregardless of when integration takes place. To get some idea of why Block

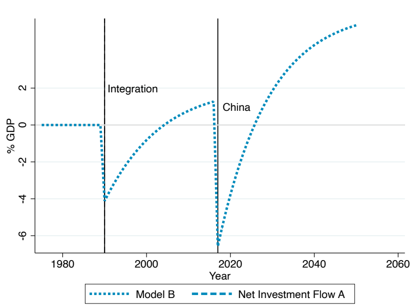
Figure 15: The impact of capital market liberalization with China on welfare in Block A and Block B



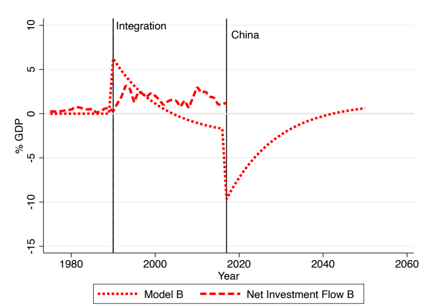
Note: The x-axis shows different opening dates. The y-axis shows the per capita CV in 2000 prices. We compute the CV as the present discounted value of expenditure under the open economy since the opening date, minus the presented discounted value of the expenditure required to keep the closed economy utility with the new prices.

Figure 16: The simulated paths of Capital inflows after integrating with China

(a) Block A



(b) Block B

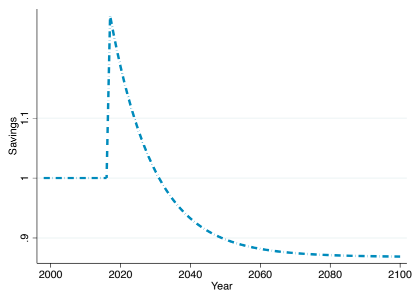


Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The dark dotted line corresponds to the simulated results of the model opening in after integrating with China. The light dashed line corresponds to the base-line model.

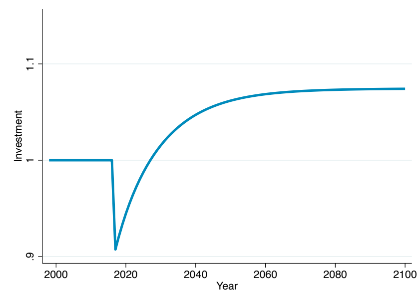
A gains more than Block B. Figures 16a and 16b illustrate the path of capital flows for two integration dates. We see that capital flows from Block A to Block B when these two regions integrate in 1990, but capital flows from both blocks towards China when China integrates. Figure 17 shows that saving rises in both blocks and investment falls.

Figure 17: The simulated paths of Savings and Investment after integrating with China: Block A

(a) Savings

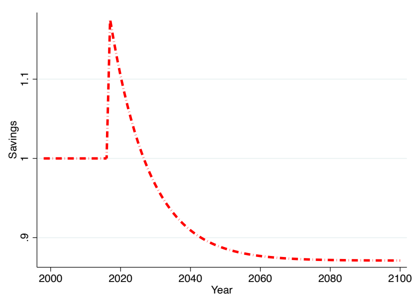


(b) Investment

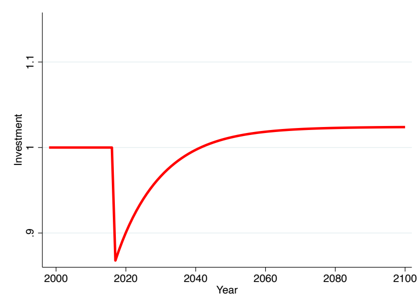


The simulated paths of Savings and Investment after integrating with China: Block B

(c) Savings



(d) Investment



Note: Each dot corresponds to an observation in Block j in year t.The x-axis shows years and the y-axis is the ratio of the counter-factual model to the vase line model. Data Source: PWT9.1. The dark dotted line corresponds to the simulated results of the model opening in after integrating with China. The light dashed line corresponds to the base-line model.

The picture that emerges is that China's liberalization presents the world with a new investment opportunity and raises the world interest rate and the marginal product of capital. This raises income in both blocks and causes capital to shift toward China. There is an additional effect of integration, however. Block A is a creditor at the time of liberalization, whereas Block B is a debtor. The rise in interest rates therefore further raises the wealth of Block A, whereas it represents a capital loss in Block B.

