Structural Change and the Dynamics of China-US Real Exchange Rate

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Abstract

We study the dynamics of the real exchange rate between China and the US since 1990. We first show that a standard Balassa-Samuelson model without structural change cannot account for the observed real exchange rate behaviour. We then extend the Balassa-Samuelson framework to a three-sector model with structural change and show that the model can quantitatively account for both the structural changes in the two countries and the behaviour of the real exchange rate. A key element of the model is frictions to labour reallocation across sectors. Between 2000 and 2010, the manufacturing sector's share of employment in China increased from 25 percent to 34 percent. We argue that this is mainly driven by a decline in the frictions to labour reallocation from agriculture to manufacturing. Without the decline in labour frictions, the manufacturing sector's share of employment in China would have declined during this period and the real value of Renminbi would have appreciated more than what is observed in the data during the same period. Our results highlights the important roles of labour market conditions and structural change in determining the dynamics of real exchange rate.

JEL Classification: F31, F41, O14, O41

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1 Introduction

In the past decade, the exchange rate between China and the US has received considerable attention from both policy circles and academia worldwide.[1] One central research question is: What determines the level and dynamics of the long-run real exchange rate between a large rich country like the US and a large and rapidly growing economy like China? A standard framework in the literature for addressing this question is the Balassa-Samuelson model, which predicts that a country's currency should appreciate in real terms as the productivity in tradable sector improves. Based on this framework and given the fast productivity growth in China's manufacturing sector, many have argued that China's currency (Renminbi) is significantly undervalued and it would have appreciated more if the Chinese government had not intervened in the currency market.[2]

The standard Balassa-Samuelson analysis is based on a model with two sectors, a tradable sector and a non-tradable sector. The model also makes two very strong simplifying assumptions: (1) The Purchasing Power Parity (PPP) holds for tradables, and (2) the composition of tradable and non-tradable sectors remains unchanged for each country. Under these assumptions, the real exchange rate dynamics is driven by the relative price of non-tradables. In this paper, we first apply this standard Balassa-Samuelson model to the real exchange rate between China and the US. Our analysis confirms the result from previous analysis that the implied real value of the Chinese currency relative to the US is much higher than the actual real exchange rate we observed in the data.

However, there has been a large literature documenting the deviation from PPP for traded goods (Rogoff, 1996) that is directly contradictory to the first assumption behind the standard Balassa-Samuelson model. In fact, Engel (1999) shows that almost all of the variations in the US real exchange rates relative to other high income countries can be accounted for by the relative prices of traded goods between countries. The second assumption, that the composition of tradable and non-tradable

[1] See, for example, Goldstein and Lardy (2008) for a collection of papers by both policy makers and academic researchers.

[2] See e.g., Bergestein (2010), Subramanian (2010), Cline and Williamson (2008), Lee, et, al. (2008), and Frankel (2006).

sectors remains unchanged, is also not supported by the data. Both China and the US have been undergoing significant structural changes in the last two decades: China is experiencing fast industrialization with labor moving from agriculture into manufacturing, whereas US is undergoing de-industrialization with labor moving from industry into services. Therefore, the real exchange rate dynamics should be affected not only by the relative prices of tradables and non-tradables, but also by the change in sectorial compositions due to the structural changes. This evidence suggests that the standard Balassa-Samuelson model may not be a good benchmark for determining the level and dynamics of equilibrium real exchange rate.[3]

In this paper, we extend the Balassa-Samuelson framework to a two-country three-sector open economy model with structural change. The three sectors are agriculture, manufacturing and services. The first two sectors produce traded goods and services are non-tradable. This model embodies three potential sources of structural changes in the two countries: the income effects due to non-homothetic preferences as in Kongsamut, Rebelo and Xie (2001), international trade as emphasized by Matsuyama (2009), and changes in labour market frictions as studied by Caselli and Coleman (2001) for the historical US. We show that the model can quantitatively account for both the structural changes in the two countries and the observed behaviour of the real exchange rate.

A key element of the model is frictions to labour reallocation across sectors. Between 2000 and 2010, the manufacturing sector's share of employment in China increased from 25 percent to 34 percent. We argue that this is mainly driven by a decline in the frictions to labour reallocation from agriculture to manufacturing. Without the decline in labour market frictions, the manufacturing sector's share of employment in China would have declined during this period and the real value of Renminbi would have appreciated more than what is observed in the data during the same period. Our results highlight the important roles of labour market conditions and structural change in determining the dynamics of real exchange rate.

Our model also allows for deviation from the the Law of One Price for traded

[3]See, Chinn and Johnston, 1996, Tica and Druzic, 2006, Lothian and Taylor, 2008, Chong, Jorda and Taylor, 2012, among others, for direct evidence against the real exchange rate predictions of the standard Balassa-Samuelson model

goods in agriculture and manufacturing. We introduce an iceberg trade cost in the model to account for the variations in the relative price of agricultural goods in the two countries. In addition, we model the final manufactured good as a composite of two traded intermediate goods produced in the two countries and that there is a home bias in the composition so that the price of the final manufactured good may be different between the two countries. Similar to Engle (1999), we find that the variation in the relative price of agricultural goods is important in accounting for the observed China-US real exchange rate dynamics.

This paper is related to two strands of literature: structural change and the determination of real exchange rate. In the literature on structure change, our paper is closely related to several recent studies of structural change in open economies, such as Echevarria (1995), Matsuyama (1992, 2009), Sposi (2012), Ui, Yi, and Zhang (2013), Kehoe, Ruhl and Steinberg (2013), Swiecki (2014) and Tombe (2015). However, none of these studies examines the implication for the dynamics of real exchange rate. Similar to us, Sposi (2012), Ui, Yi, and Zhang (2013) and Kehoe, Ruhl and Steinberg (2013) also study the dynamics of structural change in open economies, but they all focus on the structural change in one particular economy only. Our paper is to our knowledge the first paper that attempts to simultaneously account for the dynamics of structural change in more than one countries that are linked by trade.

In the literature on the determination of real exchange rate, several studies examine the Balassa-Samuelson prediction about relative productivity and real exchange rate. See, e.g., Rogoff (1996), Chinn and Johnston (1996), Canzoneri, et. al. (1996), Bergin, Glick, and Taylor (2006), Lee and Tang (2007) and Gubler and Sax (2011). None of these studies consider structural change. The paper that is most closely related to ours is the recent paper by Berka, Devereux and Engel (2015). They also emphasize the importance of relative prices of traded goods and labour market wedges in determining real exchange rate, but their focus is on the real exchange rates of the European countries and they do not consider structural change.

Finally, our paper is clearly related to the large policy literature on the determination of Renminbi's value that we cited in footnotes 1 and 2, and the papers on structural change in China by Brandt, Hsieh and Zhu (2008), Dekel and Vandenbroucke (2009), Brandt and Zhu (2010) and Tombe and Zhu (2015).

2 Data and Facts

For our quantitative analysis, we need to have sectoral price levels, labour productivities and employments for both the US and China. Furthermore, they have to be in the same units between the two countries. We construct these variables from three different sources: The 10-Sector Database (Timmer, de Vries and de Vries, 2014) and Productivity Level Database (Inklaar and Timmer, 2014), both from the Groningen Growth and Development Centre (GGDC), and the employment series constructed by Brandt and Zhu (2010). The details about how we construct these variables are given in the Data Appendix.

Figure 1 and 2 plot the employment shares of agriculture, industry and services for both the US and China between 1978 and 2010. In both countries, the employment share of agriculture decreases and the employment share of services increases over time. The two countries' shares of employment in industry, however, move in the opposite directions, rising in China but decreasing in the US. Also note that after an initial increase in the 1980s, the industry's share of employment in China remained roughly constant until 2002, when it started to increase again.

Figure 3 shows the evolution of the nominal and real exchange rates of China relative to the US during the same period. Here the real exchange rate is calculated using Penn World Table's price levels of GDP for China and the US. The value of the Renminbi was set artificially high in the early 1980s when both the nominal exchange rate and domestic prices are still largely controlled by the Chinese government. As the government gradually removed its control on domestic prices, it also gradually lowered the nominal exchange rate relative to the US. Starting in 1994, however, the nominal value of Renminbi was effectively pegged to the US dollar until 2005, when it was allowed to appreciate modestly. By 1990 China's domestic prices are largely determined by the market. As a result, despite a fixed nominal exchange rate, the real exchange rate may still move towards its equilibrium level through changes in relative prices between China and the US. There were some real increase in the value of Renminbi before the Asian Financial Crisis, but the persistent real appreciation of Renminbi did not start until 2002, around the same time when China's employment share of industry started to increase too.

Finally, since relative labour productivity levels between countries are important determinants of relative prices and therefore real exchange rate between countries, we plot in Figure 4 China's labour productivity levels relative to the US. In 1978, China's labour productivity levels were all very low, around 2-3% of the US levels. The labour productivity in both the industry and services sectors show clear convergence towards the US, reaching to 16% and 14%, respectively. In contrast, the relative labour productivity of China's agriculture remains at around 3%. This is a result of high productivity growth in the US agriculture rather than low productivity growth in the Chinese agriculture. In fact, for the entire period between 1978 and 2010, the average annual labour productivity growth rate in China's agriculture is 5.97%, slightly higher than the 5.65% average growth rate in services, but lower than the 7.53% average growth rate in industry.

We also aggregate agriculture and industry into one "tradable" sector and show this sector's relative labour productivity in Figure 4. For the entire period, the average annual growth rate of the relative productivity in this aggregated sector is slightly higher than that in services. In the last five years, however, the relative productivity growth in services is actually higher than any of the other sectors. This last fact suggests that the standard Balassa-Samuelson model is unlikely to account for the rapid real appreciation of Renminbi since 2005. We formally show this in the next section.

