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Structural Changes and the Real Exchange Rate Dynamics*

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Abstract

Since China joined the WTO in 2001, the Chinese economy has grown very rapidly, especially, the tradable goods sector. However, the Chinese real exchange rate did not exhibit a persistent and stable appreciation until 2005. This is a puzzling fact that is in-consistent with theories. This paper documents several stylized facts during the economic transition and argues that two features of Chinese economy may help explain the puzzling real exchange rate pattern for Chinese economy: i) the faster total factor productivity (TFP) growth in export sector compared with the import sector; ii) excess supply of unskilled labor. Our hypotheses are supported by cross-country evidence. Furthermore, we construct a small open economy model with an H-O trade structure and show that, due to heterogeneous skilled labor intensity in export and import sectors, the faster TFP growth in the export sector over that in the import sector will lead to the decline of return to capital and the rise of skilled wage. Therefore, the decrease of return to capital and the low unskilled wage, which is caused by the excess supply of unskilled labor, inhibit the rise in the relative price of non-tradable goods to tradable goods as well as the ap-preciation of real exchange rate. Finally, we show that a dynamic small open economy model with multiple tradable goods sectors does fairly well in explaining the Chinese real exchange rate and other stylized facts in the economic transition.

Keywords: Real Exchange Rate; Chinese Economy; Excess Labor Supply; H-O Structure

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JEL classification: F3, F4,O1, O4

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1 Introduction

This paper investigates how structural changes in the labor market and traded-good sector help to explain the puzzling dynamics of the real exchange rate in Chinese economy. According to the Balassa-Samuelson (BS) effect (Balassa, 1964; and Samuelson, 1964), a positive relationship should be observed between the economic growth and the appreciation of the real exchange rate. The BS effect is driven by productivity catch-up in a developing country's tradable sectors, which pushes up factor prices and raises prices in non-tradable goods in the country. In the period of 2001-2007, China's annual GDP growth reached an average of 11.2% and its annual growth rate of total trade is close to 20.2%. However, the China's real exchange rate depreciated about 6.7% instead (labelled as Fact 1, see Figures 1 and 2).

Several other stylized facts in China in this fast-growing period are also documented: significant current account surplus, considerable migration from rural to urban areas, the sharp rise in skilled wage premium, and lastly uneven technological progress within the tradable goods sector (see Figures 2-6). The first four facts have been well documented in literature, but the final one has not been noted yet. Using Chinese manufacturing data and Chinese custom data, we find that during the period of 2001-2006, the TFP growth rate of the export sector is significantly higher than that of import sector.

How should we interpret these puzzling real exchange rate dynamics and the above stylized facts? The key to understand is the structural change. As a developing country, there was excess supply of unskilled labor in China, which keeps the unskilled wage at the minimum level. Assuming that the export sector is skilled labor intensive, the fast growing export sector would induce large migration from rural to urban areas, and the sharp rise in skilled wage premium, the Facts 3 and 4. The import sector is more capital intensive. As the TFP growth rate of the export sector is significantly higher than that of import sector (Fact 5), using Stopler-Samuelson theorem, the return to capital may even decline, which results in capital outflow and current account surplus (Fact 2). As the unskilled wage is at the minimum level and the capital return declines, assuming that the non-tradable sector uses little skilled labor, therefore, the price of non-tradable good could decline in this fast growing period, so that real exchange rate depreciates (Fact 1).[1]

[1]The heterogeneous skill intensity across tradable sectors is critical to account for the falling rental on capital thus the depreciating real exchange rate. As a matter of fact, the heterogeneous skill intensity across tradable sectors are well-documented in Chinese data. Moreover, there are also other evidence that supports the heterogeneous skill intensity among trade sectors and firms for other countries. For example, Bernard et

To test our intuition, we further investigate the effect of the difference in the TFP growth of the export and import sectors as well as of the excess labor supply from rural to urban areas on the real exchange rate in developing countries. We conduct a panel regression in the period of 1996-2013 for 82 economies. We augment the conventional empirical models on the real exchange rate by including two additional regressors: the urban-rural migration rate and the gap between the growth rates of the export and import sectors. We find that an increase in migration rate by one standard deviation is associated with a 28% depreciation in the RER. If the migration rate is at the level of one standard deviation, then an increase in the growth rate of the export sector relative to the import sector by one standard deviation is associated with a depreciation in RER of 3%-4%. These data evidences support that the structural changes in labor market and in tradable sectors contribute significantly to the real exchange rate dynamics in developing countries.

We then develop a theoretical framework to study such effects of structural changes on the real exchange rate dynamics. We first build two static models to explain the potential depreciation of the real exchange rate during this fast-growing period. We then develop a dynamic small open economy model with an Heckshher-Ohlin structure. We consider two tradable sectors with heterogeneous factor intensity (the aforementioned H-O structure). We calibrate the model and show that the model can effectively explain the dynamics of the Chinese real exchange rate and other stylized facts documented for Chinese economy during transition, such as the significant increase in skilled labor premium. In the model, the rapid TFP progress in the export sector, which is supposedly labor intensive in China, also results in capital outflow, as observed in the Chinese data. To generate the depreciation of real exchange rate, both abundant unskilled labor supply and the uneven technological progress within the tradable good sector are essential. However, due to the fast economic development, a shortage of unskilled workers would be observed. This occurrence inevitably causes an increase in the unskilled wage, which in turn boosts the prices of the non-tradable goods and then facilitates the appreciation of the real exchange rate. This implies that the traditional Balassa-Samuelson (BS) mechanism works when there is no excess labor supply and the unskilled wage start to rise. Overall, our simulation results suggest that the real

al. (2007) for evidence for the U.S., Verhoogen (2008) for Mexico, Alcala and Hernandez (2010) for Spain, Bustos (2011) for Argentina, Molina and Muendler (2013) for Brazil, and Eslava et al. (2015) for Colombia. In a recent work, Burstein and Vogel (2017) find strong evidence that the college intensity is positive correlated to the firm size.

exchange rate exhibits an V-shape, which is the pattern observed in the Chinese data.[2]

Our paper is closely related to the literature on the determination of real exchange rate. In this literature, there are two well-known theories. The first one is the BS effect; the second one is the Froot-Rogoff effect, which postulates that the real exchange rate tends to rise with government consumption because government spending tends to fall disproportionately on domestic non-tradable goods and services (Froot and Rogoff, 1991). According to Rogoff (1996), there are considerable, although not unanimous, empirical supports for both the Balassa-Samuelson effect and the Froot-Rogoff effect. For example, Berka, Devereux and Engel (2017) investigate the link between real exchange rates and sectoral TFP for Eurozone countries. They find that real exchange rate variation, both cross-country and time series, closely accords with an amended Balassa-Samuelson interpretation, incorporating sectoral productivity shocks and a labor market wedge. Recently, Du, Wei, and Xie (2013) argued that transport infrastructure is an important determinant of the real exchange rate. The economic importance of the infrastructure effect is almost on par with that of the well-known Balassa-Samuelson effect and is much greater than the Froot-Rogoff effect. In this aspect, our paper also contributes to this literature, suggesting that migration and uneven development within tradable sectors might be important in affecting the real exchange rate dynamics.

Our work is related to a small but growing literature that considers multiple tradable sectors with different factor intensities in a general equilibrium framework. These papers include Cunat and Maffezzoli (2004), Ju and Wei (2007), Jin (2012), Jin and Li (2012), and Ju, Shi, and Wei (2013, 2014). Nevertheless, none of the existing works in this literature explicitly studies the real exchange rate. To our best knowledge, there are few theories that accounts for Chinese real exchange rate.[3] Most of the studies on the Chinese real exchange rate are empirical; for example, Cheung, Chinn, and Fujii (2008) examine whether or not the Chinese exchange rate is misaligned and how Chinese trade flows respond to the exchange rate as well as to economic activity. Recently, Du and Wei (2013) presented a model with competitive saving motivation to show that the rise of sex-ratio may help explain the decline of the real exchange rate in China. In our model, the structure changes caused by uneven

[2] Our benchmark model is simple; therefore, it can only match signs but not magnitudes. To match quantitatively with the Chinese data, we must incorporate more realistic institution features or frictions into the model.

[3] Existing literature pays little attention to the Chinese real exchange rate despite the substantial research on China's current account imbalance during that period, as conducted by scholars such as Song, Storesletten, and Zilibotti (2011), Wei and Zhang (2011), and Ju, Shi, and Wei (2013). Our paper fills this gap.

technological progress within the traded goods sector and the migration of unskilled labor supply are the key to explaining the real exchange rate. From the perspective of structural change, Wang, Xu, and Zhu (2013) also attempted to use structural change to explain the US-China bilateral real exchange rate in a two-country model. However, they focused on the structural changes among agriculture, manufacturing, and service sectors, unlike our work. Compared with their work, our paper investigates not only the real exchange rate dynamics but also other stylized facts, such as capital outflow.

The rest of the paper is organized as follows. Section 2 documents the stylized facts during China's fast-growing period. Section 3 presents cross-country empirical evidence. Section 4 presents static small open economy models of real exchange rate to show the model mechanism. Section 5 develops a dynamic model with an H-O structure to explain both the real exchange rate and current account dynamics. Section 6 reports the numerical results. Section 7 concludes this study.

2 Stylized Facts during the Transition of Chinese Economy

In this section, we document a few stylized facts regarding the Chinese economy during its fast-growing period that began in 2000.

1. V-shape exchange rate dynamics, in particular, no real exchange rate appreciation was observed during the fast-growing period (2001-2007)

   Given the fact of maintaining a high growth rate over a long period in China, a persistent real appreciation should be expected. Figure 2 shows that, however, the Chinese real exchange rate did not appreciate persistently until 2007. In particular, we do not observe real exchange rate appreciation even after China joined the WTO in 2001 and the tradable sector expanded dramatically. Instead, the real exchange rate depreciated at a rate of approximately 6.7% from 2001 to 2007. After 2007, the real exchange rate starts to appreciate. Thus, the real exchange rate exhibits a V-shape dynamics.

2. Significant trade balance and the rapid accumulation of foreign reserves

   Since 2001, the Chinese economy has been increasingly integrated into the world economy during its development. The share of international trade (export plus import) in GDP rose from less than 20% in the early 1980's to almost 70% in 2007. During the process of China's integrating into the world, we observed a considerable trade imbalance that has increased rapidly, especially in recent years. As illustrated in Figure 3, the annual average of the trade imbalance increased sharply when China joined the WTO; in 2007, China's trade balance over GDP peaked at approximately 9%. Meanwhile, the country also holds huge amount of foreign reserves that consists of roughly 50% of GDP. Such a significant trade imbalance has generated a major political and economic issue between China and its trading partners; this situation has also initiated a series of policy debates and academic controversies.

3. Considerable migration of unskilled labor from rural areas to the urban industry

   During China's transition period, we observe the large-scale migration of unskilled labor from rural areas to the urban industry. A total of 2 million migrant workers, most of which were unskilled laborers, first migrated in 1978; this number surged up to 268 million in 2013. The mobilization of labor from rural areas provides an excess supply of unskilled labor to the industry, which in turn contributed to the persistent growth of the Chinese economy. Due to rapid economic growth, substantial reports or data have been presented regarding rising migrant wages (see Figure 4), thus implying the shortage of unskilled labor in China. For example, according to the survey conducted by the CSSA, only 32% of firms could hire sufficient workers in 2007. At least one third of the firms experienced labor supply shortage, with a gap higher than 25%. Researchers such as Cai et al. (2007), Park et al. (2007), and Wang (2008), even argue that China has reached the Lewis turning point.

4. Income inequality between skilled and unskilled workers

   China's economic transition is accompanied by increasing income inequality, especially in terms of wage inequality between skilled and unskilled workers. Following Ge and Yang (2014), we use UHS data (1988-2012) to compute the skill premium. The results are reported in Figure 5, which also shows the trend of skill premium since 2000.[4] This skill premium increased considerably after China's entrance into the WTO, as widely documented in literature. However, the trend reversed in 2009; starting from this particular year, skill premium has declined rapidly from 0.474 to 0.393.[5]

[4] Here the skilled labor includes high school and college education. We also compute the case in which skilled labor only covers those with college education, and the obtained results are similar.

