De-industrialization of the Riches and the Rise of China*

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Abstract

This paper studies the impact of the industrialization of China on the U.S. industrial employment share between 1978 and 2005. A comparison of the predictions of open and closed economy models suggests that a common explanation of de-industrialization in the literature, which is based on increased productivity in industry relative to services in a closed economy setting, is not compelling. My benchmark results suggest that the closed economy model accounts for 32.8 percent of the declines in the U.S. industrial employment share while the open economy accounts for 62.6 percent of the de-industrialization in the U.S. between 1978 and 2005. Moreover, the open economy model has more explanatory power to explain the secular changes in the U.S. industrial employment share in the post-1990 period. The open economy model accounts for 83.9 percent of the de-industrialization while the closed economy accounts for 35.1 percent of the de-industrialization in the U.S. between 1992 and 2005. Counterfactual experiments show that if the Chinese economy had experienced productivity in industry equal to that of the U.S., then the role of openness would have been diminished. The higher the elasticity of substitution between home and foreign industrial goods is, the more accelerated structural transformation in the U.S.

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The majority of the existing studies on structural change examine the experience of a country in isolation, and fails to take into account the interactions between countries. This can be misleading... The central question is whether structural change in one country will slow down or speed up structural change in other countries.

— Kiminori Matsuyama (2008)

1 Introduction

As the current wave of globalization intensifies, industrialized nations are exposed to new competition in domestic and foreign markets. Reductions in trade costs and widespread economic reforms may cause shifts of comparative advantage across nations which effect domestic and international reallocations of production factors. For example, today, the majority of world manufacturing employment is located in the developing countries of Asia, especially in China. In terms of employment, China's manufacturing industry is the largest in the world, employing more manufacturing workers than the G7 countries combined. In 2007, China was the second leading exporter and third largest importer of merchandise trade in the world. Moreover, the U.S. is the largest export market for Chinese-made products (followed by Hong Kong and Japan). This paper studies the impact of the industrialization of China on the U.S. industrial employment share between 1978 and 2005.[1]

The reallocation of resources across the broad economic sectors agriculture, industry, and services is a prominent feature of economic development since the pioneering works of Fisher 1935; Clark 1940; and Kuznets 1966. In this transformation, a substantial and permanent shift occurs in the composition of income, output, and employment away from agriculture and towards industry and services. Decline in agricultural employment in early stages of development is well-established.[2] The share of agriculture in total employment, which was initially very large, has undergone a continuous decline throughout the entire path of economic development. For example, agricultural employment share in the U.S. fell from about 74 percent in 1800 to about 2 percent in 2000.[3]

On the other hand, decline (rise) in industrial (services) employment share is a relatively recent issue.[4] The share of industrial employment has been declining for more

[1]Coleman (2007) argues that in countries like Japan, South Korea, and Taiwan towards the end of the 20th century, the emergence of China seems to be associated with falling terms of trade and overall growth slowdown.

[2]See, for example, Caselli and Coleman 2001; and Dennis and İşcan 2009.

[3]http://myweb.dal.ca/tiscan/research/data/account.xls

[4]See Fuchs 1968 and Singelmann 1978 for early studies and İşcan 2010 for a recent investigation of the rise of the service employment in the U.S.

than three decades in today's most advanced economies, a phenomenon that is referred to as "de-industrialization".[5] For example, industrial employment share fell from about 33 percent to 17.6 percent, while services employment share increased from 58 percent to about 81 percent in the U.S. between 1950 and 2005 (see Data Appendix).

Existing econometric studies have argued that de-industrialization is partly explained by factors that are internal to the advanced economies. Among these internal factors are changing expenditure patterns, the faster growth of productivity in the industrial sector than in services, and the resulting decline in the relative price of manufactures.[6] In addition to the econometric studies, there are calibrated multi-sector general equilibrium models to understand the sources of the sectoral reallocation and to quantify the impact of these shifts on aggregate growth and productivity. Most of these studies utilize two (agriculture and the rest of the economy) or three (agriculture, industry, and services) sector models and generate structural transformation as a result of the differences in productivity growth across sectors (Ngai and Pissarides 2007) or based on the sectoral differences in income elasticities of demand (Kongsamut, Rebelo, and Xie 2001) or both (Duarte and Restuccia 2010).[7]