3 The Real Exchange Rate Implied by the Standard Balassa-Samuelson Model

Consider an economy with two countries, Home and Foreign, and two sectors, tradable and non-tradable. Assume that both sectors in both countries use linear production technologies with labour as the only input. Let A_T and A_N denote the labour productivity in the tradable and non-tradable sectors in Home country, respectively. Hitherto we will focus on the problems in the Home country. The corresponding problems in the Foreign country can be solved analogously, and as usual we will denote the corresponding variables in the Foreign country with an asterisk. For example, A_T^* represent the labour productivity in Foreign country's tradable sector.

The representative household's preferences over tradable and non-tradable goods is summarized by a Cobb-Douglas utility function:

$$U(C_T, C_N) = C_T^{1-\theta_N} C_N^{\theta_N}, \text{ and } 0 < \theta_N < 1.$$

Let P_T and P_N be the Home prices of tradable and non-tradable goods. The Cobb-Douglas utility function implies that the aggregate price level in the Home country is

$$P = \left(\frac{P_T}{1-\theta_N}\right)^{1-\theta_N} \left(\frac{P_N}{\theta_N}\right)^{\theta_N}.$$

Similarly, the aggregate price level in the Foreign country is

$$P^* = \left(\frac{P_T^*}{1-\theta_N^*}\right)^{1-\theta_N^*} \left(\frac{P_N^*}{\theta_N^*}\right)^{\theta_N^*}.$$

Producers' profit maximization problems lead to the following marginal conditions:

$$P_T A_T = W = P_N A_N,$$

$$P_T^* A_T^* = W^* = P_N^* A_N^*.$$

These conditions imply that $P_N = P_T A_T / A_N$ and $P_N^* = P_T^* A_T^* / A_N^*$. Substituting them into the equations for the aggregate price levels above, we have

$$P = P_T \left(\frac{1}{1-\theta_N}\right)^{1-\theta_N} \left(\frac{A_T/A_N}{\theta_N}\right)^{\theta_N},$$

$$P^* = P_T^* \left(\frac{1}{1-\theta_N^*}\right)^{1-\theta_N^*} \left(\frac{A_T^*/A_N^*}{\theta_N^*}\right)^{\theta_N^*}.$$

Under the assumption of Law of One Price for the tradable good, $P_T = P_T^*$. So the real exchange rate is

$$\frac{P}{P^*} = \frac{\left(\frac{1}{1-\theta_N}\right)^{1-\theta_N} \left(\frac{A_T/A_N}{\theta_N}\right)^{\theta_N}}{\left(\frac{1}{1-\theta_N^*}\right)^{1-\theta_N^*} \left(\frac{A_T^*/A_N^*}{\theta_N^*}\right)^{\theta_N^*}},$$

which is entirely determined by the relative productivity between the tradable sector and the non-tradable sector in the two countries.

To evaluate the prediction of this simple model, we use the aggregate of agriculture and industry as the tradable sector and services as the non-tradable sector and calculate the labour productivity levels accordingly for both China and the US. For the values of θ_N and θ_N^*, we use the share of services value-added in aggregate value-added in China and the US, respectively. We also allow these values to change from year to year as in the data. Because many prices were set administratively in early years, here and in the rest of the paper we will focus on the comparison between the model prediction and data for the period starting from 1990. Figure 5 plots the predicted and actual China-US real exchange rates. The actual real exchange rate is significantly lower than the real exchange rate predicted by the standard Balassa Samuelson model for the entire period between 1990 and 2010. This result confirms the result from previous analysis that according to Balasssa-Samuelson model, Renminbi is significantly undervalued. The model's prediction of the real exchange rate dynamics is also different from the data and, interestingly, different from the conventional wisdom.

To focus on the dynamics, Figure 6 plots the predicted and actual real exchange rates that are both normalized to 1 in year 2002, the first year after China's entry into the World Trade Organization. Despite the rapid productivity growth in China's tradable sector between 2002 and 2010, the degree of appreciation of Renminbi predicted by the Balassa-Samuelson model is actually much smaller than the actual appreciation during this period. The main reason behind this surprising result is that labour productivity growth in China's services is actually much higher than is typically assumed. Given the discrepancy between the prediction of the Balassa-Samuelson model and the actual real exchange rate behaviour, many analysts have used this as evidence about the distortions in the real value of Renminbi caused by the Chinese government's intervention in the currency market.

However, there is an alternative interpretation of the result: the standard Balassa-Samuelson model is just not a good framework for determining the behaviour of equilibrium real exchange rate because of the two very strong assumptions that we discussed in the introduction: Law of One Price for the traded goods and no structural change. In Section 3 we have already documented significant structural changes in both the US and China. Similar to what Engel (1999) found for other countries, the relative prices of the tradable sectors (agriculture and industry) between China and the US is also far from one and far from constant. For example, we constructed the relative price of agricultural sector between China and the US using the data from the GGDC 10-Sector Database and Productivity Level Database. The relative price went from 0.39 in 1990 to 1.23 in 2010. (See Figure 10 and the Data Appendix.)

Is there an extension of the standard Balassa-Samuelson model that allows for deviation from the Law of One Price and structural changes that can be used as a better framework for predicting the behaviour of real exchange rate? To answer this question we now turn to the main model of this paper.

4 A Three-Sector Open Economy Model with Structural Change

In this section we consider a multi-sector extension of the standard Balassa-Samuelson model. There are three sectors, agriculture, manufacturing and services. The first two sectors produce tradable goods and services are non-tradable. We introduce two features in this model to allow for deviations from the Law of One Price:

1. We assume that there is an exogenous price wedge between the the agricultural good produced at Home and Foreign Countries. We interpret this wedge as an iceberg trade cost in the model. In reality it could also capture terms of trade shocks and/or non-traded distribution services component of final agricultural goods. [Note: we may model this more explicitly in the next draft.]

2. We model the final manufacturing good as a CES aggregate of two traded intermediate goods produced in the Home and Foreign manufacturing sec-

tors and there is a home bias in the aggregation so that the price of the final manufacturing good may be different between the two countries.

We also introduce three potential driving forces of structural change into this model:

1. We use a Stone-Geary utility function that is used to study structural change by Kongsamut, et.. al. (2001). This non-homothetic utility generates income effects on the demand for agricultural good and services. Productivity growth in this economy will lead to structural change from agriculture to services. This is the common driving force of structural change for both Home and Foreign countries.

2. Because there are two traded sectors, trade could also leads to structural change between agriculture and manufacturing, as pointed out by Matsuyama (2009). This is the force that may lead to opposite movement of the manufacturing sector's share of total employment in the two countries.

3. Labour wedges between sectors in China. Similar to Caselli and Coleman (2001) for the case of historical US, a reduction in the wedge between agriculture and manufacturing can lead to reallocation of labour from agriculture to the manufacturing sector. We assume no labour wedges in the US. However, through trade, the reduction in the wedge may also lead to labour reallocation in the US.

4.1 Preferences and Household Income

There is a representative household in each country and their preferences for the goods produced in these sectors are summarized by the following Cobb-Douglas utility functions:

$$u = (c_a - \chi_a)^{\theta_a} c_m^{\theta_m} (c_s + \chi_s)^{\theta_s},$$

$$u^* = (c_a^* - \chi_a^*)^{\theta_a} c_m^{*\theta_m} (c_s^* + \chi_s^*)^{\theta_s}.$$

Here $\theta_i \in (0,1)$, for $i = a, m, s$; and $\theta_a + \theta_m + \theta_s = 1$.

The representative household is endowed with one unit of labour that can be allocated to work in the three sectors, $l_{a,t}$, $l_{m,t}$ and $l_{s,t}$. Let $W_{i,t}$ and $W_{i,t}^{*}$ be the home and foreign nominal wages in sector i, respectively.

Let $y_t = W_{a,t}l_{a,t} + (1-\lambda_{m,t})W_{n,t}l_{m,t} + (1-\lambda_{s,t})W_{s,t}l_{s,t}$ be the household's income. Here $\lambda_{i,t}$ is a proportional deadweight loss associated with working in sector i for $i = m, s$. These deadweight losses help to account for wage wedges between sectors observed in the data. In equilibrium household should be indifferent about which sector to work. So we have

$$W_{a,t} = (1-\lambda_{m,t})W_{m,t} = (1-\lambda_{s,t})W_{s,t},$$

and $y_t = W_{a,t}$.