[5] The decline of skill premium also implies that there is no more excess supply of unskilled labor relative

5. Higher TFP growth in exporting sectors than in importing sectors

   The growth rate of tradable sectors in China has remained high since 2001. If we decompose the aggregate TFP growth by sectors, the technological improvement across sectors follows the prevailing pattern of a fast-growing country, that is, the tradable goods sector grows faster than non-tradable goods sector does. Moreover, using the Chinese manufacturing data and Chinese custom data, we compute the average TFP growth rate in export and import sectors during the period of 2001-2006. Overall, the former is growing significantly faster than the latter is, as shown in Figure 6.[6]

3 Cross-country Evidence

Conducting a full-fledged cross-country estimation for the determinant of the real exchange rate is beyond the scope of this work. In this section, we present some empirical evidence supporting our aforementioned hypothesis, that is, the accelerated TFP growth in the export sector over that in the import sector and the abundant unskilled labor supply depress real exchange rate appreciation.

3.1 Estimation Equations

At this point, we investigate the effect of the difference in the TFP growth of the export and import sectors as well as of the excess labor supply from rural to urban areas on the real exchange rate. We augment existing empirical models on the real exchange rate by including two additional regressors: the urban-rural migration rate and the gap between the growth rates of the export and import sectors. The latter is a proxy for the TFP difference between the export and import sectors. Conventional panel regressions with country and year fixed effects are presented as well.

Our estimation specification is as follows:

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to the supply of skilled labor.

[6]Two methods (OP and ACF) are used to estimate sector-level TFP. The estimation process is detailed in Appendix. Results are similar in both method; for simplicity, we report only the TFP estimated with the ACF method depicted in Figure 6.

$$\log(RER)_{i,t}=\alpha+\beta_1\text{migration}_{i,t}+\beta_2\ \text{diff\_exim}_{it}+\beta_3\ \text{diff\_exim}_{it}*\text{migration}_{i,t}+X_{i,t}+\delta_i+\zeta_t+e_{it}$$

where $\log(RER)_{i,t}$ refers to the log of real exchange rate of country i in year t, $\text{migration}_{i,t}$ is the rural-urban migration rate of country i, diff_exim_{it} is determined by subtracting export growth rate from the import growth rate, and $\text{diff\_exim}_{it}*\text{migration}_{i,t}$ is an interaction term. $X_{i,t}$ denotes other determinants of the RER, which includes GDP per capita, government expenditure/GDP, terms of trade, net foreign asset/GDP, real interest rate, and tariff rate. The choice of control variables is guided by Rogoff (1996), the International Monetary Fund (2006), and Du, Wei, and Xie (2013). δ_i captures the country effect and ζ_t the year effect.

3.2 Data Description

We start with data for 248 economies worldwide over the period of 1996-2013. However, as some observations drop out due to missing values in different variables, we conduct the panel regression in this period for 82 economies, 70 countries, and 67 countries, as listed in Columns 1, 3-5, and 6, respectively. A list of countries is provided in the Appendix for Table 1. The definitions and descriptive statistics for key variables of interest are presented in Table 1; additional details, including data sources, are shown in the Appendix for Table 2.

Our independent variable is a country's real exchange rate (RER). Our measure of RER is the real effective exchange rate index of the International Monetary Fund, which is constructed by dividing the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) with a price deflator or index of costs. Since the nominal exchange rate enters the index in its inverse form, we inverse the term so that a rise in RER denotes real depreciation; this notation is consistent with the conventional definition of the real exchange rate in our model. Note that the base year is 2010; as a result, only changes in log of RER, rather than in its absolute value, matter in cross-country comparison. In panel data, this issue is absorbed by the country fixed effects.

We utilize two key regressors. The first one is the urban-rural migration rate. We adopted the method of regional science to compute the country-level rural outmigration rate. The underlying assumption that total population growth does not stray too far from natural urban population growth appears to be rather strong at first glance; however, a close look at evidence suggests that the differences tend to be slight, at least for cross-country studies. The data for total population growth, urban population growth, and urban ratio are all available in the World Bank's World Development Indicator (WDI).

The second key regressor is an interaction term, which is the gap between the export and import growth rates multiplied by the migration rate. According to our hypothesis, the technological improvement in the export sector alone does not induce real exchange rate depreciation. It is the coexistence of abundant unskilled labor and uneven technological improvement within tradable sectors is able to break down the Balassa-Samuelson effect. The data for export and import growth rates both originate from WDI.

We follow existing literature on the determinants of RER and include the following control variables: income per capita, government expenditure, net foreign assets, commodity terms of trade, real interest rate, and trade restriction. The detailed data sources of these variables are listed in the Appendix for Table 2.

3.3 Panel Regression Results

Table 2 reports the panel regression results. Both country fixed effects and year fixed effects are included. Following Du, Wei and Xie (2013), we re-scale all the regressors by their standard deviations in the sample so that the magnitudes of the coefficients on variables become comparable with one another. Robust standard errors are clustered by country.

As per Column 1 of Table 2, migration rate alone is included as the key regressor aside from the control variables. The coefficient on migration is statistically significant and takes a positive sign. In accordance with our theory, an increase in migration rate by one standard deviation is associated with a 28% increase in the RER. In comparison, an improvement in per capita income by one standard deviation is associated with 49% real appreciation (Balassa-Samuelson effect). A rise in government expenditure shares by one standard deviation is associated with an 7% appreciation in RER (Froot-Rogoff effect). These estimates suggest that the economic significance of urban-rural migration can be greater than half the Balassa-Samuelson effect and roughly four times stronger than the Froot-Rogoff effect.

According to Column 2 of Table 2, only export growth rate minus import growth rate is included aside from the control variables. The coefficient takes the expected sign, although this value is not significant. Based on Column 3, the coefficients of the two regressors do not change much when both migration rate and export growth rate minus import growth rate are included. Nonetheless, the potential explanatory power of the new variable is highlighted by a substantial increase in R-squared from approximately 0.20 to 0.35 and an enhancement in the significance level of the migration rate from 10% to 1%.

As per Column 4 of Table 2, an interaction term of migration rate and export growth rate minus import growth rate is included aside from the two regressors and in combination with other control variables. The coefficient on the interaction term is statistically significant and takes a positive sign, whereas the coefficient on migration rate is not significantly affected. This outcome suggests that the gap between the export and import sectors in technological progress can only influence the RER through surplus labor. That is, when migration rate is equal to zero, the TFP growth gap within sectors has no significant effect on real exchange rate. Specifically, if migration rate is at the level of one standard deviation, then an increase in the growth rate of the export sector relative to the import sector by one standard deviation is associated with a depreciation in RER of 3%-4% (as suggested by the true model presented in Column 5); this occurrence is comparable with the economic effect of the terms of trade. Furthermore, if migration rate is as high as two standard deviation levels, then the influence of the TFP growth rate gap is also doubled, and so forth.

3.4 Robustness Check

We acknowledge that there could be endogeneity problem resulting from simultaneity between RER and the growth of export and import. Furthermore, we recognize that another instance of endogeneity can arise from the possibility that current growth in export and import are not independent of past RERs. To control for such dynamic endogeneity and simultaneity, we employ the generalized method of moments (GMM) estimation procedure for dynamic panels as introduced by Arellano and Bond (1991) to our panel. Past values of RER and export growth minus import growth are used as internal instruments for current export growth minus import growth. This eliminates the need for external instruments (Wintoki, et al., 2012) .

First, we rewrite the regression model as a dynamic model that includes lagged RER as explanatory variables. Second, we empirically examine how many lags are required. Glen, Lee, and Singh (2001) and Gschwandtner (2005) suggest that two lags are sufficient to capture the persistence of dependent variables. To confirm if two lags can ensure dynamic completeness, we estimate a model with three lags and find that indeed, the first lag alone is statistically significant; other lags are insignificant.[7] Third, we apply the three higher lags of the endogenous variable, the Export_Import term as its own instruments. Finally, we estimate a one-step dynamic GMM estimator with robust stand error clustering on countries. The results are appended in Column 6 of Table 2. The Arellano-Bond test for the AR(1) first-order serial correlation tests yields a p-value of 0.0003, as expected for differenced errors. The AR(2) second-order serial correlation test generates a p-value of 0.1168 that fails to reject the null hypothesis of no second-order serial correlation. The Sargan test of over-identification produces a p-value of 0.2612; therefore we cannot reject the hypothesis that our instruments are valid.[8] Our baseline results hold qualitatively in this dynamic panel GMM regression setup, although the magnitude of coefficients varies slightly. We thus conclude that surplus labor and the higher growth of the export sector relative to the import sector may depress RER appreciation.

4 Static Models

In this section, we set up two static models to reveal the main channels that we focus in this paper. To highlight the role of the two important features of China's transition, namely, the excess supply of unskilled labor and the uneven technological progress within the tradable goods sector, we begin with the two-sector model.

4.1 Two-sector Model with "Surplus Labor"

Underlying the Balassa-Samuelson effect is the wage linkage across sectors. The technological improvement in the tradable sector increases the marginal product of labor for workers and boosts real wages. Wages are equalized across sectors as a result of labor mobility; therefore, wages in the non-tradable goods sector also increases and boosts the price for non-tradable goods. In the process, real appreciation is observed along with TFP growth. Notably, the rise in wages is the key channel to generate the Balassa-Samuelson effect in the benchmark model. This channel may be insignificant when we observe abundant supplies of labor.

[7] In the table, the coefficients for lagged RER are suppressed because they are not of interest, but these coefficients are available upon request.

[8] We also conduct the system GMM introduced by Arellano and Bover (1995) and Blundell and Bond (1998) with the xtabond2 command in STATA as written by Roodman (2009). This approach yields Hansen J test, which is robust to heteroskedasticity. The results are qualitatively similar.

Consider a small open economy where the final good is a Cobb-Douglas aggregation of tradable and non-tradable goods. The aggregate price is simply given by $P = (P_T)^{\theta} (P_N)^{1-\theta}$, where P_T and P_N (T refers to the tradable goods sector and N to the non-tradable goods sector) are the prices of tradable and non-tradable goods, respectively. In such a setting, the real exchange rate can be measured by the relative price of non-tradable to tradable goods. For simplicity, we regard the tradable goods as the numeraire, and its price is normalized to 1 so that P_N can reflect the movement of the real exchange rate. The technologies applied in the two sectors are given as follows:

$$Y_i = A_i(\frac{L_i}{1-\alpha_i})^{1-\alpha_i}(\frac{K_i}{\alpha_i})^{\alpha_i}, \tag{4.1}$$

where $i = \{T, N\}$ denotes the sector i. L_i denotes the labor used in sector i, K_i is the capital used in sector i, and A_i is the TFP in sector i, respectively. In accordance with the literature, we assume that $\alpha_T > \alpha_N$, that is, that the non-tradable goods sector is more labor intensive than the tradable goods sector is.

In a competitive equilibrium, we obtain the following optimal conditions:

$$1 = \frac{(w)^{1-\alpha_T} r^{\alpha_T}}{A_T}, \tag{4.2}$$

$$P_N = \frac{(w)^{1-\alpha_N} r^{\alpha_N}}{A_N}, \tag{4.3}$$

where r is the return to capital and w is the wage of labor.

We consider an economy with "surplus labor" from rural areas, and assume an exogenous minimum wage level $w_{\min}$. Therefore, the equilibrium for this economy is characterized by Equations (4.2) and (4.3) as well as two additional constraints:

$$w = w_{\min}, \tag{4.4}$$

$$L_T + L_N < L, \tag{4.5}$$

where L is total labor supply in this economy. In equilibrium, we can solve for return to capital as follows:[9]

$$r = (w_{\min})^{1-\frac{1}{\alpha_T}} (A_T)^{\frac{1}{\alpha_T}}\,, \tag{4.6}$$

and the price of the non-tradable goods is simply given as follows:

$$P_N = \phi_2 \frac{(A_T)^{\frac{\alpha_N}{\alpha_T}}}{A_N}. \tag{4.7}$$

where $\phi_2 = (w_{\min})^{1-\frac{\alpha_N}{\alpha_T}} > 0$. On the basis of Equation 4.7, we establish the following proposition.