The opening of China has interesting implications for the allocation of consumption and production across sectors as shown in figures 18 and 19. The increased investment opportunities lead to a surge in manufacturing production in both Blocks A and B. The increase

Figure 18: The simulated paths of Consumption and Production after integrating with China: Block A

(a) Consumption **(b)** Production

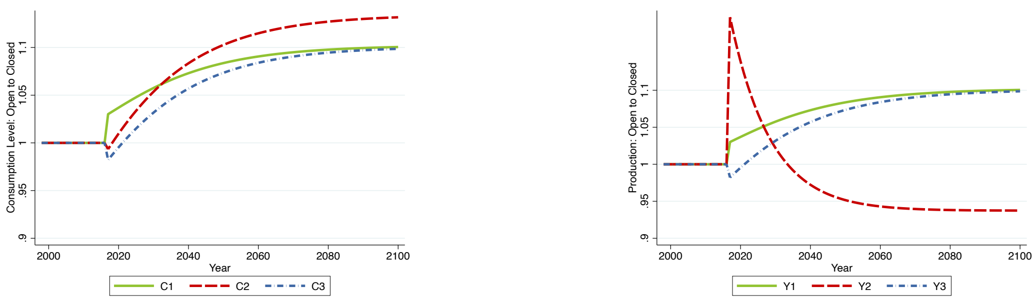
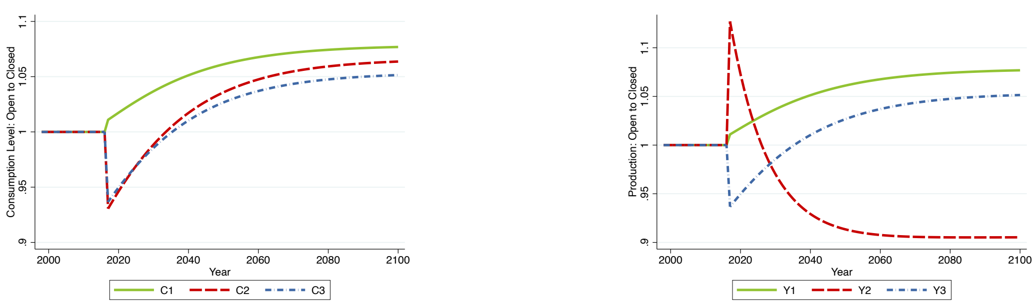


Figure 19: The simulated paths of Consumption and Production after integrating with China: Block A

(a) Consumption **(b)** Production



Note: Each line corresponds to the co Block j in year t.The x-axis shows years and the y-axis is the ratio of the counter-factual model to the vase line model. The dark dotted line corresponds to the simulated results of the model opening in after integrating with China. The light dashed line corresponds to the base-line model.

in saving, however, impacts the composition of consumption through the non-homothetic preference. Consumption shifts from manufacturing and services and towards agriculture. As a result production of services declines the most and consumption of agricultural goods actually rises.

9 Conclusions

In this paper, we develop a two-region model of the world economy that successfully mimics the dynamics of investment and sectoral change in advanced economies as well as emerging markets. The investment rate exhibits a "hump shape," increasing at early stages of economic growth and then declining at later stages. This is true of investment in both advanced and emerging economies, with the key difference being the date and income level at which the investment rate peaks. We also observe increasing shares of services in GDP and declining shares of agricultural goods in GDP, though again the timing of these changes depends on the stage of economic development. Finally we observe capital flows to emerging markets in the early 1990s that coincides with an increase in the investment rate in those economies.

We calibrate our model to macroeconomic data. The key differences between the two regions is that emerging markets start their path of economic development at a later point in time, with a lower capital stock and a less productive labor force. All other parameters governing economic growth, sector-specific production and utility functions are identical across the two regions. The model fits the data quite well, matching the timing and peak of the investment humps, the paths of sectoral change as well as the magnitude of capital flows at the time of capital market liberalization.

We then use our model to examine two counterfactuals. The first is an analysis of the welfare gains to the two regions were capital liberalization to occur at different points in time. Because we have a multi-good model, we examine compensating and equivalent variation measures of welfare that take into account dynamic changes in relative prices. We find that both regions prefer to liberalize earlier than later – the difference in autarky interest rates diminishes over time as emerging markets catch up to advanced economies, and therefore the mutual gains from trade fall over time. Interestingly, we find that the developing economies capture the lion's share of welfare gains, though the differential between welfare gains to the two regions falls with time.