The utility maximization problem of the representative domestic household is

$$max_{c_{a,t},c_{m,t},c_{s,t}} \left(c_{a,t}-\chi_a\right)^{\theta_a} c_{m,t}^{\theta_m} \left(c_{s,t}+\chi_s\right)^{\theta_s}$$

subject to the budget constraint:

$$P_{a,t}c_{a,t} + P_{m,t}c_{m,t} + P_{s,t}c_{s,t} = W_{a,t},$$

which yields the following solutions:

$$c_{a,t} = \chi_a + \theta_a \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{a,t}},$$

$$c_{m,t} = \theta_m \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{m,t}},$$

$$c_{s,t} = -\chi_s + \theta_s \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{s,t}}.$$

Let P_t be the marginal price index[4]:

$$P_t = \left(\frac{P_{a,t}}{\theta_a}\right)^{\theta_a} \left(\frac{P_{m,t}}{\theta_m}\right)^{\theta_m} \left(\frac{P_{s,t}}{\theta_s}\right)^{\theta_s}.$$

4.2 Trade

4.2.1 Agriculture

We assume that the foreign agricultural good is a perfect substitute for the home produced agricultural good, but importing it is subject to an iceberg trade cost, $\tau_{a,t}$. So,

$$P_{a,t} = \tau_{a,t} P^*_{a,t}$$

4.2.2 Manufacturing

The final manufacturing good is not tradable and it is an Arminton aggregator of intermediate goods produced in the two countries:

$$C_m = \left[\varphi^{\frac{1}{\varepsilon}} X_d^{\frac{\varepsilon-1}{\varepsilon}} + (1-\varphi)^{\frac{1}{\varepsilon}} X_f^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Here $\varepsilon > 1$ is the elasticity of substitution between the two intermediate goods, which are tradable. The home producer of the final manufacturing good has the following profit maximization problem:

$$max_{X_{d,t},X_{f,t}} P_{m,t} \left[\varphi^{\frac{1}{\varepsilon}} X_{d,t}^{\frac{\varepsilon-1}{\varepsilon}} + (1-\varphi)^{\frac{1}{\varepsilon}} X_{f,t}^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} - P_{x,t} X_{d,t} - P^*_{x,t} X_{f,t},$$

which yields the following solutions:

$$X_{d,t} = \varphi \left(\frac{P_{x,t}}{P_{m,t}}\right)^{-\varepsilon} C_{m,t}, \tag{1}$$

[4] Because of non-homotheticity, marginal price and average price are different. In the next draft we will examine the implication for the real exchange rate when it is calculated using average price levels.

$$X_{f,t} = (1-\varphi)\left(\frac{P^*_{x,t}}{P_{m,t}}\right)^{-\varepsilon} C_{m,t}, \tag{2}$$

and

$$P_{m,t} = \left[\varphi P_{x,t}^{1-\varepsilon} + (1-\varphi) P_{x,t}^{*1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

The foreign producer of the final manufacturing good has the similar maximization problem, but faces an iceberg cost for importing the intermediate good from the home country. So, we have,

$$X^*_{d,t} = \varphi\left(\frac{P^*_{x,t}}{P^*_{m,t}}\right)^{-\varepsilon} C^*_{m,t}, \tag{3}$$

$$X^*_{f,t} = (1-\varphi)\left(\frac{\tau_{m,t} P_{x,t}}{P^*_{m,t}}\right)^{-\varepsilon} C^*_{m,t}, \tag{4}$$

and

$$P^*_{m,t} = \left[\varphi P_{x,t}^{*1-\varepsilon} + (1-\varphi)\left(\tau_{m,t} P_{x,t}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

4.3 Production Technologies and Prices

Output in all three sectors are produced with linear technologies that use labour as the only input:

$$Y_{i,t} = A_{i,t} L_{i,t}, \text{ and } Y^*_{i,t} = A^*_{i,t} L^*_{i,t} i = a, m, s.$$

This implies the following:

$$P_{a,t} = \frac{W_{a,t}}{A_{a,t}}, P_{x,t} = \frac{W_{a,t}}{A_{m,t}(1-\lambda_{m,t})}, P_{s,t} = \frac{W_{a,t}}{A_{s,t}(1-\lambda_{s,t})}, \tag{5}$$

and

$$P^*_{a,t} = \frac{W^*_{a,t}}{A_{a,t}}, P^*_{x,t} = \frac{W^*_{a,t}}{A^*_{m,t}}, P^*_{s,t} = \frac{W^*_{a,t}}{A^*_{s,t}}. \tag{6}$$

From the no-arbitrage condition in the market for agricultural good, $P_{a,t} = \tau_{a,t} P^*_{a,t}$, we have

$$\frac{W_{a,t}}{W^*_{a,t}} = \tau_{a,t} \frac{A_{a,t}}{A^*_{a,t}}. \tag{7}$$

Thus,

$$\frac{P_{x,t}}{P_{x,t}^*} = \tau_{a,t} \frac{A_{a,t}}{A_{a,t}^*} \frac{A_{m,t}^*}{A_{m,t}(1-\lambda_{m,t})}, \tag{8}$$

$$\frac{P_{m,t}}{P_{m,t}^*} = \left(\frac{1-\varphi+\varphi\left(\frac{P_{x,t}}{P_{x,t}^*}\right)^{1-\varepsilon}}{\varphi+(1-\varphi)\left(\tau_{m,t}\frac{P_{x,t}}{P_{x,t}^*}\right)^{1-\varepsilon}} \right)^{\frac{1}{1-\varepsilon}},$$

$$\frac{P_{s,t}}{P_{s,t}^*} = \tau_{a,t} \frac{A_{a,t}}{A_{a,t}^*} \frac{A_{s,t}^*}{A_{s,t}(1-\lambda_{s,t})},$$

and

$$\frac{P_t}{P_t^*} = \tau_{a,t}^{\theta_a+\theta_s} \left(\frac{1-\varphi+\varphi\left(\frac{P_{x,t}}{P_{x,t}^*}\right)^{1-\varepsilon}}{\varphi+(1-\varphi)\left(\tau_{m,t}\frac{P_{x,t}}{P_{x,t}^*}\right)^{1-\varepsilon}} \right)^{\frac{\theta_m}{1-\varepsilon}} \left(\frac{A_{a,t}}{A_{a,t}^*} \frac{A_{s,t}^*}{A_{s,t}(1-\lambda_{s,t})} \right)^{\theta_s} \tag{9}$$

Given the preference parameters, the labour productivies and wedges, equation (8) and (9) can be used to directly calculate the real exchange rate P/P^* without solving the equilibrium employment shares in different sectors.

Discussion

This model's implications about the real exchange rate are different from the standard Balassa-Samuelson model in several ways:

- Trade costs induce wedges in price of tradables and therefore affect the real exchange rate. In particular, a higher (lower) cost of importing agricultural good by the Home country will lead to an increase (decrease) in both the agricultural good price and wage relative to those in the Foreign country. This will increase (decrease) the real value of domestic currency.
- A higher (lower) cost of exporting intermediate good by the manufacturing producer in the Home country will lead to an increase (decrease) in the price of manufacturing good in the Foreign country and therefore decrease (increase) the real value of domestic currency.

- A decrease (increase) in the labour wedge between the agricultural sector and the services sector will lead to a decrease (increase) in the wage of the services sector in the Home country and therefore decrease (increase) the domestic price level and the real value of domestic currency.

- A decrease (increase) in the labour wedge between the agricultural sector and the manufacturing sector will lead to a decrease (increase) in the wage of the manufacturing sector in the Home country and therefore decrease (increase) the price of the intermediate good produced by domestic producer. If there is home bias in the demand for intermediate input ($\phi > 0.5$), then this will also lead to a larger decrease (increase) in the manufacturing price in the Home country and therefore decrease (increase) the real value of domestic currency.

- When there is home bias in the demand for intermediate input, the increase in Home country's relative labour productivity in the manufacturing sector will actually lead to a decrease rather than increase in the real exchange rate.

The last implication is the exact opposite of what is predicated by the standard Balassa Samuelson model. The reason for the difference in prediction is that in our three-sector model, relative wage between the two countries is not simply determined by the relative labour productivity in the manufacturing sector, it also depends on the relative productivity in agriculture. In fact, for the current specification, the relative productivity in agriculture and the trade cost in agriculture completely pin down the relative wage. So an increase in the relative productivity in the manufacturing sector will only have the effect of lowering the relative price of manufacturing good in the Home country. In the standard Balassa-Samuelson model, however, the increase in the relative productivity in the manufacturing will completely reflected in the increase in relative wages without any impact on the relative price of the tradables, so it will lead to an increase in the real exchange rate.

4.4 Equilibrium Conditions

From the Walras Law, we can solve the equilibrium by using the market clearing conditions for two of the three sectors, services and manufacturing.

4.4.1 Services

Market clearing condition in the non-traded services sector implies

$$L_t c_{s,t} = -L_t \chi_s + \theta_s L_t \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{s,t}} = A_{s,t} L_{s,t},$$

and

$$L_t^* c_{s,t} = -L_t^* \chi_s^* + \theta_s L_t^* \frac{W_{a,t}^* - P_{a,t}^*\chi_a^* + P_{s,t}^*\chi_s^*}{P_{s,t}^*} = A_{s,t}^* L_{s,t}^*.$$

Substituting the equations for prices (5) and (6) into the equilibrium conditions for services above and solve for the employment share in the services sector yields the following:

$$l_{s,t} = -(1-\theta_s)\frac{\chi_s}{A_{s,t}} + \theta_s \left(1 - \frac{x_a}{A_{a,t}}\right)(1-\lambda_{s,t}), \tag{10}$$

$$l_{s,t} = -(1-\theta_s)\frac{\chi_s^*}{A_{s,t}^*} + \theta_s \left(1 - \frac{x_a^*}{A_{a,t}^*}\right). \tag{11}$$

4.4.2 Manufacturing

The market clearing conditions for the manufacturing sector are

$$X_{d,t} + \tau_{m,t} X_{f,t}^* = Y_{m,t} = A_{m,t} L_{m,t}$$

$$X_{d,t}^* + X_{f,t} = Y_{m,t}^* = A_{m,t}^* L_{m,t}^*$$

$$L_t c_{m,t} = C_{m,t}$$

$$L_t^* c_{m,t}^* = C_{m,t}^*$$

From the demand equations for the manufacturing sector (1)-(4), we have

$$X_{d,t} = \varphi \left(\frac{P_{x,t}}{P_{m,t}}\right)^{-\varepsilon} L_t \theta_m \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{m,t}},$$

$$X_{f,t} = (1-\varphi) \left(\frac{P_{x,t}^*}{P_{m,t}}\right)^{-\varepsilon} L_t \theta_m \frac{W_{a,t} - P_{a,t}\chi_a + P_{s,t}\chi_s}{P_{m,t}},$$

$$X_{d,t}^{*} = \varphi \left(\frac{P_{x,t}^{*}}{P_{m,t}^{*}}\right)^{-\varepsilon} L_t^{*} \theta_m \frac{W_{a,t}^{*} - P_{a,t}^{*}\chi_a + P_{s,t}^{*}\chi_s}{P_{m,t}^{*}},$$

$$X_{f,t}^{*} = (1-\varphi) \left(\frac{\tau_{m,t} P_{x,t}}{P_{m,t}^{*}}\right)^{-\varepsilon} L_t^{*} \theta_m \frac{W_{a,t}^{*} - P_{a,t}^{*}\chi_a + P_{s,t}^{*}\chi_s}{P_{m,t}^{*}}.$$