The majority of the existing studies on structural transformation examine the experience of a country in isolation failing to take into account the interactions between countries. There are a few very recent studies investigating the relationship between openness and the different aspects of structural transformation. For example, Stefanski (2011) analyzes the impact of structural transformation on global oil prices (rather than employment shares) and finds that structural transformation in China and India accounts for up to 26 percent of the increase in the oil price in the OECD over the 1970-2010 period. Teignier (2011) studies the effect of international trade on de-agriculturalization and argues that trade accelerates the structural transformation, i.e., if the United Kingdom had been in autarky, the agricultural employment share in 1800 would have been around 80 percent instead of 35 percent. Yi and Zhang (2011) develop a two-country, three-sector model (agriculture and manufacturing are tradable sectors and the service sector is non-tradable) and show that in an advanced economy, the manufacturing sector will decline at a faster rate, and the services sector will grow at a faster rate, in an open economy relative to the closed economy.

[5]Job losses in the industrial sector are part of a long trend as all the G7 countries increasingly become service economies. In the G7, the share of employment in industry reached a peak in 1969 (38.3 percent) and the share was 23.7 percent in 2006 (OECD Labor Force Statistics).

[6]See, for example, Alderson 1999; Rowthorn and Ramaswamy 1999; Rowthorn and Coutts 2004; Nickell, Redding, and Swaffield 2008; and Kollmeyer 2009.

[7]See Foellmi and Zweimüller 2008; Buera and Kaboski 2009a,b; Matsuyama 2009 and the references therein for recent studies of structural transformation.

I develop a two-country, three-sector model, in which countries trade industrial goods. Goods are differentiated by the productivity growth with which they are domestically produced. These features of the model and the degree of substitutability in preferences between home and foreign produced units of industrial goods endogenously determine a country's equilibrium pattern of production and trade. I study the quantitative predictions of the model economy over the sample period spanning 1978-2005 with sectoral data from China and the U.S.

A comparison of the predictions of open and closed economy models suggests that a common explanation of de-industrialization in the literature, which is based on increased productivity in industry relative to services in a closed economy setting, is not compelling. My benchmark results suggest that the closed economy model accounts for 32.8 percent of the declines in the U.S. industrial employment share while the open economy accounts for 62.6 percent of the de-industrialization in the U.S. between 1978 and 2005. Moreover, the open economy model has more explanatory power to explain the secular changes in the U.S. industrial employment share in the post-1990 period. The open economy model accounts for 83.9 percent of the de-industrialization while the closed economy accounts for 35.1 percent of the de-industrialization in the U.S. between 1992 and 2005. Counterfactual experiments show that if the Chinese economy had experienced productivity in industry equal to that of the U.S., then the role of openness would have been diminished. The higher the elasticity of substitution between home and foreign industrial goods is, the more accelerated structural transformation in the U.S.

Several sectoral studies provide a breakdown of convergence and catch-up arguing that there are large and systematic differences in sectoral productivity across countries and these sectoral differences are important for understanding movements in aggregate income and productivity without exploring the role of openness in this catching-up process (see, for example, Bernard and Jones 1996 and Duarte and Restuccia 2010). My contribution is to explain the role of the differences in sectoral productivity growth rates in different countries to explain the secular changes in employment shares. I find that differences in sectoral productivity growth rates between China and the U.S. play an important role in accounting for annual changes in the U.S. industrial employment share.

The rest of the paper is organized as follows. Section 2 presents a three-sector closed economy model, characterizes the competitive equilibrium, and derives equilibrium conditions for sectoral employment shares. Section 3 develops a three-sector, two-country, perfect foresight economy where differences between the U.S. and China with respect to the exogenous sectoral growth rates are introduced as driving forces. This section also presents the calibration of the model and the quantitative analysis. Section 4 concludes.