The second experiment is to consider the impact of China's integration into global financial markets. We model this as creating a new opportunity for both advanced and emerging markets to earn a higher rate of return on capital investment in China. Again, both regions gain, but China's opening redistributes capital away from emerging markets toward China.

Because advanced economies are already a net creditor in global financial markets, the increase in the global interest rate generates a positive wealth effect and an increase in demand for nontraded goods and services.

References

Acemoglu, D. and Guerrieri, V. (2008). Capital deepening and nonbalanced economic growth. *Journal of political Economy*, 116(3):467–498.

Alvarez-Cuadrado, F., Van Long, N., and Poschke, M. (2017). Capital–labor substitution, structural change, and growth. *Theoretical Economics*, 12(3):1229–1266.

Boppart, T. (2014). Structural change and the kaldor facts in a growth model with relative price effects and non-gorman preferences. *Econometrica*, 82(6):2167–2196.

Cai, W., Ravikumar, B., and Riezman, R. G. (2015). The quantitative importance of openness in development. *Economic Inquiry*, 53(4):1839–1849.

Calvo, G. A., Izquierdo, A., and Talvi, E. (2006). Sudden stops and phoenix miracles in emerging markets. *American Economic Review*, 96(2):405–410.

Comin, D. A., Lashkari, D., and Mestieri, M. (2015). Structural change with long-run income and price effects. Technical report, National Bureau of Economic Research.

Echevarria, C. (1997). Changes in sectoral composition associated with economic growth. *International economic review*, pages 431–452.

Foellmi, R. and Zweimüller, J. (2008). Structural change, engel's consumption cycles and kaldor's facts of economic growth. *Journal of monetary Economics*, 55(7):1317–1328.

Fujiwara, I. and Matsuyama, K. (2020). A technology-gap model of premature deindustrialization.

Garcia-Santana, M., Pijoan-Mas, J., and Villacorta, L. (2016). Investment demand and structural change.

Herrendorf, B., Herrington, C., and Valentinyi, A. (2015). Sectoral technology and structural transformation. *American Economic Journal: Macroeconomics*, 7(4):104–33.

Kehoe, T. J., Ruhl, K. J., and Steinberg, J. B. (2018). Global imbalances and structural change in the united states. *Journal of Political Economy*, 126(2):761–796.

Kongsamut, P., Rebelo, S., and Xie, D. (2001). Beyond balanced growth. *The Review of Economic Studies*, 68(4):869–882.

Matsuyama, K. (2009). Structural change in an interdependent world: A global view of manufacturing decline. *Journal of the European Economic Association*, 7(2-3):478–486.

Moro, A. (2015). Structural change, growth, and volatility. *American Economic Journal: Macroeconomics*, 7(3):259–94.

Ngai, L. R. and Pissarides, C. A. (2007). Structural change in a multisector model of growth. *American economic review*, 97(1):429–443.

Rodrik, D. (2016). Premature deindustrialization. *Journal of economic growth*, 21(1):1–33.

Sposi, M. (2019). Evolving comparative advantage, sectoral linkages, and structural change. *Journal of Monetary Economics*, 103:75–87.

Świkecki, T. (2017). Determinants of structural change. *Review of Economic Dynamics*, 24:95–131.

Uy, T., Yi, K.-M., and Zhang, J. (2013). Structural change in an open economy. *Journal of Monetary Economics*, 60(6):667–682.

Ventura, J. (1997). Growth and interdependence. *The Quarterly Journal of Economics*, 112(1):57–84.

A Appendix: Data

Using data from PWT 9.1, we aggregate real GDP in PPP constant dollars , GDP in nominal dollars, population, and total investment in nominal dollars, into blocks A and B, as the sum of the country level values n in block i and year t.[10] Using these values, we compute real GDP in PPP *per capita* and the investment ratio, per block as the ratio of the aggregated GDP PPP to population, and total investment to GDP in nominal US, correspondingly.[11]

Using data from WDI, we aggregate sectoral shares as the average sectoral share per year within a block. The reason to use a different aggregation method is because before 1980, there are substantial missing values in the cross-section, and the first method would result in an under estimation. Table 1 shows the summary statistics for the main variables of our analysis.