Proposition 1 *Consider an economy with "surplus labor". If the growth rate of technology in the tradable goods and non-tradable goods sectors satisfy the following condition* $\frac{g(A_T)}{g(A_N)} > \frac{\alpha_T}{\alpha_N} > 1$, *the (weaken) Balassa-Samuelson effect remains and real exchange rate appreciates with technology improvements.*

The proof is trivial and the intuition is straightforward: although the wage of labor is depressed to the minimum level, technological improvement drives up the demand for capital, which in turn boosts the real interest rate and increases the price of non-tradable goods. Note that P_N would drop if all sectors grow at the same rate. So result differs from that of the benchmark model of BS effect, where the real exchange rate appreciates as long as $A_T > A_N$. This outcome implies that if the technologies in both sectors improve, the price of non-tradable goods does not rise unless the tradable sector grows much faster than the non-tradable sector does. Therefore, introducing "surplus labor" into the benchmark model exerts a new effect on real exchange rates; nevertheless, a weak version of the Balassa-Samuelson effect remains.

4.2 Three-Sector Model with "Surplus Labor"

In this section, we propose a novel mechanism through which the Balassa-Samuelson effect may fail and a rapid growing economy may still experience real depreciation as well as cur-

[9] When the wage is depressed to the minimum level, the small open economy cannot take the world interest rate as given. There must be imperfect capital mobility across border. Therefore, the domestic return to capital can be determined endogenously, which guarantees the economy to produce both tradable goods. In this setting, the return to captial is the key to generate BS effect.

rent account surplus. To provide a transparent quantification of this new channel, we now introduce the Hecksher-Ohlin structure into the model. In particular, there are two tradable sectors that produce good 1 and good 2, and one nontradable sector that produces nontradable good 3. Skilled labor, unskilled labor and capital are available for production. Now the productions in both tradable and nontradable sectors use all the three factors. Therefore, the production functions in the four sectors are simply given by

$$Y_{it} = A_{it}(\frac{N_{it}}{\beta_i})^{\beta_i}(\frac{L_{it}}{\alpha_i})^{\alpha_i}(\frac{K_{it}}{\gamma_i})^{\gamma_i}, \tag{4.8}$$

where $i = \{1, 2, N\}$ denotes sector i; α_i, β_i, and γ_i are the unskilled labor income share, skilled labor income share, and capital income share in sector i, respectively. More specifically, the two tradable sectors, sector 1 and sector 2, are export and import sectors, respectively; sector N is the non-tradable sector.

Let p_i denotes the price of goods i. Then firm's optimal decisions on factor allocation give us

$$w_t L_{it} = \alpha_i p_{it} Y_{it}; \quad s_t N_{it} = \beta_i p_{it} Y_{it}, \text{ and } r_t K_{it} = \gamma_i p_{it} Y_{it}. \tag{4.9}$$

We can rewrite above equations (4.9) as the following:

$$p_{it} = \frac{(w_t)^{\alpha_i} (s_t)^{\beta_i} (r_t)^{\gamma_i}}{A_{it}}. \tag{4.10}$$

Let $\hat{x} = \Delta X/X$ denotes the ralative change of variable X. We can rewrite equation (4.10) as the following:

$$\hat{p}_{it} = \alpha_i \hat{w}_t + \beta_i \hat{s}_t + \gamma_i \hat{r}_t - \hat{a}_{it}. \tag{4.11}$$

Since this is a small open economy, the prices of tradable goods, p_{1t} and p_{2t}, is exogenously determined by the world market. Moreover, we focus on the scenario where there is excess labor supply. Therefore, $w_t = w_{\min}$ in equilibrium. Therefore, we have

$$\hat{p}_{it} = 0, \tag{4.12}$$

and

$$\hat{w}_t = 0. \tag{4.13}$$

Put equations (4.12) and (4.13) into (4.11), we have

$$\hat{r}_t = -\frac{\frac{1}{\beta_1}\hat{a}_{1t} - \frac{1}{\beta_2}\hat{a}_{2t}}{\frac{\gamma_2}{\beta_2} - \frac{\gamma_1}{\beta_1}}, \tag{4.14}$$

Thus, as long as the export sector is relatively more unskilled labor intensive than the import sector, i.e., $\frac{\gamma_2}{\beta_2} > \frac{\gamma_1}{\beta_1}$, the increase in A_{1t} will lead to the decline of return to capital. This result is essentially a corollary from the Stolper-Samuelson theorem. The intuition is straightforward: Since sector 1 is relatively more labor intensive, the technological progress in sector 1 reduces the relative demand of capital, and thereby leads to a fall in the rental rate of capital.

The price of non-tradable goods is endogenously determined, and it can be written as follows,

$$\hat{p}_N = \frac{\frac{\beta_N}{\beta_1}\frac{\gamma_2}{\beta_2} - \frac{\gamma_N}{\beta_1}}{\frac{\gamma_2}{\beta_2} - \frac{\gamma_1}{\beta_1}}\hat{a}_{1t} + \frac{\beta_N}{\beta_2}\frac{\frac{\gamma_N}{\beta_N} - \frac{\gamma_1}{\beta_1}}{\frac{\gamma_2}{\beta_2} - \frac{\gamma_1}{\beta_1}}\hat{a}_{2t} - \hat{a}_{3t}. \tag{4.15}$$

The above equation implies that as long as the skilled labor income share in the non-tradable sector, β_N, is not too high, a TPF growth in sector 1 can generate a decline in the price of non-tradable goods. Since the aggregate price is given by $P = (p_1)^{\theta_1}(p_2)^{\theta_2}(p_N)^{1-\theta_1-\theta_2}$, where θ_1 and θ_2 are the shares of two tradable goods in the final goods, and both p_{1t} and p_{2t} are exogenously given, a decline in p_{3t} indicates a real depreciation. Thus, our mechanism provide an opposite prediction on the real exchange rate compared to traditional Balassa-Samuelson effect.

In particular, define the skilled labor income share $\beta_N^* \equiv \frac{\gamma_N}{\gamma_2}\beta_2$. We need $\beta_N < \beta_N^*$ so that our mechanism dominates. Note that the condition $\beta_N > \beta_N^*$ is equivalent to $\frac{\beta_N}{\gamma_N} < \frac{\beta_2}{\gamma_2}$. Therefore, as long as the non-tradable sector is less skilled intensive than the import sector (and thus the export sector as well), the rapid growth in export sector induces the real depreciation. This finding suggests that uneven technology progress within the tradable sector and the abundant labor supply may reverse the Balassa-Samuelson effect.

We summarize the above findings as follows:

Proposition 2 *With excess supply of labor, the technological improvement in the more (less) labor-intensive tradable sector will lead to the decline (rise) of return to capital. Moreover,* *if non-trable sector is less (more) skilled intensive than the tradable sector, the real exchange rate will depreciate (appreciate).*

5 A Three-sector Dynamic General Equilibrium Model

The setup discussed above is simple and involves only the supply side of the economy. This setup can be used to analyze the long-run trend of real exchange rates. However, such a framework, as interesting as it is, cannot be used to examine the current account dynamics and other issues given that the demand side is neglected. As described in this section, we extend previous static models to a dynamic setting and develop a theory of economic transition that is consistent with the empirical facts documented in Section 2. We consider a small open economy that takes the prices of tradable goods as given.

We assume that the home country has an excess supply of unskilled-labor in addition to two tradable sectors and a non-tradable sector. Three factors are available for production: skilled labor, unskilled labor, and capital. The tradable goods sectors use all three factors, whereas non-tradable goods sector utilizes only unskilled labor and capital.[10]

5.1 Technology

The production functions in the three sectors are expressed as follows:

$$Y_j = A_j(\frac{N_j}{\beta_j})^{\beta_j}(\frac{L_j}{\alpha_j})^{\alpha_j}(\frac{K_j}{1-\alpha_j-\beta_j})^{1-\alpha_j-\beta_j}; j = 1, 2 \tag{5.1}$$

$$Y_N = A_N(\frac{L_N}{\alpha_N})^{\alpha_N}(\frac{K_N}{1-\alpha_N})^{1-\alpha_N}; \tag{5.2}$$

where N is skilled labor and L is unskilled labor. Sectors 1 and 2 are tradable goods sectors while sector 3 is the non-tradable goods sector. Capital and labor are presumably mobile

[10] As we illustrated in the static mode, the main mechanism on the real exchange rate works as long as the non-tradable sector is relatively less skilled labor intensive than the tradable sectors. The assumption that skilled labor income share equals to zero simplify our quantitative analysis significantly, but with the main channel sustained. Empirically, there are strong evidence in the literature on skill premium between tradable sectors and non-tradable sectors, which implies tradable sectors are more skilled labor intensive.

across sectors.[11] In equilibrium, we have the following conditions:

$$
\begin{aligned}
wL_j &= \alpha_j p_j y_j, \quad j=1,2 && (5.3a)\\
sN_j &= \beta_j p_j y_j \ , \quad j=1,2 && (5.3b)\\
rK_j &= (1-\alpha_j-\beta_j) p_j y_j, \quad j=1,2 && (5.3c)\\
wL_N &= \alpha_N p_N y_N, && (5.3d)\\
rK_N &= (1-\alpha_N) p_N y_N, && (5.3e)
\end{aligned}
$$

where $p_j = \frac{(w)^{\alpha_j}(s)^{\beta_j}(r)^{1-\alpha_j-\beta_j}}{A_j}$, $j=1,2$ and $p_N = \frac{(w)^{\alpha_N}(r)^{1-\alpha_N}}{A_N}$ are the sector prices for tradable goods and non-tradable goods, respectively.

We assume that there is a representative final goods producer, who aggregates the three sectoral goods into the final goods, that is, $D_t = G(D_{1t}, D_{2t}, D_{3t})$. For simplicity, we consider a Cobb-Douglas aggregation, $D_t = \frac{(D_{1t})^{\theta_1}(D_{2t})^{\theta_2}(D_{3t})^{(1-\theta_1-\theta_2)}}{(\theta_1)^{\theta_1}(\theta_2)^{\theta_2}(1-\theta_1-\theta_2)^{(1-\theta_1-\theta_2)}}$. Given the aggregation structure, the consumer price index is simply given by $P = (p_1)^{\theta_1}(p_2)^{\theta_2}(p_N)^{(1-\theta_1-\theta_2)}$. In such a setting, we can simply define the real exchange rate as $\frac{1}{p_N^{(1-\theta_1-\theta_2)}}$.[12]

5.2 The Household

The economy is inhibited by a continuum of identical and infinitely lived households that can be aggregated into a representative household. The preference of the representative household over consumption can be summarized by $\sum_{t=0}^{\infty} \tilde{\beta}_t U(C_t)$, where C_t denotes the consumption of the final goods and $\tilde{\beta}_t$ is the discount factor between period 0 and t, as given by

$$\tilde{\beta}_{t+1} = \beta\left(\tilde{C}_t\right)\tilde{\beta}_t, \ t \geq 0,$$

where $\tilde{\beta}_0 = 1$ and $\beta_{\tilde{C}} < 0$. We assume that the endogenous discount factor does not depend on the consumption of an individual household, but rather on the average per capita consumption

[11] For convenient presentation, we drop the subscription of T and N for the traded goods and non-traded goods sectors.

[12] Note that, the prices of traded goods are constant in the model; therefore, the changes in the price of non-traded goods can reflect the changes in the real exchange rate. We can consider the deviation from law of one price in the traded good sector so as to make the model more realistic, but this does not bring new insight for the paper. Hence, for simplicity, we focus on the relative price of non-traded goods to traded goods.

$\tilde{C}$, which an individual household takes as given. This preference specification was originally proposed by Uzawa (1968) and was introduced into the small open economy literature by Mendoza (1991).