2 Structural Transformation in Closed Economy

2.1 Economic Environment

Households and preferences. The economy is populated by an infinitely-lived representative household of constant size over time. The population size is normalized to one, without loss of generality. I assume that the household is endowed with one unit of productive time that it supplies inelastically to the market and consumption is the only determinant of the instantaneous utility function, which is given by:

$$U(\bar{A}, C) = \bar{A} + \log(C) \tag{1}$$

The instantaneous utility is defined over the agricultural good $(\bar{A})$ and the composite consumption good (C), which is derived from the industry and services:

$$C = (\gamma^{1-\eta} I^{\eta} + (1-\gamma)^{1-\eta} S^{\eta})^{1/\eta}, \tag{2}$$

where I is the consumption of the industrial good, and S is the consumption of the services. The elasticity of substitution between industrial goods and the services is given by $1/(1-\eta)$. The weight γ influences how non-agricultural consumption expenditure is allocated between industry and services.[8]

At each date, and given prices, the household chooses consumption of each good to maximize his lifetime utility subject to the budget constraint,

$$p_A \bar{A} + p_I I + p_S S = \omega, \tag{3}$$

where p_j is the price of good-*j* output and ω is the wage-rate in the economy.

Firms and technologies. There are three goods produced. The production function for sector *j* is given by

$$Y_j = \theta_j L_j, \tag{4}$$

[8] The utility function belongs to the following general type of utility function:

$$U(A, C) = \begin{cases} \bar{A}, & \text{if } A < \bar{A}, \\ \log(C) + \bar{A}, & \text{if } A \geq \bar{A}. \end{cases}$$

This specification of preferences implies that the economy specializes in agriculture until the subsistence level $\bar{A}$ is reached. Moreover, the economy will never produce more agricultural good than $\bar{A}$. Once $\bar{A}$ is reached, the representative household will supply labor to the non-agricultural sectors. Technological progress and this specification of preferences cause structural change, with the economy shifting from a preponderance of agricultural production to marginalization of the same sector (see Laitner 2000, Stokey 2001, Gollin, Parente, and Rogerson 2002, 2004, 2007).

where Y_j is output of sector *j*, L_j is labor allocated to production, and θ_j is sector *j*'s labor productivity. Since I abstract from capital and fixed factors in production, differences in labor productivity implicitly incorporates differences due to capital as well as due to the institutional differences across sectors. Firm *j* problem is given by

$$max \quad p_j Y_j - \omega L_j \qquad s.t. \qquad Y_j = \theta_j L_j, \qquad L_j > 0. \tag{5}$$

Equilibrium. Given a set of prices $\{p_A, p_I, p_S, \omega\}$, a competitive equilibrium consists of consumption decisions that are the household's allocations $\{\bar{A}, I, S\}$, and factor allocations for the firms $\{L_A, L_I, L_S\}$ such that given prices, the firm's allocations solve its profit maximization problem, the household's allocations solve the household's utility maximization problem, and factor and product markets clear:

$$L_A + L_I + L_S = 1, \tag{6}$$

$$\bar{A} = Y_A, \quad I = Y_I, \quad S = Y_S. \tag{7}$$

Sectoral Employment Shares. Sectoral employment shares at a certain date are given as follows.

$$L_A = \bar{A}/\theta_A, \qquad L_I = \frac{\Delta(1 - (\bar{A}/\theta_A))}{1 + \Delta}, \qquad L_S = 1 - L_A - L_I, \tag{8}$$

where $\Delta \equiv (\gamma/(1-\gamma))(\theta_I/\theta_S)^{-\eta/(\eta-1)}$.

Employment share in agriculture is determined solely by the subsistence constraint and labor productivity in agriculture. Employment share in agriculture is negatively correlated with productivity in this sector (and it is independent of productivity in other sectors). Hence, increases in the level of agricultural productivity push labor out of the agricultural sector, since the same amount of agricultural goods can be produced with lower levels of employment. I only allow labor push channel to explain de-agriculturulization excluding the labor pull mechanism (improvements in non-agricultural technology attract labor out of agriculture) stressed by Lewis 1954, Harris and Todaro 1970, and Hansen and Prescott 2002. Alvarez-Cuadrado and Poschke (2011) study de-agriculturalization in 12 industrialized countries since the 19th century.[9] They argue that productivity improvements in the agricultural sector are the main driver of structural change (movements of resources out of the agricultural sector) since 1960s.

Allocation of labor to a non-agricultural sector depends not only in that sector's labor

[9]The countries are Belgium, Canada, Finland, France, Germany, Japan, the Netherlands, South Korea, Spain, Sweden, the U.K., and the U.S.

productivity but also on productivity in other sectors. Productivity in agriculture affects all non-agricultural sectors as it determines the amount of labor left to be allocated among the non-agricultural sectors. When $1/(1-\eta) < 1$, faster productivity growth in industry leads to Baumol's prediction for services with labor moving of industry, i.e., labor goes to the slow-growing service sector (Baumol 1967 and Nordhaus 2008).