Simplifying, we have

$$X_{d,t} = \varphi \theta_m \left(A_{m,t}(1-\lambda_{m,t})\right)^{\varepsilon} \left(\frac{W_{a,t}}{P_{m,t}}\right)^{1-\varepsilon} \mu_t L_t,$$

$$X_{f,t} = (1-\varphi)\theta_m \left(\frac{W_{a,t}}{W_{a,t}^{*}} A_{m,t}^{*}\right)^{\varepsilon} \left(\frac{W_{a,t}}{P_{m,t}}\right)^{1-\varepsilon} \mu_t L_t,$$

$$X_{d,t}^{*} = \varphi \theta_m A_{m,t}^{*\varepsilon} \left(\frac{W_{a,t}^{*}}{P_{m,t}^{*}}\right)^{1-\varepsilon} \mu_t^{*} L_t^{*},$$

$$X_{f,t}^{*} = (1-\varphi)\theta_m \left(\frac{W_{a,t}^{*}}{W_{a,t}} \frac{A_{m,t}(1-\lambda_{m,t})}{\tau_{m,t}}\right)^{\varepsilon} \left(\frac{W_{a,t}^{*}}{P_{m,t}^{*}}\right)^{1-\varepsilon} \mu_t^{*} L_t^{*}.$$

Here

$$\mu_t = 1 - \frac{\chi_a}{A_{a,t}} + \frac{\chi_s}{A_{s,t}(1-\lambda_{s,t})},$$

and

$$\mu_t^{*} = 1 - \frac{\chi_a^{*}}{A_{a,t}^{*}} + \frac{\chi_s^{*}}{A_{s,t}^{*}}.$$

Substituting these intermediate good demand functions into the market clearing conditions for the manufacturing sector and solving for the employment shares in the sector yields the following:

$$l_{m,t} = \theta_m A_{m,t}^{\varepsilon-1}(1-\lambda_{m,t})^{\varepsilon} \left[\varphi \left(\frac{W_{a,t}}{P_{m,t}}\right)^{1-\varepsilon} \mu_t + (1-\varphi)\tau_{m,t}^{1-\varepsilon} \left(\frac{W_{a,t}^{*}}{W_{a,t}}\right)^{\varepsilon} \left(\frac{W_{a,t}^{*}}{P_{m,t}^{*}}\right)^{1-\varepsilon} \mu_t^{*} \frac{L_t^{*}}{L_t}\right],$$

$$l_{m,t}^{*} = \theta_m A_{m,t}^{*\varepsilon-1} \left[\varphi \left(\frac{W_{a,t}^{*}}{P_{m,t}^{*}}\right)^{1-\varepsilon} \mu_t^{*} + (1-\varphi) \left(\frac{W_{a,t}}{W_{a,t}^{*}}\right)^{\varepsilon} \left(\frac{W_{a,t}}{P_{m,t}}\right)^{1-\varepsilon} \mu_t \frac{L_t}{L_t^{*}}\right].$$

Finally, note that

$$\frac{W_{a,t}}{P_{m,t}} = \left[\varphi \left(A_{m,t}(1-\lambda_{m,t}) \right)^{\varepsilon-1} + (1-\varphi) \left(\tau_{a,t} \frac{A_{a,t}}{A^*_{a,t}} A^*_{m,t} \right)^{\varepsilon-1} \right]^{\frac{1}{\varepsilon-1}},$$

$$\frac{W^*_{a,t}}{P^*_{m,t}} = \left[\varphi A^{*\varepsilon-1}_{m,t} + (1-\varphi) \left(\frac{A^*_{a,t}}{\tau_{m,t}\tau_{a,t}A_{a,t}} A_{m,t}(1-\lambda_{m,t}) \right)^{\varepsilon-1} \right]^{\frac{1}{\varepsilon-1}}.$$

Substituting them and the equation for relative wage (7) into the equations for the manufacturing employment shares, we have,

$$l_{m,t} = \theta_m \left[\frac{\varphi(1-\lambda_{m,t}) \left(\frac{A^*_{a,t}}{\tau_{a,t}A_{a,t}} \right)^{\varepsilon-1} \mu_t}{\varphi \left(\frac{A^*_{a,t}}{\tau_{a,t}A_{a,t}} \right)^{\varepsilon-1} + (1-\varphi) \left(\frac{A^*_{m,t}}{A_{m,t}(1-\lambda_{m,t})} \right)^{\varepsilon-1}} + \frac{(1-\varphi)(1-\lambda_{m,t})\tau_{m,t}^{1-\varepsilon} \left(\frac{A^*_{a,t}}{\tau_{a,t}A_{a,t}} \right)^{\varepsilon} \mu^*_t \frac{L^*_t}{L_t}}{\varphi \left(\frac{A^*_{m,t}}{A_{m,t}(1-\lambda_{m,t})} \right)^{\varepsilon-1} + (1-\varphi) \left(\frac{A^*_{a,t}}{\tau_{m,t}\tau_{a,t}A_{a,t}} \right)^{\varepsilon-1}} \right], \tag{12}$$

$$l^*_{m,t} = \theta_m \left[\frac{\varphi \left(\frac{\tau_{a,t}A_{a,t}}{A^*_{a,t}} \right)^{\varepsilon-1} \mu^*_t}{\varphi \left(\frac{\tau_{a,t}A_{a,t}}{A^*_{a,t}} \right)^{\varepsilon-1} + (1-\varphi) \left(\frac{A_{m,t}(1-\lambda_{m,t})}{\tau_{m,t}A^*_{m,t}} \right)^{\varepsilon-1}} + \frac{(1-\varphi) \left(\frac{\tau_{a,t}A_{a,t}}{A^*_{a,t}} \right)^{\varepsilon} \mu_t \frac{L_t}{L^*_t}}{\varphi \left(\frac{A_{m,t}(1-\lambda_{m,t})}{A^*_{m,t}} \right)^{\varepsilon-1} + (1-\varphi) \left(\frac{\tau_{a,t}A_{a,t}}{A^*_{a,t}} \right)^{\varepsilon-1}} \right]. \tag{13}$$

Discussion

Equation (10)-(13) can be used to calculate the equilibrium employment shares in the three sectors for both countries. In addition to the standard income effect on structural change due to the non-homothetic preferences, there are two other sources of structural change:

- A decrease (increase) in import cost of the agricultural good or decrease (increase) in the export cost the manufacturing producer in the Home country will lead to a decrease (increase) in the employment share of agriculture sector and increase (decrease) in the employment share of the manufacturing sector in the domestic economy. The effects on the employment shares in the Foreign country are the opposite.
- A decrease (increase) in the labour wedge between the agricultural sector and the services sector will lead to an increase (decrease) in the Home country's employment share of the services sector.
- A decrease (increase) in the labour wedge between the agricultural sector and the manufacturing sector will lead to an increase (decrease) in the Home

country's manufacturing share of employment and a decrease (increase) in the Home country's share of employment in agriculture. The effects on the employment shares in the Foreign country are the opposite.

- An increase (decrease) in the relative labour productivity of the manufacturing sector will lead to an increase (decrease) in the Home country's manufacturing share of employment and a decrease (increase) in the Foreign country's manufacturing share of employment. The effects on agriculture's share of employment in the two countries are the opposite.

5 Quantitative Analysis

We now discuss how we calibrate the model in Section 4 and report the results of our quantitative exercises.

5.1 Calibration

For the iceberg importing cost $\tau_{a,t}$, we directly calculate it as the relative price of agricultural sector between China and the US that we discussed in Section 3. For now we set $\tau_{m,t} = 1$. For the preferences parameters θ_i, $i = a, m, s$, we use the values estimated by Herrendorf et. al. (2013): $\theta_m = 0.14$ and $\theta_s = 0.84$, $\theta_a = 1 - \theta_m - \theta_s$. We simply set the value of home bias $\phi = 0.9$ and the elasticity of substitution between the home and foreign intermediate goods $\varepsilon = 1.8$. We assume that the labour wedge between the agriculture and services, $\lambda_{s,t} = \overline{\lambda}_s$ is a constant.

We then use the following steps to calibrate the value of subsistence terms $\chi_a, \chi_s, \chi_a^*, \chi_s^*$, the constant labour wedge for services, $\overline{\lambda}_s$, and the time varying labour wedges for manufacturing, $\lambda_{m,t}$.

- For any given value of χ_a^*, we choose the value of χ_s^* such that the predicted US employment share of services given by equation (11) fit the data best. Similarly, for any given χ_a, we choose the value of χ_s and the value of of the constant labour wedge for services $\overline{\lambda}_s$ such that the predicted Chinese employment share of services given by equation (10) fit the data best.

- We then choose χ_a and χ_a^* to that best fit the agriculture's share of employment in both China and the US.

- Finally, we choose the time varying labour wedge for manufacturing so that the predicted employment share of manufacturing in China matches the data exactly for each year.