The budget constraint and capital accumulation are expressed as follows:

$$P_t C_t + P_t I_t + P_t B_{t+1} + P_t \frac{\psi}{2} \left(B_{t+1} - \bar{B}\right)^2 = s_t N_t + w_t L_t + r_t K_t + (1 + r^*) P_t B_t, \tag{5.4}$$

$$(1 - \delta) K_t + I_t = K_{t+1}. \tag{5.5}$$

where N_t denotes skilled labor, L_t indicates unskilled labor, and r^* is the world interest rate, which is taken as given in our small open economy setup.

The first-order conditions with respect to C_t, K_{t+1}, and B_{t+1} yield the following:

$$U'(C_t) \left[1 + \psi \left(B_{t+1} - \bar{B}\right)\right] = (1 + r^*) \beta \left(\tilde{C}_t\right) U'(C_{t+1}), \tag{5.6}$$

$$U'(C_t) = \beta \left(\tilde{C}_t\right) U'(C_{t+1}) \left[1 - \delta + \frac{r_{t+1}}{P_{t+1}}\right]. \tag{5.7}$$

By using Equations (5.6) and (5.7), we immediately obtain

$$1 + \psi \left(B_{t+1} - \bar{B}\right) = \frac{1 + r^*}{1 - \delta + r_{t+1}/P_{t+1}}; \tag{5.8}$$

Therefore, households will choose to purchase additional foreign assets when the domestic interest rate decreases, thus resulting in capital inflow and current account surplus.

5.3 Characterization of Equilibrium

Now we are ready to characterize a competitive equilibrium. We first denote the aggregate demand of domestic residences for final goods as below

$$D_t = C_t + I_t + \frac{\psi}{2} \left(B_{t+1} - \bar{B}\right)^2. \tag{5.9}$$

Therefore, the domestic demands for tradable and non-tradable goods are given as follows, respectively,

$$D_{1t} = \theta_1 \frac{P_t D_t}{p_{1t}}, \tag{5.10}$$

$$D_{2t} = \theta_2 \frac{P_t D_t}{p_{2t}}, \tag{5.11}$$

$$D_{Nt} = (1 - \theta_1 - \theta_2) \frac{P_t D_t}{p_{Nt}}. \tag{5.12}$$

Let production in each sector j be Y^j. Then market clear condition for non-tradable goods requires:

$$Y_{Nt} = D_{Nt}. \tag{5.13}$$

The domestic factor markets also clear, implying that

$$N_1 + N_2 = N, \tag{5.14}$$

$$K_1 + K_2 + K_N = K, \tag{5.15}$$

$$L_1 + L_2 + L_N \leq L. \tag{5.16}$$

We divide the transition of the economy into two stages. At the first stage when TFP level is low, there are abundant unskilled labor, hence, $L_1 + L_2 + L_N < L$. The wage of unskilled workers is fixed at the minium level $w_{\min}$. As TFP keeps growing, the economy enters into the second stage and the excess unskilled labor supply disappears. The wage of unskilled workers starts to grow with the technology improvement. To simplify the analysis, we assume that the wage of unskilled workers w exogeneously increases as TFP grows at the second stage.

The pattern of unskilled labor wage is imposed exogenously in this section. We can endogenize such structure by introducing an agriculture sector into the economy. In the first stage, there exists excess unskilled labor in the agriculture sector, which implies that the unskilled labor will only be compensated by minimum wage. When the economy enters into the second stage, the unskilled labor constraint binds, and after which the unskilled wage rises endogenously with technology progress. In Technical Appendix B, we formally develop the extended model and show that the unskilled wage dynamics presents the same pattern as that assumed in this section.

Finally, a competitive equilibrium consists of a set of prices, allocation rules, and trade shares, such that: (1) given the prices, all firm's inputs satisfy the FOCs and the outputs are given by the production functions. (2) Given the prices, the consumers' demand satisfies the first-order conditions derived from the household's problem, and the bonds holdings satisfy the asset pricing rule (5.8). (3) The prices ensure the market clearing conditions for labor, capital, non-tradable goods, and the household budget constraint.

6 Quantitative Analysis

6.1 Calibration

Our model is calibrated at annual frequency. The parameter values are summarized in Table 3. We assume the period utility function $u(c) = \frac{C^{1-\gamma}}{1-\gamma}$, where the inverse of the elasticity of intertemporal substitution $\gamma = 2$. The steady state discount factor $\beta = 0.96$, which implies a 4% annual world interest rate. Following Choi, Mark, and Sul (2008), the endogenous time discount factor takes the function form $\beta\left(\tilde{C}_t\right) = \beta\left(\frac{\tilde{C}_t}{\tilde{C}}\right)^{-\phi}$, where $\phi = 0.1$.

We assume that non-tradable goods constitute approximately 50% of the final goods and that the tradable goods have equal share in the final good; this implies that $\theta_1 = \theta_2 = 0.25$. We set the production parameters as follows: $\alpha_1 = 0.35, \beta_1 = 0.35$, $\alpha_2 = 0.1, \beta_2 = 0.1, \alpha_N = 0.65$ such that the average capital shares in the tradable and non-tradable goods sector are 0.55 and 0.35, respectively; These shares are similar to those estimated from China's input-output table in 2002. The annual depreciation rate of capital δ is set to 0.1. Following Schmitt-Grohe and Uribe (2003), the coefficient for bond adjustment costs ψ_b is set to 0.0007. For simplicity, the value of the skilled-labor supply N is normalized to 1.

Table 3: Parameter Values in the Calibrations

β	discount factor in steady state	0.96
γ	inverse of the elasticity of intertemporal substitution	2
α_1	unskilled-labor share in sector 1	0.35
β_1	skilled-labor share in sector 1	0.35
α_2	unskilled-labor share in sector 2	0.1
β_2	skilled-labor share in sector 2	0.1
α_N	unskilled-labor share in sector 3	0.65
θ_1	share of goods 1 in the final goods	0.25
θ_2	share of goods 2 in the final goods	0.25
N	skilled-labor supply	1
ψ_b	coefficient for convex bond adjustment costs	0.0007
δ	capital depreciation rate	0.1
ϕ	parameter of endogenous discount factor	0.1
$\overline{B}$	initial bond level	0
A_1	productivity in sector 1	1
A_2	productivity in sector 2	1
A_N	productivity in non-tradable sector	1

It is assumed that sectoral productivity $A_1 = A_2 = A_N = 1$ in the initial steady state. We further choose the prices of tradable goods prices to make $r = r^*$ so that $B = 0$ in the initial period. Given the prices, we pin down the initial unskilled-wage, which is assumed to be exogenous in the model. The numerical methods for solving steady state and transition dynamics are presented in Technical Appendix A.

6.2 Results

As explained in this section, we evaluate the model quantitatively. Note that we are interested in the dynamics of the real exchange rate and current account in an economy featured with abundant unskilled labor supply as well as the experience of fast TFP growth in tradable sectors. Thus, we consider that our modeling economy starts from the initial steady state while $A_1 = 1$ and transits to the new steady state with $A_1 = 1.04$ while A_2 and A_N remain unchanged.[13] Following Chen, Imrohoroglu, and Imrohoroglu (2006), we solve the transition dynamics with the shooting algorithm.

6.2.1 TFP Shocks and Wage Structure

Based on the evidence we described in Section 2, the exporting sector generically grows faster than importing sector does while China has maintained a high growth rate in the tradable goods sectors since 2001 (see Figure 6). Moreover, the supply of unskilled labor from rural areas has continually increased since the early 1990s, which drives the upward trend of skill premium. Significant controversies have arisen on whether or not China has reached the Lewis turning point, that is, whether or not an excess supply of unskilled labor is detected. Interestingly, Bai, Liu, and Wen (2020) recently reported that the skill premium began to decrease after 2008.

To capture the technological improvement in China after 2001, we normalize the TFP growth in both the import and non-tradable goods sectors and consider permanent TFP growth in the export sector. In particular, the TFP in this sector increases smoothly by 4%, whereas those of the other two sectors remain unchanged. Based on the aforementioned feature of the wage structure in China, the wage of unskilled labor remains constant at the first stage of our modeling economy. The wage rate starts to increase at the second stage. Eventually, both the TFP in the export sector and wage stop growing, and the economy arrives at the new steady state.

As for the wage structure of unskilled labor, it presents different patterns as the economy grows. In particular, we can divide the transition of the economy into two stages. At the first stage when TFP level is low, there are abundant unskilled labor supply and thus the unskilled labor constraint does not bind. The wage of unskilled workers is fixed at the minium level. As the economy keeps growing and enters into the second stage, the demand for unskilled labor is much higher so that the excess unskilled labor supply disappears. The wage of unskilled workers then starts to grow with the technology improvement.

The details of the TFP shocks and of the changes in wage structure are described in Figure 7.

[13] Since we normalize A_2 and A_3 in our simulation, our results of the variables can be interpreted as the departure from their long-run trend.

6.2.2 Factor Prices and Goods Prices

The effect of TFP shocks on factor prices are summarized in Figure 8. As we expected, the technological improvement in the export sector, which is the labor-intensive sector, leads to a fall in the return to capital.[14] Wage inequality continues to increase. At the first stage in which the wage of unskilled labor is constant, the demand for skilled labor rises with TFP growth, which drives the upward trend of skill premium. During the second stage, the wages for both unskilled and skilled workers start to increase. The skill premium may still increase, but its growth rate slows down slightly.

In our environment, the law of one price holds. Thus, the prices of tradable goods p_1 and p_2 are not affected by TFP shocks. The price of non-tradable goods p_N responds to the shocks quite differently at the two stages. In the early stage wherein abundant unskilled labor supply and its wage w do not respond to technological improvement, the price of non-tradable goods drops with the decline of r. This result is straightforward since unskilled labor and capital alone are used for production in the non-tradable goods sector. In the second stage in which the unskilled labor constraint starts to become binding, the wage of unskilled workers increases and boosts the price of the non-tradable goods. Moreover, the effect of rising wages on p_N dominates that of decreasing return to capital, and overall, p_N begins to rise in the second stage. The aggregate price P follows the same pattern as p_N: dropping at the first stage and then rising to the new steady state. The effects on the prices of goods are illustrated in Figure 8.

6.2.3 Real Exchange Rate, Trade, and Foreign Asset Holdings

Our paper focuses on the trend of real exchange rate. As the evidence presented above indicates, the Chinese real exchange rate depreciated first and then began to appreciate recently. Qualitatively, our model can replicate this interesting pattern.[15] The dynamics of

[14] Note that another channel that may contribute to the fall in the return to capital is the FDI inflows during this period. However, in the early years of 2000 in China, the FDI inflow only accounts for 3-4 percent of GDP, while the domestic investment is more than 35 percent of GDP. Therefore, given the relative size of FDI to domestic investment, it is difficult to argue that FDI inflow is the key driving force that pushes down the return to capital, even though it may has some impacts on the return to capital. To simply the analysis, we abstract FDI flows from the model.

[15] Quantitatively, there still a large room to improve. Nonetheless, we will leave this aspect for subsequent research.

real exchange rate are described in Figure 9.

Figure 9 also illustrates the dynamics of exports, imports, foreign asset holdings, and current accounts. With the technological improvement in the export sector, both the export and import sector expand and double in volume; this outcome is also qualitatively consistent with Chinese data suggesting that trade expanded rapidly after 2001. Meanwhile, net export is positive; therefore, the economy starts to accumulate additional foreign assets. The holdings of foreign bonds holdings rise significantly during this period from 0% to more than 3% of GDP. During entire periods with fast-growing TFP, the economy runs a current account surplus.

6.2.4 Factor Allocations, Aggregate Consumption, and Output

We compute the transition dynamics for factor allocations, aggregate consumption, and outputs. The results are summarized in Figure 10.