2.2 Quantitative Analysis

Calibration. The model economy is calibrated to 1950 for the U.S. In particular, the model is parameterized so that it matches sectoral employment shares in 1950. All time series are de-trended using the Hodrick-Prescott filter with a smoothing parameter of 6.25 before any ratios are computed.[10] I normalize productivity levels across sectors to one in 1950. I use data on sectoral labor productivity growth to obtain the time paths of sectoral productivity between 1950 and 2005.

I calibrate subsistence in agriculture so that the equilibrium of the model matches the share of employment in agriculture for 1950. This suggests that $\bar{A}$=0.0875. I calibrate γ to match the industrial employment share in 1950 and obtain γ=0.3652. Both $\bar{A}$ and γ are calibrated independent of the elasticity of the substitution parameter. The recent literature provides a range of estimates for $1/(1-\eta)$. Rogerson (2008), Bah (2009), and Duarte and Restuccia (2010) study a similar closed economy multi sector models and calibrate an elasticity of 0.44, 0.45, and 0.40, respectively, studying the U.S. data for the post-1950 period. Ngai and Pissarides (2004, 2008) cite the empirical literature and argue that the elasticity of substitution lies between 0.1 and 0.3. I study three values of $1/(1-\eta)$: 0.1, 0.3, and 0.45.

Results. Panel (a) in Figure 1 plots the agricultural employment share in the model and the data. The model generated agricultural employment share seems to capture the secular movements in the data reasonably well. For example, during the 1950-1998 period, the model predicts a decline in the agricultural employment share of 7.0 percentage points, which is almost all of the actual decline in the data.[11] The agricultural employ-

[10] I am interested in long-term trends, not in yearly fluctuations. I follow Ravn and Uhlig (2002) for choosing 6.25 as a smoothing parameter. The features that I emphasize also hold for other smoothing parameter values for annual data such as 100 and 400. See, also, Jaimovich and Siu (2009) for a very similar discussion of the Hodrick-Prescott filter for annual data.

[11] Between 1950 and 1977, the model predicts a decline in the agricultural employment share of 4.8 percentage points, which is 72.1 percent of the actual decline in the data. I compute this statistic as follows. The model predicts that agricultural employment share decreases by 4.8 percent (from 8.75 percent in 1950 to 3.95 percent in 1977, a 100*ln(8.75/3.95)/27=2.94 percent annual decrease) while in the data the decrease is 5.84 percent (from 8.75 percent to 2.91 percent, a 100*ln(8.75/2.91)/27=4.07 percent annual decrease. Thus, the model accounts for 100*2.94/4.07=72.1 percent of the decline in agricultural employment share between

ment shares generated by the model are smaller than those in the data after 1998 and the model underpredicts the magnitude of the agricultural employment share by 10.5 percent on average between 1999 and 2005.[12]