5.2 Results

Figure 7 and 8 plots the actual employment shares and the predicted employment shares from the calibrated model, for the US and China, respectively. The model fits the employment share dynamics of both countries quite well. Figure 9 plots the actual and predicted China-US real exchange rate. The model also captures the real exchange rate dynamics well, especially the sharp increase in the real exchange rate since 2004. There are two wedges that we introduce into our model that are particularly important in matching the structural change and real exchange rate dynamics of the model and the data: the relative price wedge in agriculture, $\tau_{a,t}$, and the labour market wedge for the manufacturing sector, $\lambda_{m,t}$. Figure 10 plots these two wedges. We can see that there had been a significant increase in the relative price wedge and significant decline in the labour market wedge since 2004. What are the impact of these changes in wedges on structural change and the real exchange rate dynamics? We investigate this question with two counter-factual simulations.

First, we replace the actual labour market wedge with a constant wedge that equals the average of the calibrated wedges in the period from from 1990 to 2003. Figure 11 and 12 show the impact of this change on structural changes in the two countries. With the constant labour wedge, the US manufacturing sector's employment share would increase instead of decline after 2004. In contrast, China's manufacturing share of employment would decline rather than increase after 2004. The effects on the agriculture's share of employment in the two countries are the exactly opposite. So the fast rise of the manufacturing sector's share of employment in China and the steady decline in the US in recent years may well be a result of the decline in the labour market frictions in China. Figure 13 also shows the impact of the reduction in labor market wedge on the real exchange rate. In the counterfactual case of no reduction of the wedge, Renminbi would have appreciated even more since 20004. The reduction in the labour wedge helps to slowdown the increase in the manufacturing sector's wage in China and therefore also helps to slowdown the speed of Renminbi appreciation.

Next, we keep the labour market wedges as in the benchmark case, but replace the actual relative prices in agriculture by the average of the relative prices in the period from 1990 to 2003. It turns out that this change had very little effect on the structural changes in the two countries. However, the change has a major impact of the real exchange rate dynamics, the model implies that Renminbi would continue to depreciate steadily after 2004, reverse the trend we see in the data and the bench mark model.

In summary, our quantitative exercises show that our extension of the standard Balassa-Samuelson model is able to account for both the China-US real exchange rate dynamics and the structural changes in China and the US. While the reduction in labour market wedge are crucial for the structural changes we see in the two countries in recent years, the changes in goods market wedge and labour market wedge are both important for accounting for the real exchange rate dynamics.

6 Conclusion

The standard Balassa-Samuelson model is widely used for determining the equilibrium value of the Chinese currency, Renminbi, and based on this analysis it is often suggested that the Renminbi is significantly under valued. In this paper we show that the discrepancy of the predicted and actual real exchange rate is mainly due to the restrictive assumptions of the standard Balassa-Samuelson model. We use a three-sector open economy model of structural change to reexamine the determination of the China-US real exchange rate and find that the model can quantitatively account for both the structural changes in the two countries and the dynamics of the real exchange rate observed in the data. We also find that changes in the relative prices of agricultural goods between the two countries and the changes in the labour market wedge between agriculture and manufacturing in China are important determinants of the real exchange rate dynamics. We think it is important then to investigate further the more fundamental sources of the variations in these two variables.

Figure 1. Employment Shares in the US

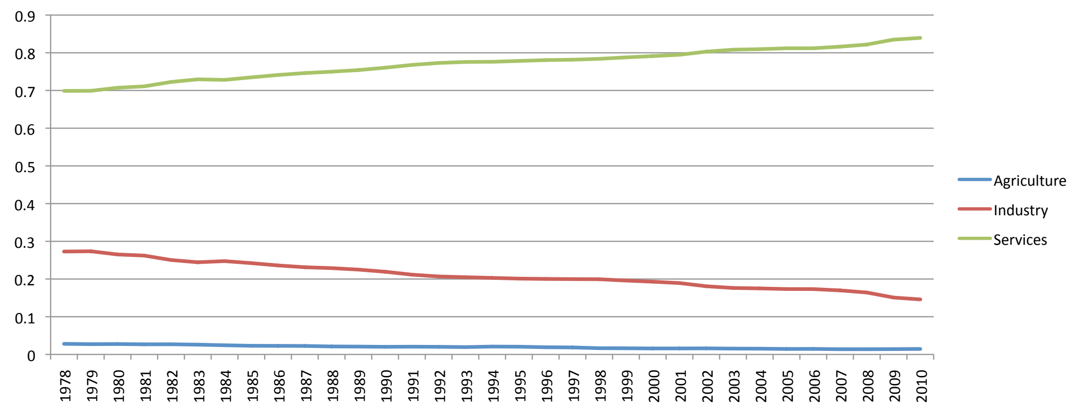


Figure 2. Employment Shares in China

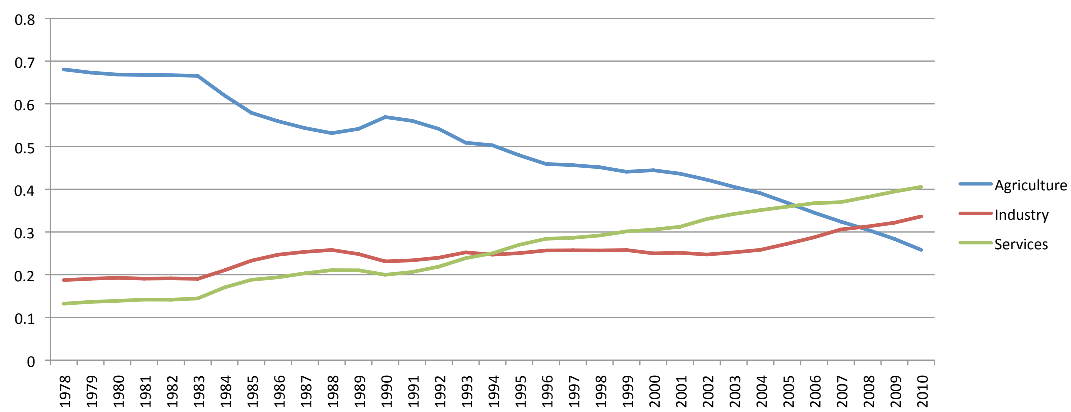
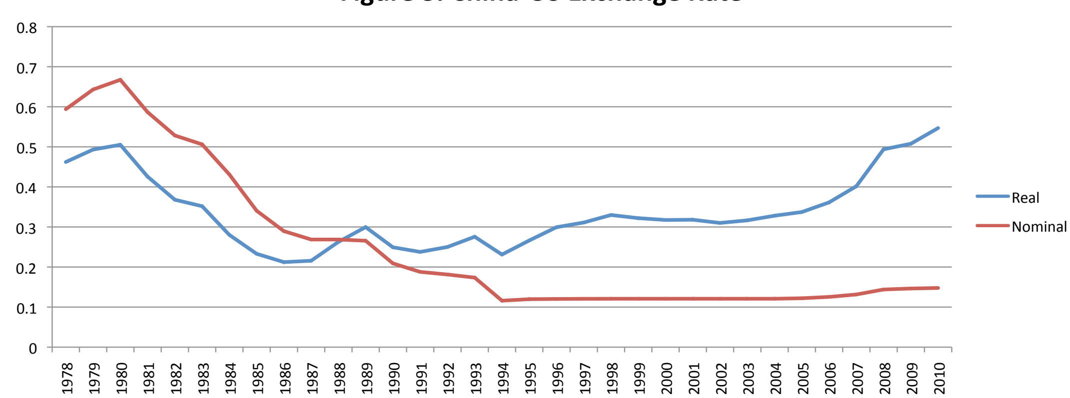


Figure 3. China-US Exchange Rate



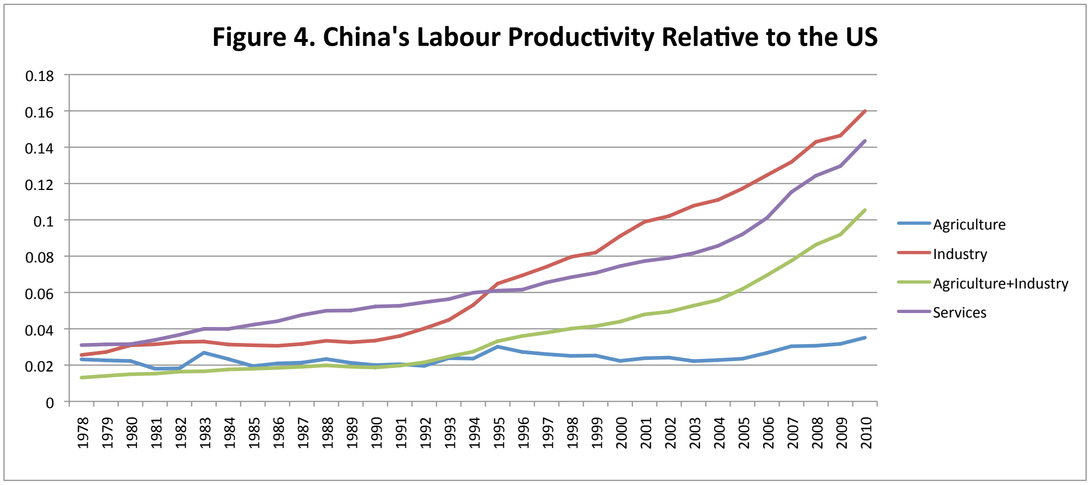


Figure 4. China's Labour Productivity Relative to the US
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Agriculture
Industry
Agriculture+Industry
Services