With the accelerated TFP growth rate in the export sector, more resources unsurprisingly flow into this sector. The export sector begins to use increased amounts of capital, skilled labor, and unskilled labor, thereby driving up its output rapidly. Meanwhile, the expansion of the export section crowds out all factors for the other two sectors; as the result, output declines in these sectors. Interestingly, aggregate consumption, capital stock, and output drop with an increasing A_1.[16]

7 Conclusion

This paper presents a simple theory to explain the dynamics of China's real exchange rate and other stylized facts during the fast-growing period since China joined the WTO. We argue that the faster TFP growth in the export sector over that in the import sector and the excess supply of unskilled labor may help explain the Chinese real exchange rate and other stylized facts, such as the significant current account surplus and the considerable rise of skilled wage premium. Surprisingly, our hypothesis is also supported by cross-country evidence. We first build static models to explain why the real exchange rate may depreciate

[16]Note that we normalize A_2 and A_3 in the model. Therefore, declines in consumpiton and output should not be intepreted as the reduction in level; rather, the results should be interpreted as relative changes from their trends.

during this fast-growing period; subsequently, we develop a dynamic general model with an H-O structure and heterogenous (skilled vs unskilled) labor to explain the dynamics of both the real exchange rate and current account.

The goal of our present study is to propose a novel mechanism through which a rapid growing economy may still experience real depreciation as well as current account surplus. To provide a transparent quantification of this new channel, we consider a very simple model, and therefore is limited quantitatively to match the level of China's current account. Building a fully-fledged model that can explain quantitatively the current account dynamics is certainly an important topic, but is also beyond the scope of this paper. We leave this for future research.

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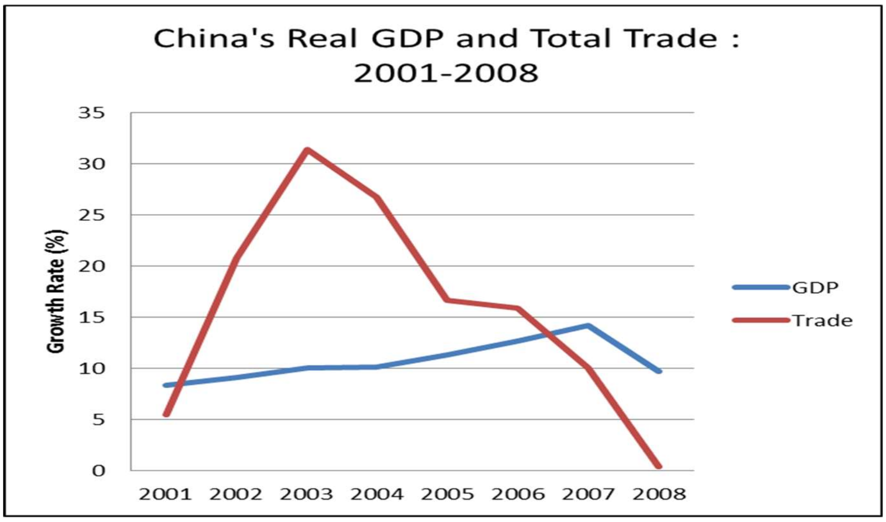
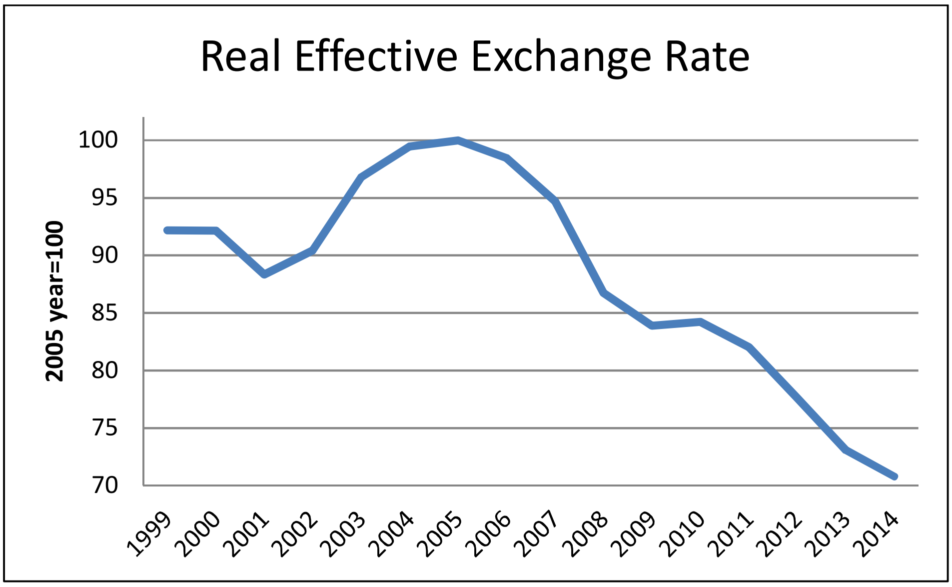
Figure 1:



Source: National Bureau of Statistics of China

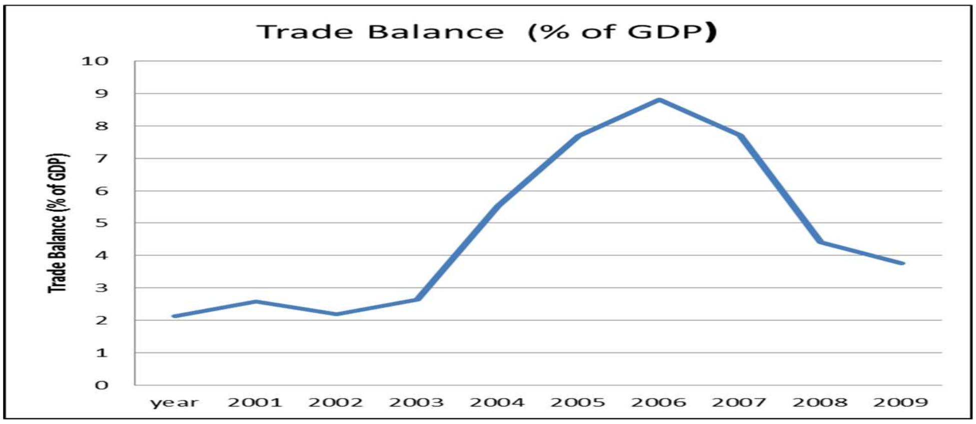
Figure 2:



Source: International Monetary Fund, International Financial Statistics

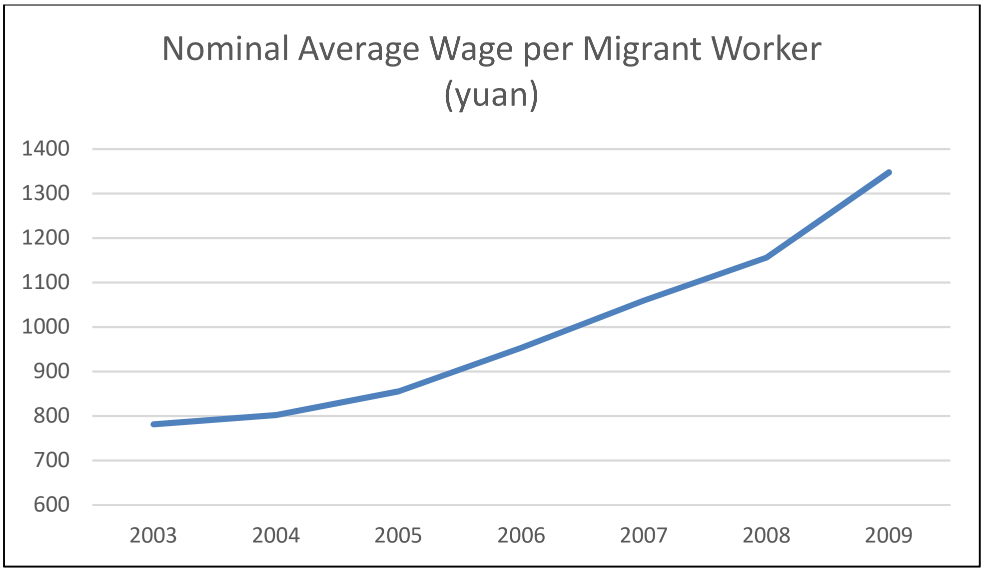
Real effective exchange rate index (2005 = 100)

Figure 3:



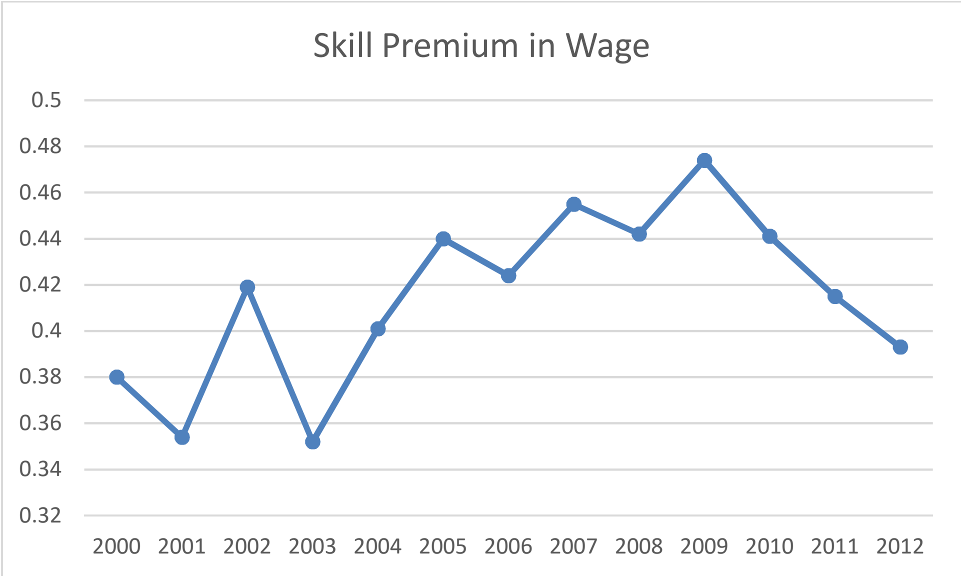
Source: International Monetary Fund, Balance of Payments Statistics Yearbook and data files

Figure4:



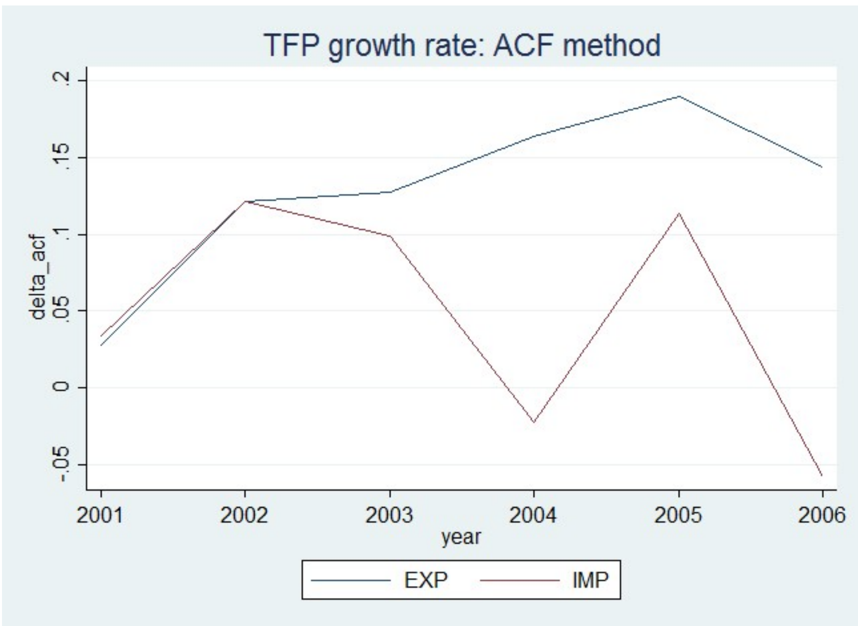
Source: Zhao and Wu (2008) for 2003-6; Ministry of Agriculture (2010) for 2007-9

Figure 5:



Source: UHS data, computation results from Bai, Liu and Yao (2015)

Figure 6:



Source: Author's Computation using the Chinese manufacturing

data and Chinese custom data

Figure 7:

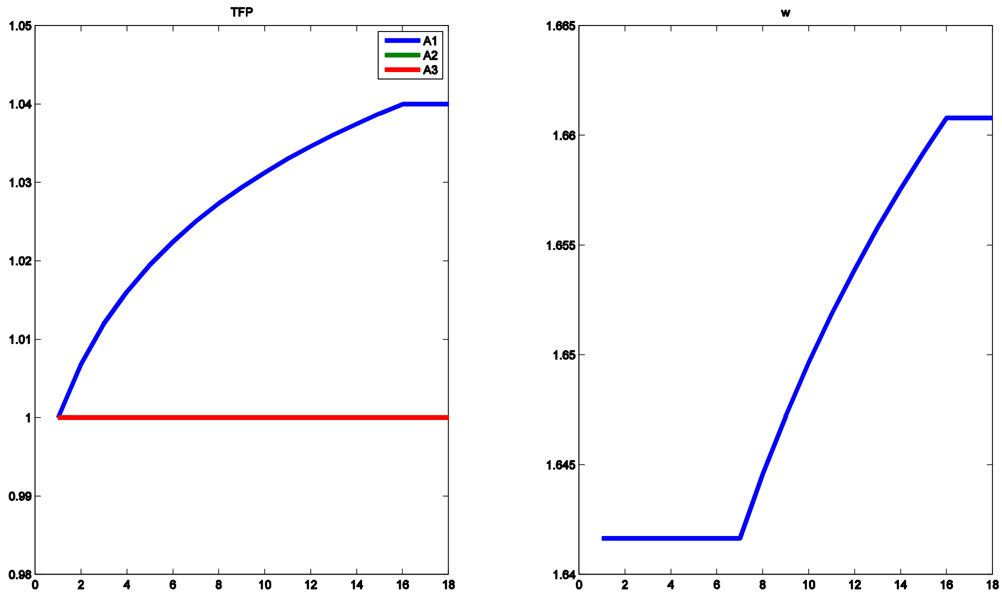


Figure 8:

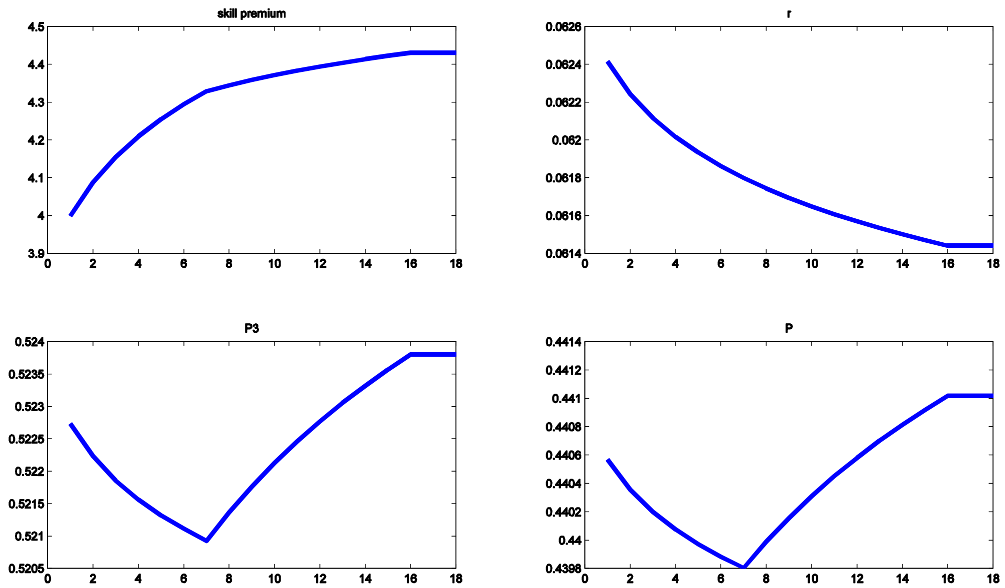


Figure 9:

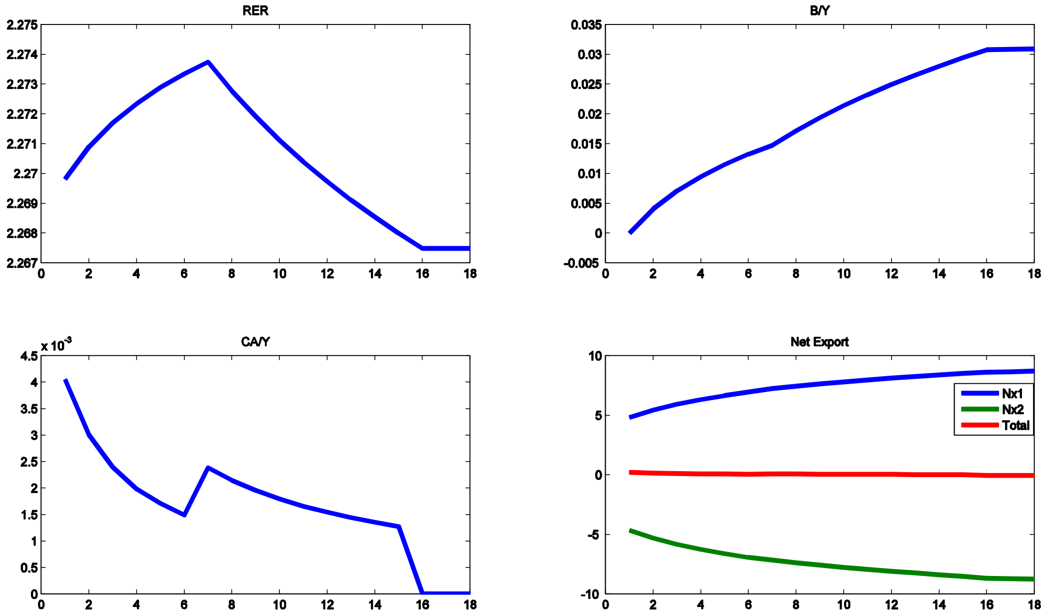


Figure 10: Factor Allocations, Aggregate Consumption and Output

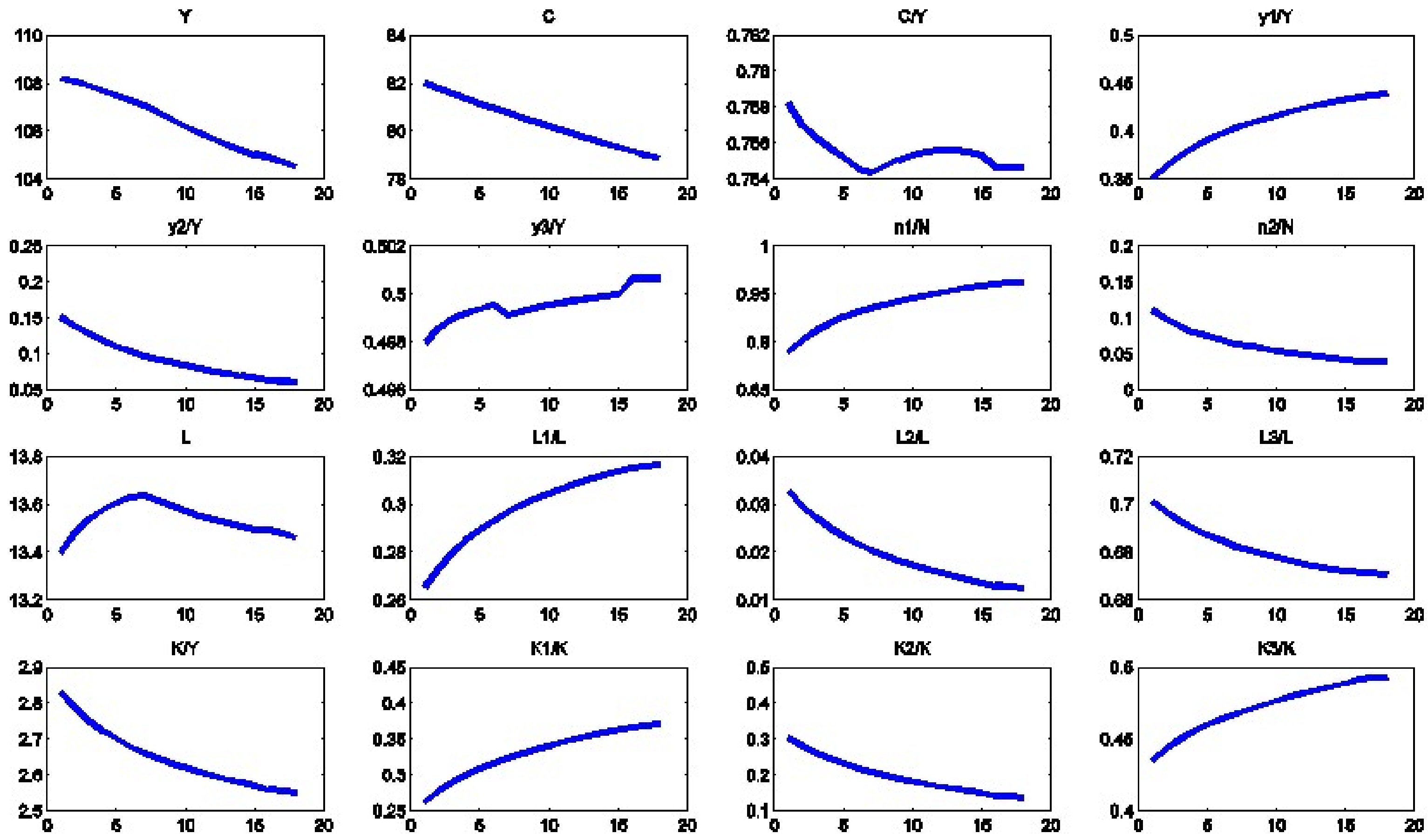


Table 1: Definition and Summary Statistics of Key Variables for Cross Countries (1996-2013)

Variable Definitions	Variable Names	Obs	Mean	Std. Dev.	Min	Max
RER = Real Exchange Rate	***Log (100/REER*100)***	1689	4.56	0.24	2.28	5.60
Migration Rate = $(\mu_t-\rho_t)u_t/(1-u_t)$	***Migration Rate***	4278	0.98	5.51	-5.08	350.72
Export_Import_Developing = Export growth rate – import growth rate	***Diff_exim***	2835	-0.26	7.50	-20.45	21.57
Log GDP per capita in 2011 PPP dollars	***Log GDP/capita***	3942	8.98	1.22	5.02	11.84
GOV/GDP = (government expenditure/GDP)	***GOV/GDP***	3676	16.19	7.96	2.05	156.53
Terms of Trade (ToT)= Net barter terms of trade index (2000 = 100)	***Terms of Trade***	3105	108.17	32.19	21.22	262.09
Net Foreign Asset/GDP	***NFA/GDP***	3126	0.25	0.82	-1.98	14.06
Real Interest Rate, in %	***Real Interest Rate***	2565	8.14	20.07	-96.87	572.94
Tariff Rate = Trade weighted applied tariff rate, in percentage points	***Tariff Rate***	2108	7.22	8.87	0.00	254.58

Data Sources: For detailed information on data sources and definition of terms, please refer to Appendix Table 2