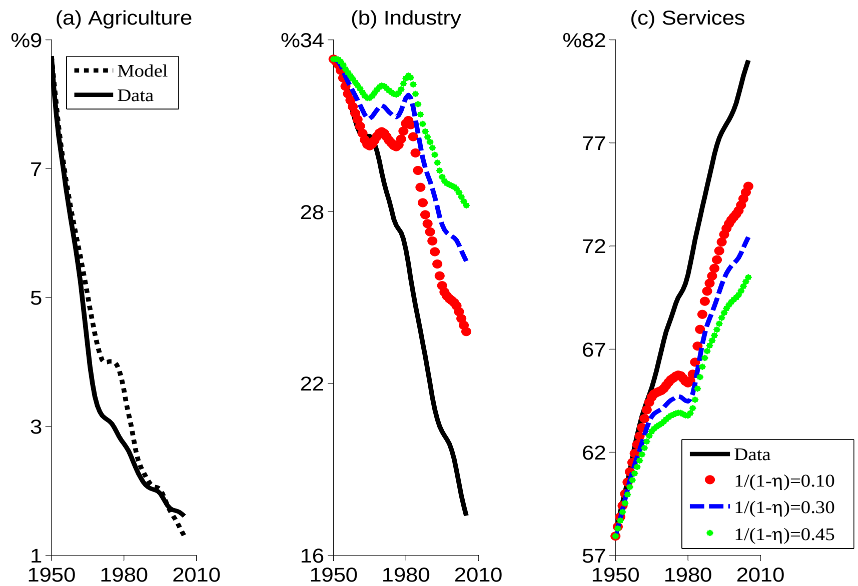

Figure 1: Sectoral Employment Shares in the Closed Economy

Panel (b) in Figure 1 shows that the model overpredicts the industrial employment share for almost all the years during the sample period. The model predicts a decline in the industrial employment share of 5.1 percentage points between 1950 and 2005, which is only 25.6 percent of the actual decline in the data when $1/(1-\eta) = 0.45$.[13] The model accounts for 36.6 percent of the decline in industrial employment share when $1/(1-\eta) = 0.30$ and it predicts a decline in the industrial employment share of 9.5 percentage points between 1950 and 2005, which is 51.7 percent of the actual decline in the

1950 and 1977. The model overpredicts the magnitude of the agricultural employment share by 24.2 percent on average between 1978 and 1985 and 4.1 percent on average between 1986 and 1998.

[12] Incorporating land into the agricultural production function does not change the qualitative nature of the results. I let agricultural production function be $Y_A = \theta_A(L_A)^\alpha$, where α is the income share of labor in agriculture and I normalize land to be one. Employment share in agriculture is now given by: $L_A = (\bar{A}/\theta_A)^{1/\alpha}$. I follow Restuccia, Yang, and Zhu (2008) and the references therein and set $\alpha = 0.7$. The agricultural employment shares generated by the model with land are slightly smaller than those in the model without land.

[13] I compute this statistic as follows. The model predicts that the industrial employment share decreases by 5.1 percent (from 33.3 percent in 1950 to 28.2 percent in 2005, a 100*ln(33.3/28.2)/55=0.30 percent annual decrease) while in the data the decrease is 15.9 percent (from 33.3 percent to 17.4 percent, a 100*ln(33.3/17.4)/55=1.18 percent annual decrease. This implies that the model accounts for 100*0.30/1.18=25.6 percent of the decline in industrial employment share.

data when $1/(1-\eta) = 0.10$. These results suggest that the model predictions get close to match the data as the elasticity of substitution decreases, i.e., the model with $\eta = 0.1$ fits better, relatively, compared to the other two cases. The intuition is that preferences over the non-agricultural goods approach a Cobb-Douglas when $1/(1-\eta)$ approaches 1 so that the substitution effect vanishes regardless of the magnitude of the differences between sectoral productivity differences.

The gap between the model and the data is increasing steadily. Especially, there is a large gap between the model and the data in the last three decades. The model overpredicts the magnitude of the industrial employment share by 26.6 percent on average between 1975 and 1990 and 51 percent on average between 1990 and 2005 when $1/(1-\eta) = 0.45$ and it overpredicts the magnitude of the industrial employment share by around 18 percent on average between 1975 and 1990 and 29.5 percent on average between 1990 and 2005 when $1/(1-\eta) = 0.10$. The reason that there is a considerable gap between the model and the actual data for the U.S. industrial employment share in the last three decades is that productivity gains in industry relative to services are not high enough to move the labor out of the industrial sector. This problem is robust under different values of the elasticity of substitution between industrial goods and the services.

My findings are consistent with some recent studies. For example, Obstfeld and Rogoff (2002, Chapter 4) look at the relationship between productivity change and manufacturing employment and argue that domestic differential productivity gains in manufacturing may not necessarily explain de-industrialization in today's riches. Matsuyama (2009) presents a simple analytical example demonstrating how misleading writing down a closed economy model can be in the context of productivity-based theory of manufacturing employment decline. These two studies do not take the implications of the theory to the data. Buera and Kaboski (2009b), taking the implications of calibrated closed economy to the historical data for the structural transformation experience of the U.S. between 1870 and 2000, find that the model cannot account for the steep decline in manufacturing and rise in services in the later data. Similarly, İşcan (2010) studies a three-sector closed economy model and finds considerable gaps between the model and the data, i.e. the data exhibits a relatively sharp decline in manufacturing employment share over the last three decades of the 20th century, whereas the predicted series are rather flat.