Table 10: Summary Statistics

	Mean	**Std. Dev**	**Min**	**Max**	**T**
GDP PC in PPP	28400.01	10881.53	11452.16	47523.39	58
Investment to GDP	24.09	1.99	19.54	27.81	58
Agriculture to GDP	4.37	2.36	1.65	10.55	58
Manufacturing to GDP	27.26	2.73	22.25	30.70	58
Services-GDP to GDP	59.90	4.53	53.72	66.64	48

[10] Block level variables are defined as $X_{i,t} = \sum_{n=1}^{N} x_{i,n,t}$

[11] Block level ratios are defined $\frac{X_{i,t}}{Y_{i,t}} = \frac{\sum_{n=1}^{N} x_{i,n,t}}{\sum_{n=1}^{N} y_{i,n,t}}$

B Appendix: Trade by sector

Figure 20: All Countries in Blocks A and B

(a) Exports **(b)** Imports

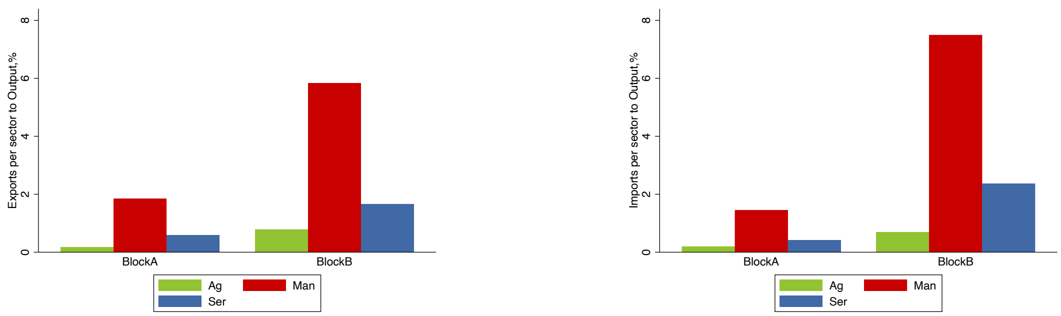
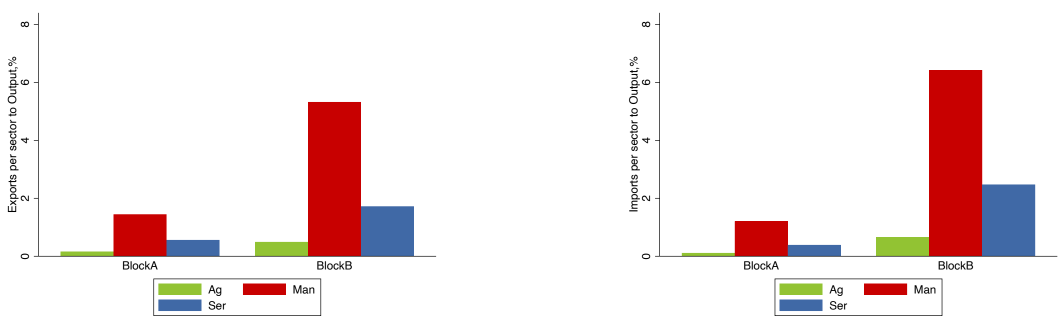


Figure 21: Excluding Mexico

(a) Exports **(b)** Imports



Note: We use data from the WIOD input output tables from 2000-2014. Agriculture corresponds to ISIC divisions 1-5. Manufacturing corresponds to ISIC divisions 10-45. Services correspond to ISIC divisions 50-99. Each bar in Panels A and C represents the average exports per sector to total output in Blocks A and B between 2000-2014. Each bar in Panels B and S represents the average exports per sector to total output in Blocks A and B between 2000-2014.

C Appendix: Calibration

C.1 Labor Shares

Table 11: Summary Statistics: Capital Shares per Country of Block A over years 2000-2014

	Agriculture, θ	**Manufacturing,** γ	**Services,** φ
AUS	.7	.3	.4
AUT	.1	.4	.4
BEL	.5	.4	.4
CAN	.8	.4	.4
CHE	.3	.4	.4
DEU	.2	.3	.4
DNK	.7	.3	.3
FIN	.3	.4	.4
FRA	.4	.3	.4
GBR	.7	.2	.3
ITA	.5	.3	.5
JPN	.5	.3	.4
LUX	.2	.3	.5
NLD	.8	.4	.4
NOR	.9	.3	.4
SWE	.4	.5	.4
USA	.7	.4	.4

C.2 TFP Growth

Table 12: Summary Statistics: TFP Growth Rates per Country of Block A over years 2000-2014