Table 2: Panel Regressions

Dependent Variable	Log Real Exchange Rate(Index 2010=100)					
	(1)	(2)	(3)	(4)	(5)	(6)
Migration Rate	0.283*		0.274***	0.267***	0.265***	0.136***
	(0.148)		(0.0898)	(0.0915)	(0.0923)	(0.0344)
Diff_exim		0.00612	0.00613	0.00225		1.34e-05
		(0.00534)	(0.00537)	(0.00581)		(0.00587)
Diff_exim *Migration Rate				0.0322*	0.0384**	0.0534***
				(0.0184)	(0.0190)	(0.0175)
lgdp_pcsd	-0.493***	-0.507***	-0.546***	-0.544***	-0.543***	-0.330**
	(0.0756)	(0.105)	(0.107)	(0.105)	(0.105)	(0.136)
gov_gdpsd	-0.0698**	-0.102*	-0.105*	-0.103*	-0.102*	0.0258
	(0.0335)	(0.0560)	(0.0566)	(0.0571)	(0.0574)	(0.0258)
totsd	-0.0229	-0.0417**	-0.0340**	-0.0348**	-0.0350**	-0.000561
	(0.0259)	(0.0161)	(0.0169)	(0.0171)	(0.0172)	(0.0293)
nfa_gdpsd	0.0983**	0.147**	0.144***	0.145***	0.144***	0.0469**
	(0.0413)	(0.0556)	(0.0508)	(0.0516)	(0.0514)	(0.0230)
rirsd	-0.00195	-0.0454	-0.0439	-0.0447	-0.0444	-0.0265**
	(0.0178)	(0.0302)	(0.0287)	(0.0283)	(0.0283)	(0.0122)
tariffsd	-0.0554	-0.0312	-0.0306	-0.0322	-0.0323	0.0230
	(0.0348)	(0.0474)	(0.0469)	(0.0470)	(0.0470)	(0.0163)
Observations	710	599	585	585	585	448
R-squared	0.198	0.331	0.348	0.350	0.350	/
Number of id	82	71	70	70	70	67
Country FE	YES	YES	YES	YES	YES	/
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix for Table 1: List of countries used in the cross-country sample

82 countries included in Column 1 are: Algeria*, Antigua and Barbuda, Armenia*, Australia*, Bahamas*, The, Bahrain*, Belgium*, Belize*, Bolivia*, Bulgaria*, Burundi*, Cameroon*, Canada*, Central African Republic*, Chile*, China*, Colombia*, Congo, Dem. Rep. *, Costa Rica*, Croatia*, Cyprus*, Czech Republic*, Denmark*, Dominica, Dominican Republic*, Ecuador*, Equatorial Guinea*, Fiji, Finland*, France*, Gabon*, Gambia, The, Georgia*, Germany*, Greece*, Grenada, Guyana, Hungary*, Iceland*, Iran, Islamic Rep. *, Ireland*, Israel*, Italy*, Japan*, Lesotho*, Macedonia, FYR*, Malawi*, Malaysia*, Malta*, Mexico*, Moldova*, Morocco*, Netherlands*, New Zealand*, Nicaragua*, Nigeria*, Norway*, Pakistan*, Papua New Guinea*, Paraguay*, Philippines*, Poland*, Romania*, Russian Federation*, Sierra Leone, Slovak Republic*, Solomon Islands, South Africa*, Spain*, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sweden*, Switzerland*, Tonga, Trinidad and Tobago*, Uganda*, Ukraine*, United Kingdom*, United States*, Uruguay*, Venezuela, RB*

Notes: A subset of 70 countries, denoted by a "*", are also included in Column 3 – 5.

Appendix for Table 2: Detail of Data Resource and Definition

No.	Variable	Component	Source
1	Real Exchange Rate (2010=100)	Real Effective Exchange Rate Index (2010=100)	World Bank: http://data.worldbank.org/indicator/PX.REX.REER
2	Migration Rate	Rate of growth of total population (annual %)	World Bank: http://data.worldbank.org/indicator/SP.POP.GROW
		Rate of growth of urban population (annual %)	World Bank: http://data.worldbank.org/indicator/SP.URB.GROW
		Urban population (% of total)	World Bank: http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS
3	Diff_exim	Exports of goods and services (annual % growth)	World Bank: http://data.worldbank.org/indicator/NE.EXP.GNFS.KD.ZG
		Imports of goods and services (annual % growth)	World Bank: http://data.worldbank.org/indicator/NE.IMP.GNFS.KD.ZG
4	GDP per capita	GDP, PPP (constant 2011 international $)	World Bank: http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD
5	GOV/GDP	General government final consumption expenditure (% of GDP)	World Bank: http://data.worldbank.org/indicator/NE.CON.GOVT.ZS
		GDP (current LCU)	World Bank: http://data.worldbank.org/indicator/NY.GDP.MKTP.CN
6	Terms of Trade	Net barter terms of trade index (2000 = 100)	World Bank: http://data.worldbank.org/indicator/TT.PRI.MRCH.XD.WD
7	Net Foreign Assets/GDP	Net foreign assets (current LCU)	World Bank: http://data.worldbank.org/indicator/FM.AST.NFRG.CN
8	Real interest rate (%)	Lending interest rate adjusted for inflation, GDP deflator	World Bank: http://data.worldbank.org/indicator/FR.INR.RINR
9	Tariff Rate	Net barter terms of trade index (2000 = 100)	World Bank: http://data.worldbank.org/indicator/TT.PRI.MRCH.XD.WD

Data and Methods for TFP Estimation (not for publication):

2000-2006 merged industrial firm data and custom data (Generally 30% of custom firms can be matched.)

year	merged	manu	custom
2000	26359	162885	88105
2001	30446	171256	97086
2002	34861	181557	113473
2003	39772	196222	134826
2004	61734	279092	165372
2005	62664	271835	191346
2006	66380	301961	219942

OP method:
Assume capital is dynamic input and labor is freely adjusted in each period, and investment is strictly increasing in TFP. Firm's exit rate is related to its age, capital stock and use Poisson distribution to proxy it. Then use the high order polynomial term to proxy the TFP in regression.

ACF method:
Assume capital is dynamic input and labor is freely adjusted in each period, and investment in strictly increasing in TFP, but material input is. No exit rate included. However material and labor may have collinearity problem. So lag term of labor is used as IV for labor, and the high order polynomial term is used to proxy the TFP in regression.
ACF is an updated version of OP without exit rate. TFP can be considered as the adjusted Solow residual.

Importing sector and exporting sector:
Calculate the total import and export of each 4 digit level industry; if export is larger than import, then define it as exporting sector, otherwise, it is importing sector. The number of exporting sector is larger than importing sector.

Aggregate TFP growth rate:
Use value added of each firm as weight; calculate the weighted average TFP of each industry and also its growth rate year over year. During which, the extreme value of TFP is trimmed. The extreme values may come from the wrong data reported by firms.
Then calculate the growth rate of importing sector and exporting sector by weighted average growth rate of the corresponding industry in each sector. The year over year growth rates of TFP from OP method and ACF method generally give the same pattern.

Technical Appendix (not for publication)

A Solving Steady State and Transition Dynamics

A.1 Steady State

In the steady state, w is exogenous since there is excess labor supply in home country. Moreover, $B_{t+1} = \bar{B}_h = 0$, $C_t = C_{t+1}$.[17]

A.1.1 Equilibrium Conditions

The following conditions must hold in a stationary equilibrium.

- Asset pricing for bonds:

$$\frac{r}{P} = r^* + \delta; \tag{A.1}$$

- Euler equation,

$$1 = \beta\left(\tilde{C}_{ht}\right)\left(1 - \delta + \frac{r_h}{P_h}\right) = \beta\left(\tilde{C}_{ht}\right)(1 + r^*); \tag{A.2}$$

- 8 equations of efficient production, (5.3a);
- 3 unit cost equations and 1 Price index, (**??**)-(**??**);
- 3 Factor allocation across sectors:

$$N_1 + N_2 = N; \tag{A.3}$$

$$K_1 + K_2 + K_N = K; \tag{A.4}$$

$$L_1 + L_2 + L_N = L; \tag{A.5}$$

- Budget constraint,

$$P_t D_t = s_t N_t + w_t L_t + r_t K_t + r^* P_t B_t, \tag{A.6}$$

[17] Let's assume that there is no perpetual TFP growth in S.S. (it can be easily extended)

A.1.2 Computing the initial S.S.

Here is the steps that we solve for the steady state for our modeling economy. Note that in our SOE, $r^* = 1/\beta - 1$ taken exogenously.

1. $r^* = 1/\beta - 1$. Immediately, we obtain r/P
2. Given $w, p_1 = 1$, according to 4 equations of prices, we obtain $\{s, p_2, p_N, P\}$ as functions of r.
$$p_j = \frac{(w)^{\alpha_j}(s)^{\beta_j}(r)^{1-\alpha_j-\beta_j}}{A_j},\ p_N = \frac{(w)^{\alpha_N}(r)^{1-\alpha_N}}{A_N};$$
$$\Longrightarrow s = \left[\frac{A_1 p_1}{(w)^{\alpha_1}(r)^{1-\alpha_1-\beta_1}}\right]^{\frac{1}{\beta_1}};$$
3. Use r/P, we can pin down r
4. Then pick N_1, we can solve for $\{N_2, Y_1, Y_2, K_1, K_2, L_1, L_2\}$
5. Given capital stock K, we can solve for $\{K_N, L_N\}$
6. Then N_1 can be pinned down by:
$$\frac{wL_N}{\alpha_N} = (1 - \theta_1 - \theta_2)(s_t N_t + w_t L_t + r_t K_t + r^* P_t B_t)$$
And thus, we can solve for the total labor supply when the constraint does not bind.

A.1.3 Computing the final S.S.

Note that $w = 0.4597$, $p_1 = 1$ and $p_2 = 0.5270$, which are given by the initial steady state.

1. given $\{w, p_1, p_2\}$, we can solve $\{r, s, p_N\}$ using unit cost functions
2. compute P by price index
3. since $r^* = 1/\beta - 1$. Immediately, we obtain B by $1 + \psi\left(B - \bar{B}\right) = \frac{1+r^*}{1-\delta+r/P}$
4. compute C by (A.2)

- $\left(\frac{\tilde{C}_t}{\tilde{C}}\right)^{\phi} = \beta\left(1-\delta+\frac{r_h}{P_h}\right)$

5. $P_t D_t$ is a function of K_t

   - $PD = PC + P_t\delta K + P_t\frac{\psi}{2}\left(B_{t+1}-\bar{B}\right)^2$

6. thus, L_N is a function of K

$$\frac{wL_N}{\alpha_N} = p_{3t}Y_{3t} = p_{3t}D_{3t} = (1-\theta_1-\theta_2)\left(P_t D_t\right)$$

7. once we get L_N, we have $y_N \& K_N$ as a function of K

$$\begin{aligned} wL_N &= \alpha_N p_N y_N, \\ rK_N &= (1-\alpha_N) p_N y_N, \end{aligned}$$

8. from resource reallocation, $\{K_1, K_2, N_1, N_2, L_1, L_2, L\}$ are functions of K

$$\begin{aligned} wL_j &= \alpha_j p_j y_j, \quad j = 1,2 \\ sN_j &= \beta_j p_j y_j\ , \quad j = 1,2 \\ rK_j &= (1-\alpha_j-\beta_j) p_j y_j, \quad j = 1,2 \end{aligned}$$

$$\Longrightarrow k_j^N = \frac{K_j}{N_j} = \frac{(1-\alpha_j-\beta_j)}{\beta_j}\frac{s}{r};$$

   - $k_1^N N_1 + k_2^N N_2 = K - K_N \Longrightarrow N_1 = \frac{K-K_N-k_2^N N}{k_1^N-k_2^N} \Longrightarrow N_2, K_1, K_2$
   - $sN_j = \beta_j p_j y_j \Longrightarrow y_1 \& y_2$
   - $wL_j = \alpha_j p_j y_j \Longrightarrow L_1 \& L_2$

9. Finally, the budget constraint (A.6) will pin down K

$$P_t D_t = s_t N_t + w_t L_t + r_t K_t + r^* P_t B_t$$

Therefore, we solved the case where there is unskilled labor surplus.

A.2 Transition Dynamics

We are interested in the transition dynamics of the real exchange rate for an economy with abundant unskilled labor supply that experiences fast TFP growth in tradable good sector. Therefore, it is necessary to go beyond the steady state analysis and compute the transition path for the economy facing a permanent TFP shock.