3 Structural Transformation in Open Economy

3.1 Economic Environment

The world consists of two countries, denoted by *i=1,2*. Each country is inhabited by a continuum of identical and infinitely lived households that can be aggregated into a representative household. The three sectors (goods) are the agricultural sector, denoted "A", the industrial sector, denoted "I", and the service sector, denoted "S". Goods are differentiated by the labor productivity with which they are domestically produced and trade is allowed only in industrial sector. Industrial good produced in different countries is imperfectly substitutable in consumption. This feature of the model and the degree of substitutability in preferences between home and foreign produced units of each good endogenously determine a country's equilibrium pattern of production and trade.

Households and preferences. There is a representative agent in each country who consumes all three types of good and works. Labor is inelastically supplied. The preference structure of an agent in country *i* is given by the following period utility function

$$U(\bar{\mathrm{A}}^i, C^i) = \bar{\mathrm{A}}^i + \log(C^i). \tag{9}$$

The composite consumption good in country *i*:

$$C^i = \Big((\gamma^i)^{1-\eta}(I^i)^\eta + (1-\gamma^i)^{1-\eta}(S^i)^\eta\Big)^{1/\eta}, \tag{10}$$

where $1/(1-\eta)$ is substitution elasticity between industry and services and γ^i is share of industry in non-agricultural consumption in country *i*. Industrial good consumption in country *i* is given by following aggregation:

$$I^i = \Big((\mu^i)^{1-\rho}(I^i_i)^\rho + (1-\mu^i)^{1-\rho}(I^i_k)^\rho\Big)^{1/\rho}, \tag{11}$$

where $1/(1-\rho)$ is the elasticity of substitution between domestically produced and imported industrial goods, and μ^i is home-product consumption bias, i.e., $\mu^i \in (0.5, 1)$ is the weight that households place on their own country's industrial good. This can also be interpreted as a stand-in for the explicit introduction of trade costs for goods and services, which are omitted from the present model. Industrial products from different countries are imperfect substitutes; thus, demand for products is distinguished by place of production, i.e., I^i_k is the country i consumption of the industrial goods produced in country k.

Firms and technologies. The production technologies in all sectors are assumed to be linear in labor, constant returns to scale technologies and given by, for country *i=1,2* and *j=A,I,S*,

$$Y_j^i = \theta_j^i L_j^i. \tag{12}$$

Output of each sector by country *i* is given by Y_j^i. Labor is mobile among the three sectors and perfect competition prevails in the labor market. L_j^i represents the employment in country *i* sector *j* and the sectoral productivity sequences are given by θ_j^i. The problem confronted by sector *j* in country *i* is the problem of maximizing profits subject to the production technology;

$$max \quad p_j^i Y_j^i - \omega^i L_j^i \qquad s.t. \qquad Y_j^i = \theta_j^i L_j^i, \qquad L_j^i > 0, \tag{13}$$

where p_j^i is the producer price of the good *j* in country *i*, and ω^i is real wage in country *i*.

Planner's Problem. I assume complete international financial markets so that I can solve for the Pareto-optimal allocation, and hence for the competitive equilibrium, by maximizing the social welfare function with strictly positive welfare weights α^i for each country such that $\alpha^1 + \alpha^2 = 1$. The world social planner faces the following problem feasibility constraints:

The agent in each country is endowed with one unit of time in every period and allocates his time across alternative employment activities in the domestic country.

$$L_A^i + L_I^i + L_S^i = 1. \tag{14}$$

Sectoral feasibility constraints for each sector in each country are given by:

$$Y_A^i = \theta_A^i L_A^i = \bar{\text{A}}^i, \qquad Y_I^i = \theta_I^i L_I^i = I_i^i + I_i^k, \qquad Y_S^i = \theta_S^i L_S^i = S^i. \tag{15}$$