	Agriculture, θ	**Manufacturing, γ**	**Services, φ**
AUS	.97	1.03	1.01
AUT	.93	1	1.01
BEL	1.04	1.02	1.02
CAN	1	1.05	.99
CHE	.98	1	.99
DEU	.98	.99	1
DNK	1.02	1.01	1.02
FIN	.96	1.07	1.02
FRA	1.07	1.04	1.02
GBR	1.06	1.05	1
ITA	1	1.04	1
JPN	1.1	1.02	.96
LUX	.99	1.05	1.03
NLD	.98	1	1.01
NOR	1.02	1.02	1.02
SWE	.98	1.05	1.02
USA	.96	.96	1

C.3 Consumption

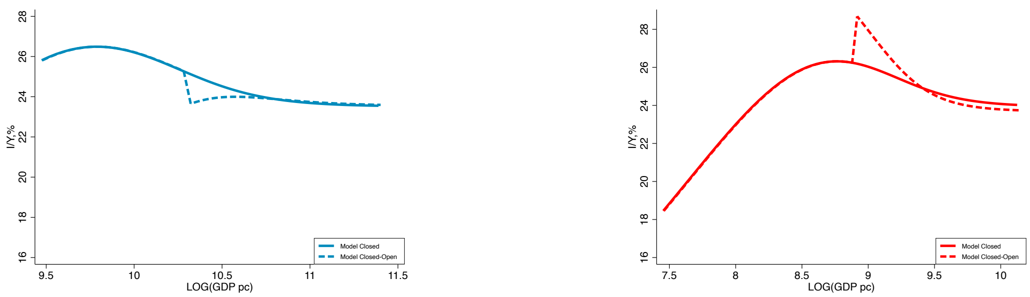
Table 13: Average Consumption per Country of Block A over years 2017 and 1975

	Agriculture	**Manufacturing**	**Services**
Australia	3874.274	11872.88	25420.59
Australia	3874.274	11872.88	25420.59
Austria	2630.536	6747.661	11297.2
Belgium	2962.257	6371.655	10555.16
Canada	3715.006	14683.48	22427.56
Denmark	2714.97	6111.601	11470.92
Finland	4392.96	12602.02	20914.89
France	2689.101	5762.119	10848.71
Germany	2681.967	6764.6	11477.18
Italy	2768.873	5934.714	8181.778
Japan	2227.786	5685.481	9543.691
Netherlands	2557.68	6141.847	10920.4
Norway	3731.433	15969.81	23701.71
Sweden	4188.276	13623.22	20510.75
Switzerland	5197.166	14044.35	22924.07
United Kingdom	2209.871	6305.555	11225.35
United States	2614.634	8529.077	16013.71

D Appendix: Comparing the Model to the Data

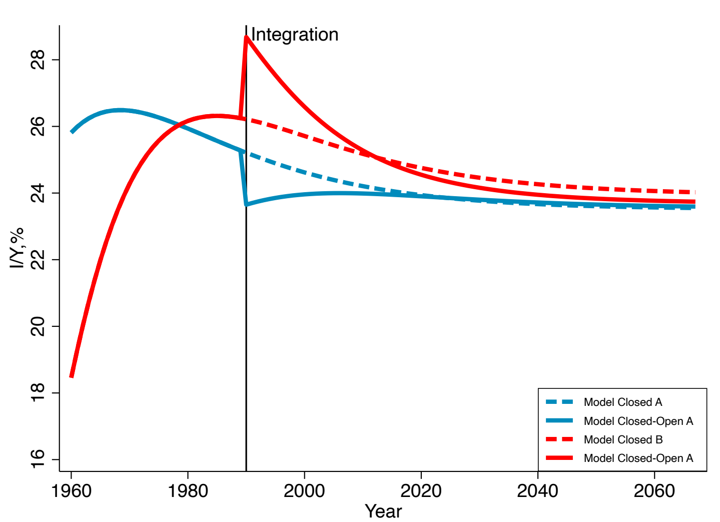
Figure 22: The simulated paths of the investment rate relative to real per capita GDP for both Blocks A and B, 1960-2067

(a) Block A **(b)** Block B



Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The solid line corresponds to the simulated results of the closed economy, and the dashed line corresponds to the open economy opening in 1990.

Figure 23: The simulated paths of the investment rate relative to time for both Blocks A and B,1960-2067



Note: Each dot corresponds to an observation in Block j in year t. Data Source: PWT9.1. The solid line corresponds to the simulated results of the closed economy, and the dashed line corresponds to the open economy opening in 1990.