Consider the economy starts from initial steady state. Now suppose A_1 increases from 1.0 to 1.04, while A_2 and A_N stay unchanged. Following Chen, Imrohoroglu and Imrohoroglu (2006), we use shooting algorithm to solve the dynamics. Here is the details:

1. given TFP series, wage and exogenous prices of tradable goods, we can solve for $\{r_t, s_t, p_{N,t}, P_t, B_{t+1}\}$

   (a) solve $\{r_t, s_t, p_{N,t}\}$ using unit cost functions

   (b) compute P by price index

   (c) B_{t+1} is given by $1 + \psi\left(B_{t+1} - \bar{B}\right) = \frac{1+r^*}{1-\delta+r_{t+1}/P_{t+1}}$;

2. Given current period capital stock, K_t, solve the real allocations.

   (a) compute aggregate demand

$$P_t D_t = s_t N_t + w_t L_t + r_t K_t + (1 + r^*) P_t B_t - P_t B_{t+1}$$

   (b) Compute L_{3t}, Y_{3t} :

$$\frac{wL_N}{\alpha_N} = p_{3t} Y_{3t} = p_{3t} D_{3t} = (1 - \theta_1 - \theta_2)(P_t D_t)$$

   (c) once we get L_{3t}, we have $y_{3t} \& K_{3t}$ as a function of K

$$\begin{aligned} wL_N &= \alpha_N p_N y_N, \\ rK_N &= (1 - \alpha_N) p_N y_N, \end{aligned}$$

(d) from resource reallocation, we obtain $\{K_1, K_2, N_1, N_2, L_1, L_2, L\}$

$$k_j^N = \frac{K_j}{N_j} = \frac{(1-\alpha_j-\beta_j)}{\beta_j}\frac{s}{r};$$

$$N_1 = \frac{K - K_N - k_2^N N}{k_1^N - k_2^N}.$$

and then solve for $N_2, K_1, K_2, L_1, L_2, y_1, y_2$.

3. Guess K_{t+1},

(a) get investment and consumption as follows:

$$I_t = K_{t+1} - (1-\delta) K_t;$$

$$C_t = D_t - I_t - \frac{\psi}{2}\left(B_{t+1} - \bar{B}\right)^2.$$

(b) can compute next period consumption by:

$$(C_{t+1})^{\rho+\phi} = \beta (C_t)^\rho \left(\bar{C}\right)^\phi \left[1 - \delta + \frac{r_{t+1}}{P_{t+1}}\right];$$

(c) compute real allocations in period $t+1$, $D_{t+1}, L_{t+1}, Y_{t+1}, ...$ following step 2

(d) compute I_{t+1} by

$$I_{t+1} = D_{t+1} - C_{t+1} - \frac{\psi}{2}\left(B_{t+2} - \bar{B}\right)^2$$

(e) thus, we obtain K_{t+2} by

$$K_{t+2} = I_{t+1} + (1-\delta) K_{t+1}.$$

and iterate.

4. If diverge, adjust initial guess and go to step 3.

The above algorithm can find a stable transition path to the new steady state for the emerging economy.

B Introducing Endogenous Wage Structure

In this appendix, to make the unskilled wage endogenously determined, we introduce an agriculture sector in the small open economy. In the early stage of development, there is excess unskilled labor supply in the agriculture sector, which implied that the unskilled labor will be only compensated by minimum wage. However, due to technology improvement, when it reaches a certain threshold, the demand for unskilled labor will rise up, and eventually there will no excess unskilled labor supply in the economy. As a result, in the second stage, the unskilled wage will be endogenously determined in the labor market and goes up with technology progress.

B.1 Model

We describe the economy in details as below. There are four sectors that produce tradable good 1, tradable good 2, agriculture good 3 and nontradable good 4, respectively. Skilled labor, unskilled labor and capital are available for production. In particular, tradable goods 1 and 2 use all three factors. The agriculture product is also tradable goods, but its production only uses unskilled labor and capital. The non-tradeable goods 4 only uses unskilled labor and capital as that in the paper. The production functions in the four sectors are simply given by

$$Y_{it} = A_{it} F_i \left(L_{it}, N_{it}, K_{it} \right), \quad i = 1, 2; \tag{B.7}$$

$$Y_{jt} = A_{jt} F_j \left(L_{jt}, K_{jt} \right), \quad j = 3, 4; \tag{B.8}$$

where N_i denotes for skilled labor used in sector i ($i = 1, 2$), and L_j for unskilled labor used in sector j ($j = 1, 2, 3, 4$). A_{it} measures total factor productivity in sector i, which is exogenous in the model. All production functions are assumed to be homogeneous of degree one. Both capital and labor are mobile across sectors. The market is perfectly competitive. Thus, the profit maximization generates:

$$w_t = \frac{\partial Y_{it}}{\partial L_{it}} = \frac{\partial Y_{jt}}{\partial L_{jt}}; \tag{B.9}$$

$$s_t = \frac{\partial Y_{it}}{\partial N_{it}}; \tag{B.10}$$

$$r_t = \frac{\partial Y_{it}}{\partial K_{it}} = \frac{\partial Y_{jt}}{\partial K_{jt}}; \tag{B.11}$$

where w_t, s_t, r_t are factor prices for unskilled labor, skilled labor and capital, respectively.

The unit cost function for Y_{it} is $c_i(A_{it}, w_t, s_t, r_t)$, and for Y_{jt} is $c_j(A_{jt}, w_t, r_t)$, where $i = 1, 2$; $j = 3, 4$. Free entry ensures zero profit for the intermediate goods producers. Let p_{it} be the price of intermediate goods i. We assume that the country's endowment is always within the diversification cone so that both intermediate goods are produced. In period t the zero profit condition implies that

$$p_{it} = c_i(A_{it}, w_t, s_t, r_t), \quad i = 1, 2; \tag{B.12}$$

$$p_{jt} = c_j(A_{jt}, w_t, r_t), \quad j = 3, 4; \tag{B.13}$$

The market clearing conditions for the endowments:

$$\sum_{i=1}^{4} L_{it} = L_t; \tag{B.14}$$

$$\sum_{i=1}^{4} K_{it} = K_t; \tag{B.15}$$

$$\sum_{i=1}^{2} N_{it} = N_t; \tag{B.16}$$

Let's assume that the total supply of unskilled labor is $\bar{L}$. Then, if $L_t < \bar{L}$, i.e., the unskilled-labor supply constraint doesn't bind, we have $w = w_{\min}$. In this case, we always have

$$p_{3t} > c_3(A_{3t}, w_t, r_t) \equiv p_{3t}^h; \tag{B.17}$$

where p_3^h is price of agriculture good 3, which is lower than the world price p_{3t}. In this case, home country exports the agriculture goods. The wedge in the home price of good 3 can be interpret as export cost (or taxes imposed by home country).

There is a competitive final goods sector which aggregates the 4 intermediate goods into final goods, $D_t = G(D_{1t}, D_{2t}, D_{3t}, D_{4t})$. Accordingly, the price follows:

$$P_t = \Phi(p_{1t}, p_{2t}, p_{3t}, p_{4t}); \tag{B.18}$$

The household's problem is the same as that in the paper, and thus the two key equations from the demand side are

$$U'\left(C_t\right)=\beta\left(\tilde{C}_t\right)U'\left(C_{t+1}\right)\left[1-\delta+\frac{r_{t+1}}{P_{t+1}}\right]; \tag{B.19}$$

$$1+\psi\left(B_{t+1}-\bar{B}\right)=\frac{1+r^*}{1-\delta+r_{t+1}/P_{t+1}}. \tag{B.20}$$

Finally, we are ready to characterize a competitive equilibrium. In addition to the above optimal conditions from households and firms, we have also have the nontradable goods market clearing condition to close the model,

$$p_{4t}Y_{4t}=p_{4t}D_{4t}. \tag{B.21}$$

B.2 Wage Structure

As in the paper, we are interested in the relative technology improvement of tradable goods sector 1. To simplify our analysis, we assume A_1 keeps rising while A_j $(j=2,3,4)$ maintain unchanged. Let's first focus on the case where there is excess labor supply in the economy, and thus $w_t=w_{\min}$. The zero-profit conditions (B.12) pin down s_t and r_t

$$s_t=\phi_1\left(A_{1t},p_{1t},p_{2t},w_{\min}\right); \tag{B.22}$$

$$r_t=\phi_2\left(A_{1t},p_{1t},p_{2t},w_{\min}\right); \tag{B.23}$$

where $\frac{d(s_t)}{d(A_{1t})}>0$ and $\frac{d(r_t)}{d(A_{1t})}<0$ by Stolper–Samuelson Theorem, since sector 2 uses capital intensively compared to sector 1. We can then solve p_{3t} and p_{4t} using (B.13). Obviously, $\frac{d(p_{4t})}{d(A_t)}<0$. Therefore, there is real depreciation with the increases in A_{1t}. We then can solve $\{L_i,N_j,K_i\}_{i=1,2,3,4;\ j=1,2}$ by equations (B.9)-(B.11) and (B.14)-(B.16). Note that when w_t is fixed at $w_{\min}$, L_t is endogenously determined, and is an increasing function of A_{1t}, i.e., $\frac{d(L_t)}{d(A_{1t})}>0$. Therefore, as long as A_{1t} keeps increasing, the unskilled labor supply constraint will bind eventually.

Let $L_t = \Gamma(A_{1t})$ denotes the labor demand function derived above. Suppose

$$\bar{L} = \Gamma(A^*), \tag{B.24}$$

where $\bar{L}$ is the total supply of unskilled labor. Then A^* is the threshold of A_{1t}, above which the excess labor supply has been exhausted and wage of unskilled labor, w_t, starts to grow.

Here we summarize above findings. If the initial level of A_{1t} is lower than the threshold level, A^*, the economy will experience two stages as follows:

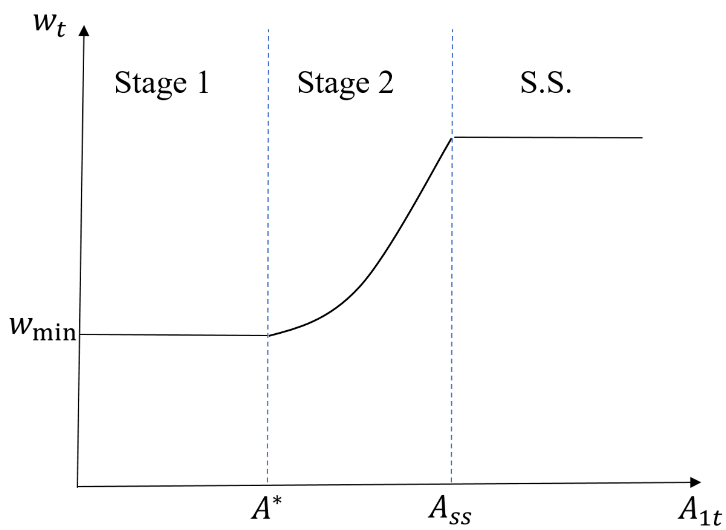
i) In the early stage, the production efficiency is very low in home country. In particular, $A_{1t} \leq A^*$. There is excess supply of unskilled labor in the economy. Therefore, the wage of unskilled worker is fixed at the minimum level, $w_{\min}$, and the labor allocation constraint does not hold:

$$L = \sum_{i=1}^{4} L_i = \Gamma(A_{1t}) \leq \bar{L}. \tag{B.25}$$

In this case, $p_{3t} > c_3(A_{3t}, w_t, r_t) \equiv p_{3t}^h$, i.e., home price of agriculture goods is lower than world price. $w_{\min}$ is exogenous. Other Factor prices, s_t and r_t, are determined by $p_{it} = c_i$, where $i = 1, 2$. Home country experiences real depreciation as A_{1t} grows over time.

ii) In the second stage, when TFP catches up and grows above a certain threshold, i.e., $A_{1t} > A^*$. The unskilled labor constraint binds. Then wage starts to grow. In this case, home price of agriculture goods catches up with the world price. Factor prices (w_t, s_t, r_t) are determined by $p_{it} = c_i$, where $i = 1, 2, 3$. Wage of unskilled worker is endogenously determined and increases with A_{1t} at this stage.

The following figure illustrates the pattern of wage of unskilled labor:



The model presented in this appendix delivers the same pattern of wage structure as that in the paper, while here the economy can transit from stage 1 to stage 2 as technology is improving. Wage responds to the TFP progress endogenously. The economy experiences real depreciation at stage 1, and the real exchange rate starts to appreciate when entering into stage 2 during which $A_{1t} > A^*$. Other results are essentially the same as that in the paper. All of the results are available upon request.