The employment share in agriculture is determined solely by the subsistence constraint and labor productivity in agriculture in each country as we observe in the closed economy solution:

$$L_A^i = \bar{\text{A}}^i / \theta_A^i. \tag{16}$$

Industrial employment shares and bilateral exports, $\{L_I^1, L_I^2, I_2^1, I_1^2\}$, in each country are given by the following system of equations (combined with the feasibility conditions):

$$\Big(\frac{\alpha^1}{\alpha^2}\Big)\Big(\frac{\gamma^1}{\gamma^2}\Big)^{1-\eta}\Big(\frac{\mu^1}{1-\mu^2}\Big)^{1-\rho} = \Big(\frac{I_1^1}{I_1^2}\Big)^{1-\rho}\Big(\frac{I^1}{I^2}\Big)^{\rho-\eta}\Big(\frac{C^1}{C^2}\Big)^{\eta}, \tag{17}$$

$$\left(\frac{\alpha^1}{\alpha^2}\right)\left(\frac{\gamma^1}{\gamma^2}\right)^{1-\eta}\left(\frac{1-\mu^1}{\mu^2}\right)^{1-\rho} = \left(\frac{I_2^1}{I_2^2}\right)^{1-\rho}\left(\frac{I^1}{I^2}\right)^{\rho-\eta}\left(\frac{C^1}{C^2}\right)^{\eta}, \tag{18}$$

$$\left(\frac{\gamma^1}{1-\gamma^1}\right)^{1-\eta}\left(\mu^1\right)^{1-\rho}\left(\frac{\theta_I^1}{\theta_S^1}\right) = \left(\frac{I_1^1}{I^1}\right)^{1-\rho}\left(\frac{I^1}{S^1}\right)^{1-\eta}, \tag{19}$$

$$\left(\frac{\gamma^2}{1-\gamma^2}\right)^{1-\eta}\left(\mu^2\right)^{1-\rho}\left(\frac{\theta_I^2}{\theta_S^2}\right) = \left(\frac{I_2^2}{I^2}\right)^{1-\rho}\left(\frac{I^2}{S^2}\right)^{1-\eta}. \tag{20}$$

If p_I^1 and p_I^2 are the prices of the industrial goods produced in each country, then the terms of trade can be defined as $q \equiv p_I^2/p_I^1$. In equilibrium, this relative price can be computed from the marginal rate of substitution in the industrial good consumption aggregators. If the industrial good in country 1 is chosen as numeraire, i.e., $(p_I^1 \equiv 1)$, then the equilibrium sectoral prices are characterized by the following equations:

$$p_I^2 = \left(\frac{\mu^2}{1-\mu^2} * \frac{I_1^2}{I_2^2}\right)^{1-\rho} = \left(\frac{1-\mu^1}{\mu^1} * \frac{I_1^1}{I_2^1}\right)^{1-\rho}. \tag{21}$$

Since labor is freely mobile across sectors within a country and the production functions of the three final goods sectors are assumed to be linear in labor I have the following relative prices for agricultural goods and services in each country:

$$p_A^1 = \theta_I^1/\theta_A^1, p_S^1 = \theta_I^1/\theta_S^1, \qquad p_A^2 = p_I^2 * (\theta_I^2/\theta_A^2), p_S^2 = p_I^2 * (\theta_I^2/\theta_S^2). \tag{22}$$

The import ratio is defined by I_2^1/I_1^1 in country 1. Similarly, the import ratio is defined by I_1^2/I_2^2 in country 2. Sectoral productivity differences across countries affect the sectoral import ratios. In addition, the variability of the terms of trade is influenced by the elasticity of substitution between foreign and domestic industrial goods. If industrial goods produced in each country are perfect substitutes, i.e., $\rho \to 1$, then terms of trade does not vary.

3.2 Quantitative Analysis

Calibration. All sectoral productivity sequences are taken from the data, where I measure productivity as value added per worker. All time series are de-trended using the Hodrick-Prescott filter with a smoothing parameter of 6.25 before any ratios are computed. Choosing values for the productivity levels θ_j^i amounts to choosing units; therefore, I normalize those to 1 in 1978. The levels of sectoral labor productivity for 1978 together with data on growth rates of sectoral value added per worker in local currency units imply time paths for sectoral labor productivity in each country between 1978 and 2005.