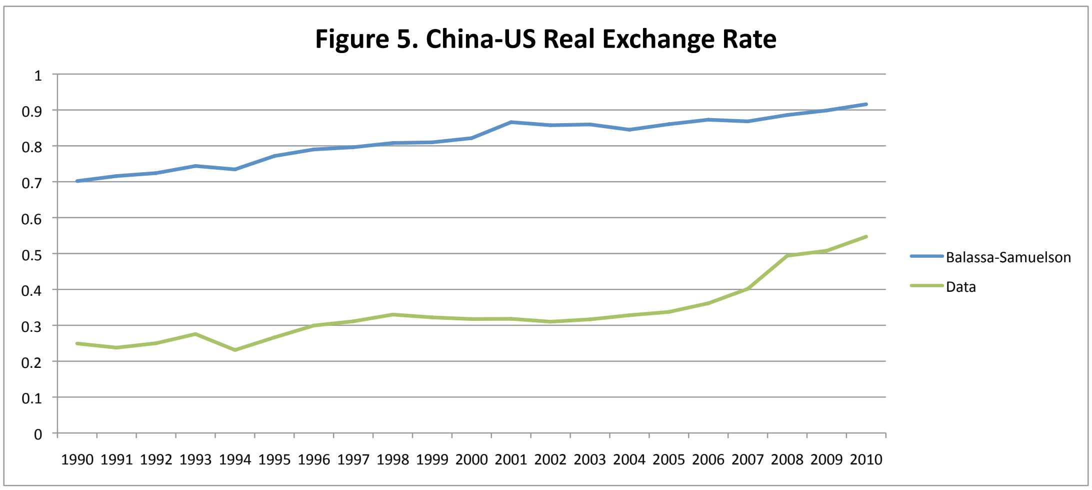


Figure 5. China-US Real Exchange Rate
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Balassa-Samuelson
Data

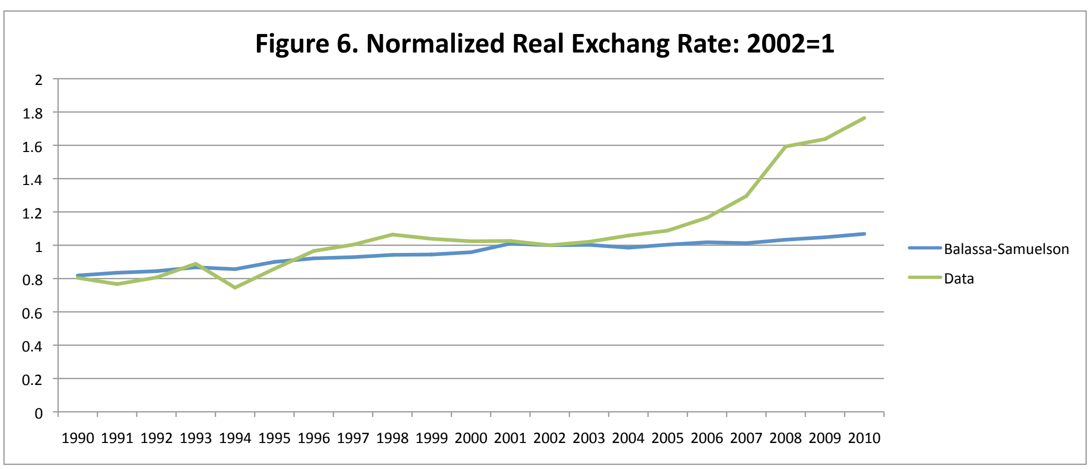
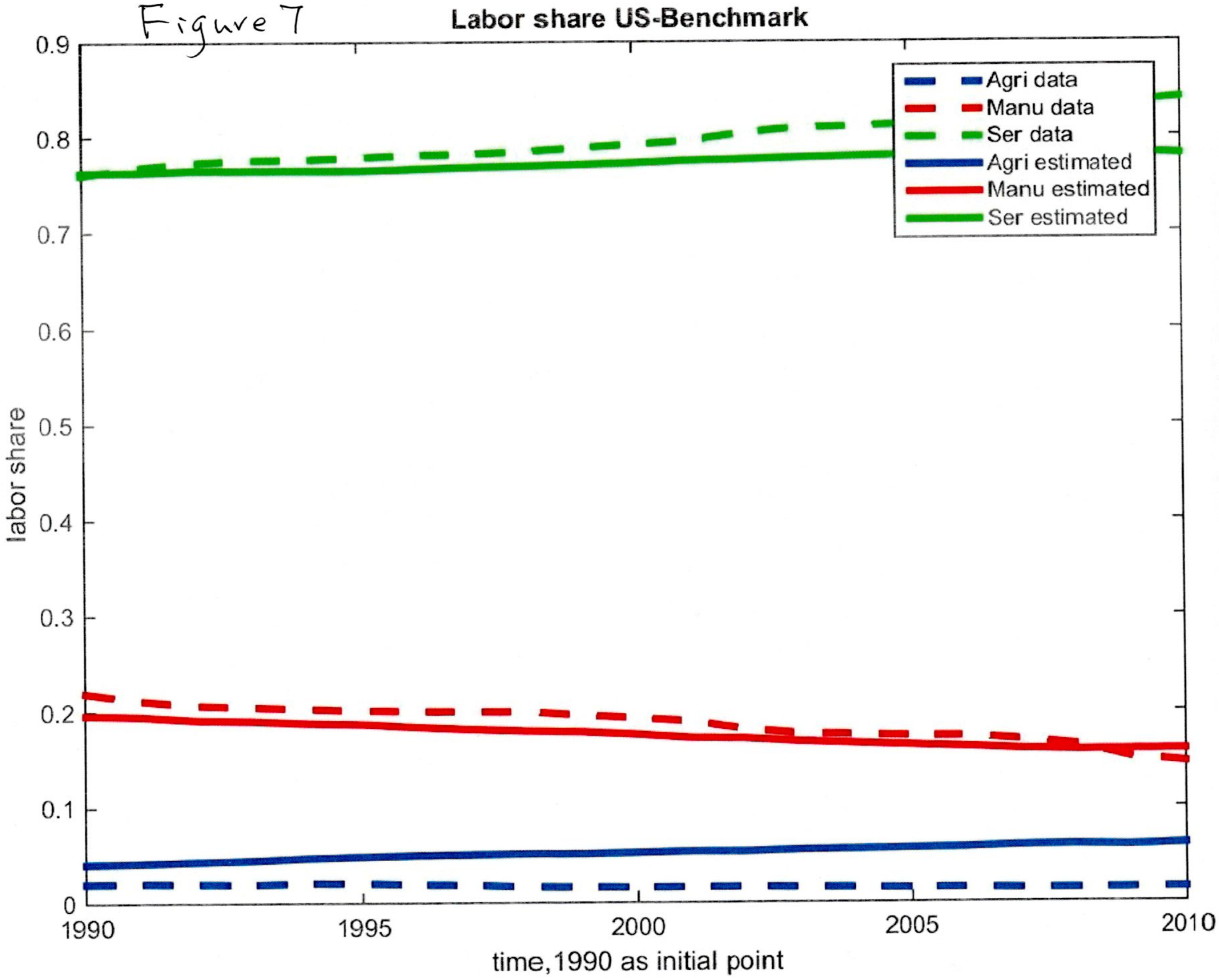


Figure 6. Normalized Real Exchang Rate: 2002=1
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Balassa-Samuelson
Data

Figure 7



Labor share US-Benchmark
labor share
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1990
1995
2000
2005
2010
time,1990 as initial point
Agri data
Manu data
Ser data
Agri estimated
Manu estimated
Ser estimated

Figure 8.

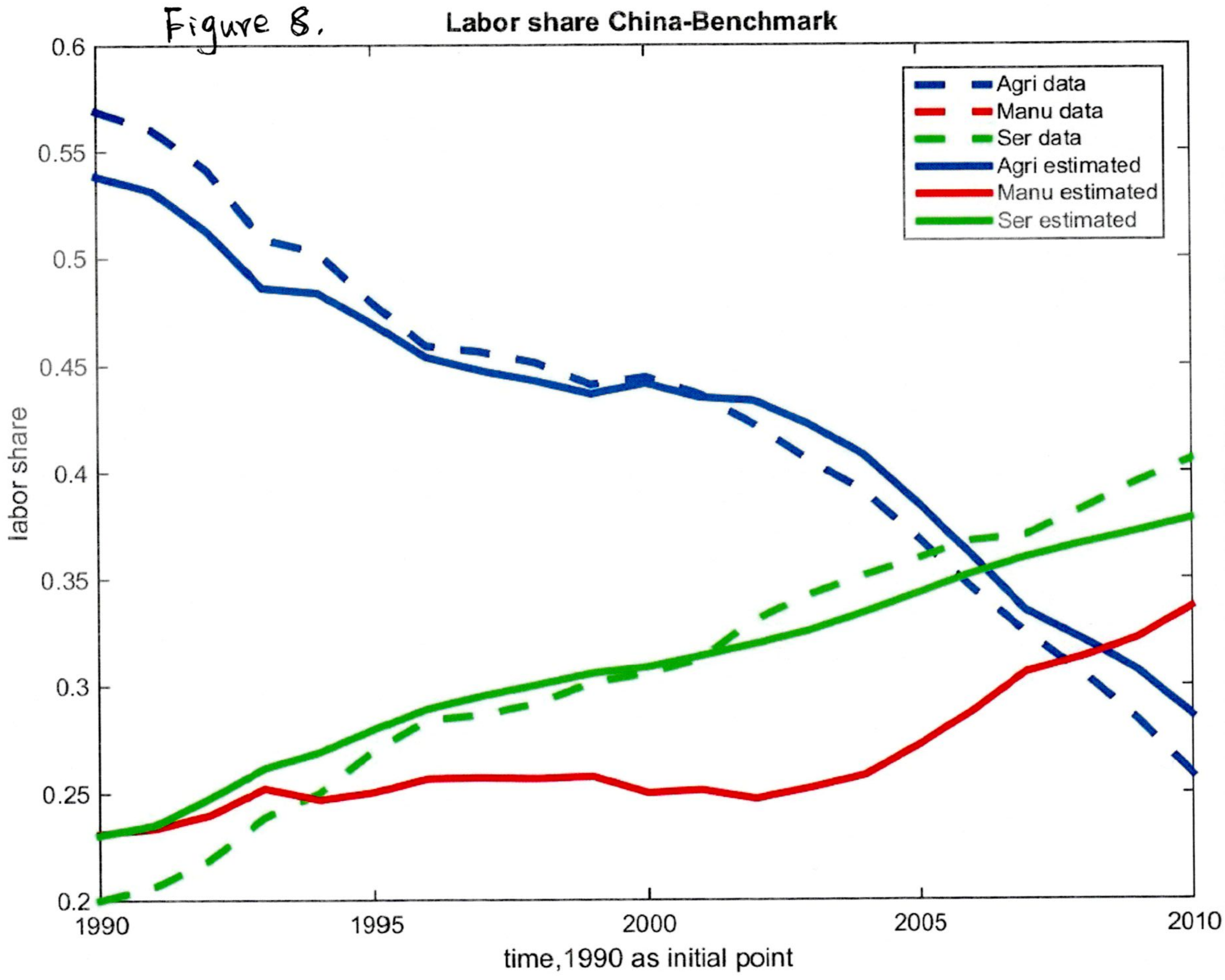

Labor share China-Benchmark
Agri data
Manu data
Ser data
Agri estimated
Manu estimated
Ser estimated
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
labor share
1990
1995
2000
2005
2010
time,1990 as initial point

Figure 9. Predicted and Actual Real Exchange Rate

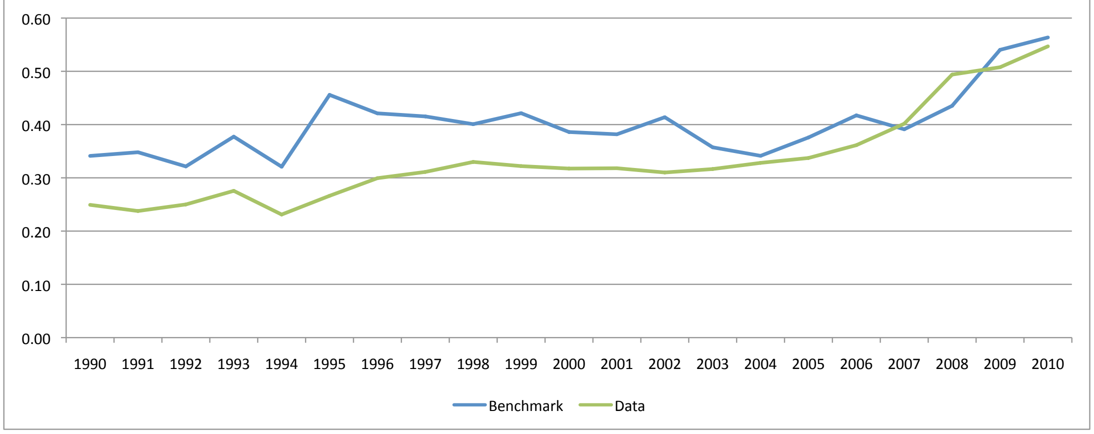


Figure 10. Wedges

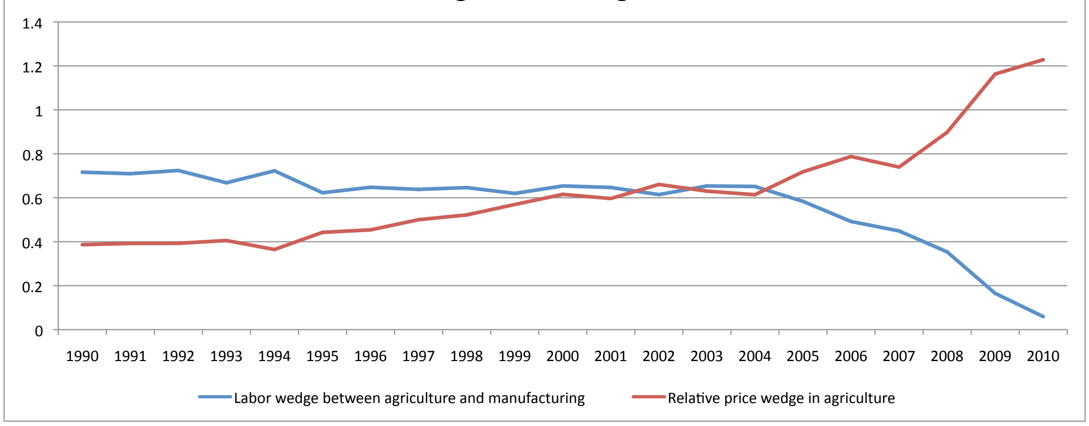
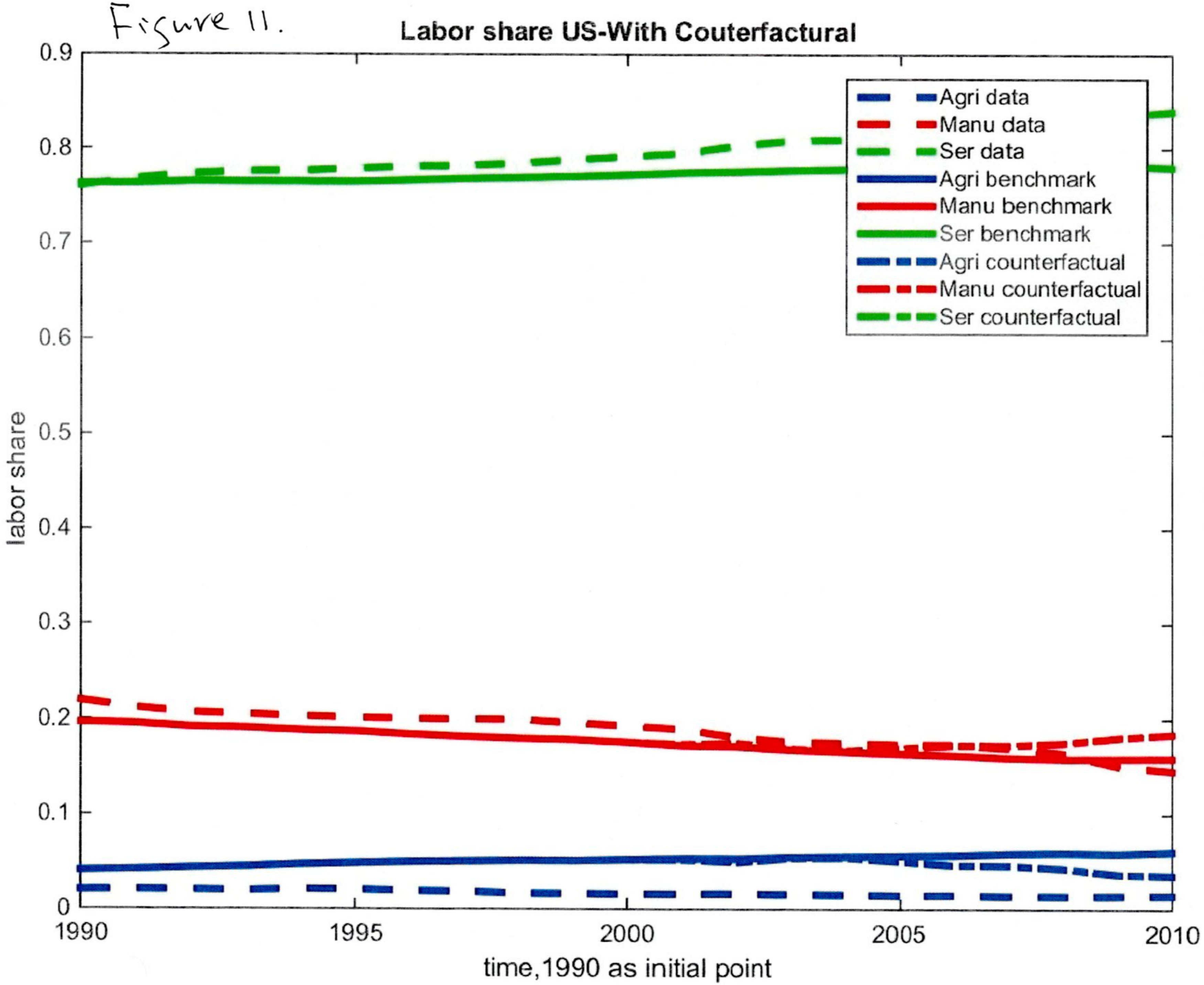
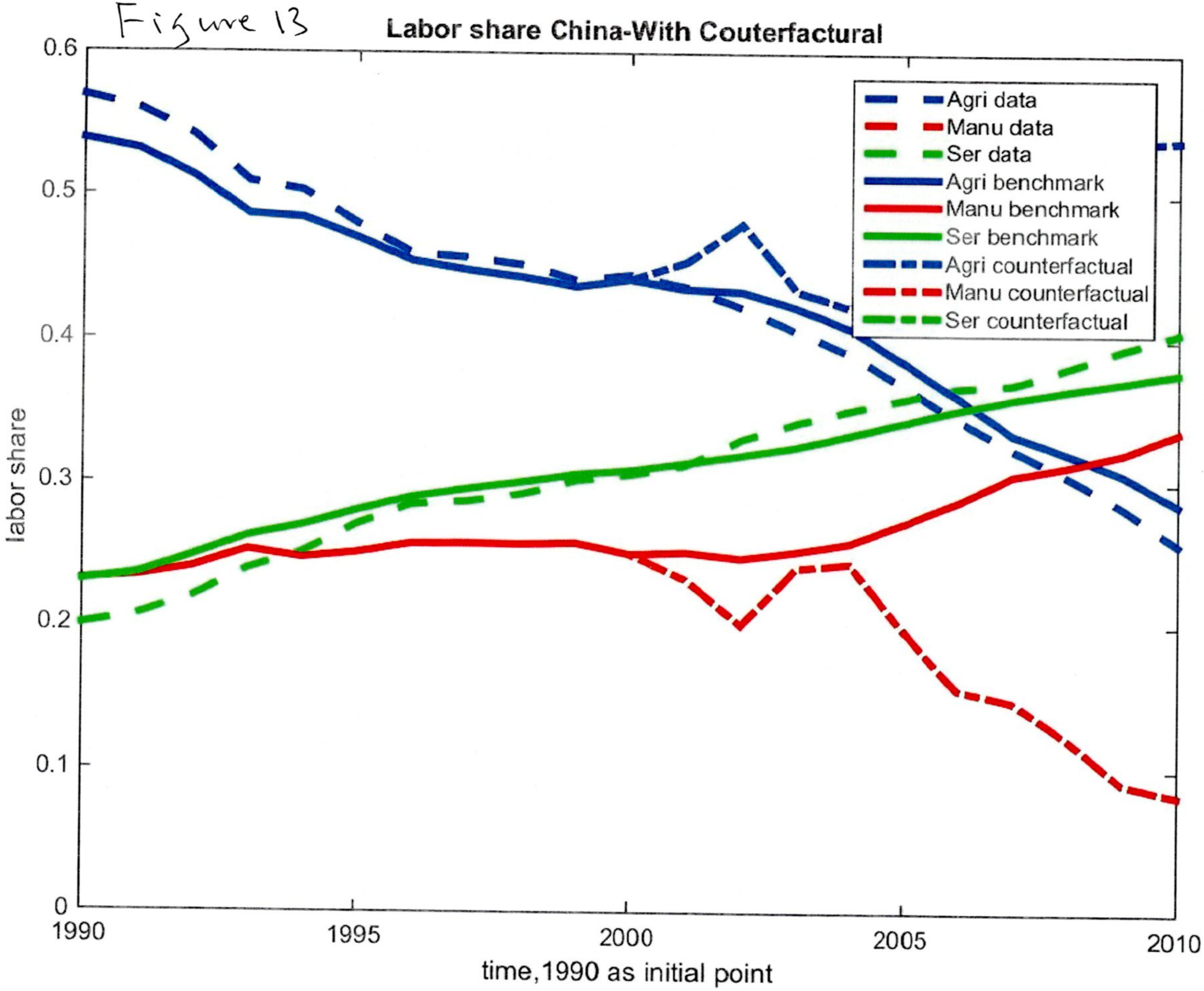


Figure 11.



Labor share US-With Couterfactural
labor share
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1990
1995
2000
2005
2010
time,1990 as initial point
Agri data
Manu data
Ser data
Agri benchmark
Manu benchmark
Ser benchmark
Agri counterfactual
Manu counterfactual
Ser counterfactual

Figure 13


Labor share China-With Couterfactural
labor share
time,1990 as initial point
0.6
0.5
0.4
0.3
0.2
0.1
0
1990
1995
2000
2005
2010
Agri data
Manu data
Ser data
Agri benchmark
Manu benchmark
Ser benchmark
Agri counterfactual
Manu counterfactual
Ser counterfactual

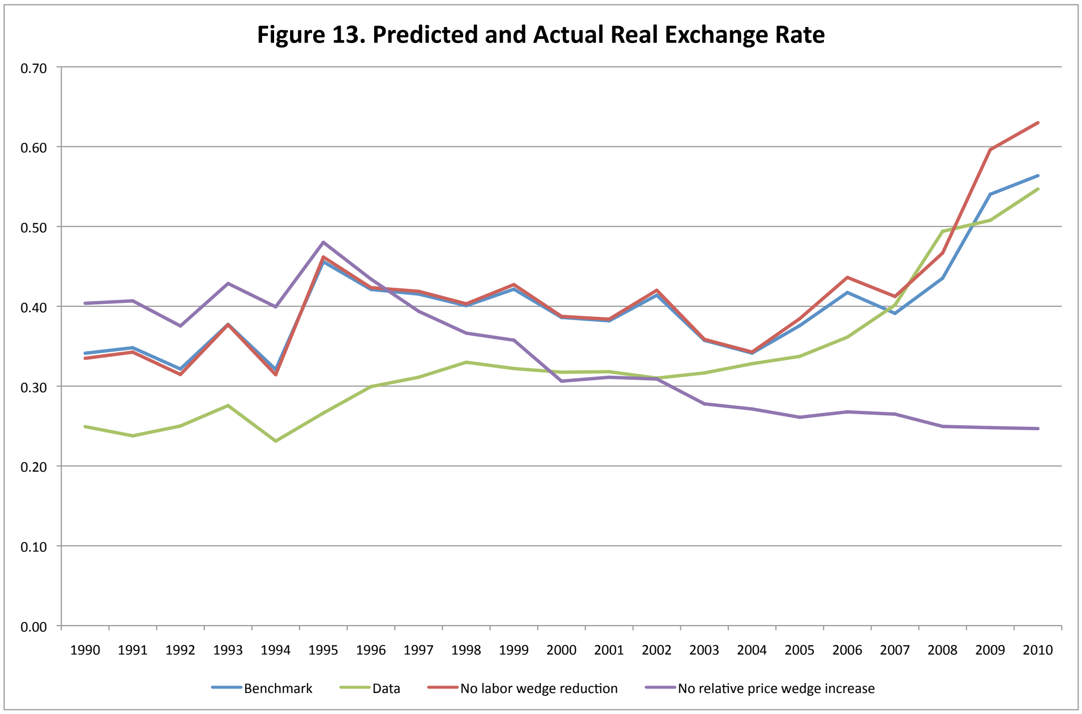


Figure 13. Predicted and Actual Real Exchange Rate
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Benchmark
Data
No labor wedge reduction
No relative price wedge increase

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Data Appendix

For our quantitative analysis, we need to have sectoral price levels, labour productivities and employments for both the US and China. Furthermore, they have to be in the same units between the two countries. This appendix describes how we construct these variables from three different sources: The 10-Sector Database (Timmer, de Vries and de Vries, 2014) and Productivity Level Database (Inklaar and Timmer, 2014), both from the Groningen Growth and Development Centre (GGDC), and the employment series constructed by Brandt and Zhu (2010).

A Employment

For the US series, we construct them from the GGDC 10-Sector Database. For China, we use the data constructed by Brandt and Zhu (2010). Note that the series constructed by Brandt and Zhu (2010) are different from those reported in the GGDC 10-Sector Database because they make adjustments to the agricultural employment to correct the over reporting by the National Bureau of Statistics of China.

B Price Levels in the Base Year (2005)

The GGDC 10-Sector Database provides both the nominal and real value-added at 2005 national prices for 10 sectors: 1. Agriculture, hunting, forestry and fishing (AtB); 2. Mining and quarrying (C); 3. Manufacturing (D); 4. Electricity, gas and water supply (E); 5. Construction (F); 6. Wholesale and retail trade, hotels and restaurants (GtH); 7. Transport, storage, and communication (I); 8. Finance, insurance, real estate and business services (JtK); 9. Government services (LtN); and 10. Community, social and personal services (OtP). We aggregate them into nominal and real value-added for the three sectors: Agriculture, Industry and Services. Here Agriculture is identical to the first sector (AtB), Industry is the sum of sector 2-5, and Services is the sum of sector 6-10.

The GGDC Productivity Level Database also provides the relative prices for the same 10 sectors for the year of 2005. The relative price of sector i in country j is defined as

$$P^j_{i,2005} = \frac{\text{National Price Value-Added of Sector i in Country j and Year } 2005/E^j_{2005}}{\text{2005 International Price Value-Added of sector i in Country j and Year 2005}}.$$

Here E^j_t is the nominal exchange rate of currency in country j against the US dollar in year t. This relative price is effectively the ratio of the sector i value-added priced at national prices (in US dollar) and international prices (in US dollar as well). From these relative prices, we can also generate relative prices for the more aggregate three sectors as follows:

$$P^j_{a,2005} = P^j_{1,2005},$$

$$P^j_{m,2005} = \frac{\text{National Price Value-Added of Industry in Country j and year 2005}}{\sum_{i=2}^{5}\left(\text{National Price Value-Added of Sector i in Country j and year } 2005/P^j_{k,2005}\right)},$$

$$P_s^j = \frac{\text{National Price Value-Added of Services in Country j and year 2005}}{\sum_{i=6}^{10}\left(\text{National Price Value-Added of Sector i in Country j and year 2005}/P_{k,2005}^j\right)}.$$

C Real Value-Added and Labor Productivity by Sector in 2005 International Dollars

With the price levels in 2005, we can calculate real value-added of sector i in country j at 2005 international prices as

$$Y_{i,2005}^j = \frac{\text{National Price Value-Added of Sector i in Country j and Year 2005}}{E_{2005}^j P_{i,2005}^j}.$$

We then assume that the real growth rate of 2005 International Price Value-Added in sector i is the same as the real GDP growth rate of that sector (calculated using 2005 national prices). So,

$$Y_{i,t}^j = \frac{\text{2005 National Price Value-Added of Sector i in Country j and Year t}}{\text{2005 National Price Value-Added of Sector i in Country j and Year 2005}} \times Y_{i,2005}^j.$$

The labor productivities are then calculated as

$$A_{i,t}^j = Y_{i,t}^j / L_{i,t}^j$$

D Price Levels in All Years

Given the real-value added in 2005 international prices, we can calculated the price levels in all years as:

$$P_{i,t}^j = \frac{\text{Nominal Value-Added of Sector i in Country j and Year t}}{E_t^j Y_{i,t}^j}$$

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