Table 1: Parameter Values for the Benchmark Economy

		U.S.	China
$\bar{A}$	Subsistence level of consumption in agriculture	0.0280	0.7080
γ	Utility weight on industrial goods	0.2966	0.5646
μ	Home-bias	0.9516	0.9917
$1/(1-\eta)$	Elasticity of substitution between industry and services	0.45	0.45
$1/(1-\rho)$	Elasticity of substitution between home and foreign goods	1.5	1.5

Social planner's weights, α^1 and α^2, are calibrated to match the GDP ratio between the U.S. and China in 1978.[14]. I set the elasticity of substitution between tradables (industry) and nontradables (services) as $1/(1-\eta) = 0.45$. I set the elasticity of substitution between home and foreign goods as $1/(1-\rho) = 1.5$. It is common in many applied macroeconomic models to choose values of the elasticity of substitution between 1 and 1.5.[15] I report the results of the model under alternative values of η and ρ where I present sensitivity analysis. $\bar{A}^i$ is calibrated to match employment share of agriculture in 1978 in each country. I calibrate γ^i and μ^i to match the average export to output ratios in industry and to match the industrial employment shares in 1978.[16,17] Table 1 summarizes the parameter values.

3.2.1 Benchmark Results

Chinese Structural Transformation. Panel (a) in Figure 2 shows the model predictions for the agricultural employment share in China. The model overpredicts the transition of labor out of agriculture and the differences between the model's predictions and the actual agricultural employment share is large. The model predicts a more dramatic de-agriculturalization in China than observed in the data, i.e., between 1978 and 2005, the agricultural employment share falls 35 percent in China but 73 percent in the model.

[14] I use the series "Total GDP, in millions of 2009 US$ (converted to 2009 price level with updated 2005 EKS PPPs)" from The Conference Board Total Economy Database Output, Labor and Labor Productivity Country Details, 1950-2009.

[15] See Bodenstein 2010 for a very recent discussion.

[16] I use bilateral trade data where the U.S. is reporter country (exports to and imports from China). The data are from the OECD International Trade by Commodity Database. The SITC rev. 2 codes as proxy for industry are: 5, 6, 7, 8 minus 68.

[17] Alternatively, I can calibrate the home-bias parameters to match the initial year data on imports and domestic traded goods. In this case, I obtain results very close to the closed economy predictions because of the fact that China had very low trade volumes in 1978.

The only mechanism at work to explain the changes in the agricultural employment share is productivity growth in agriculture. However, there are mechanisms at work in the actual Chinese economy that I do not model. For example, there were institutional constraints for labor moving out of the agricultural sector such as the residential registration (hukou) system, under which official sanction was required for any change of residence. Restrictions on migration confined the majority of the labor force to the primary sector. This can be one explanation for model's prediction of dramatic de-agriculturalization.[18] Since the purpose of this paper is to examine the effect of the structural transformation of China on the de-industrialization of the U.S., I introduce time-varying agricultural wedge for China into the model economy feeding the disparity between the model-predicted employment share in agriculture and the actual data to account for all the possible factors affecting the labor moving out of agriculture.

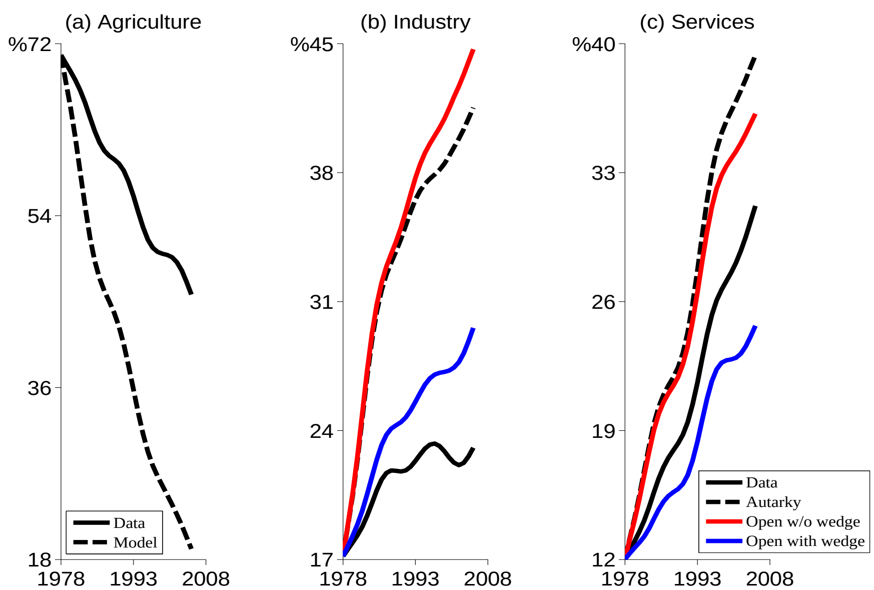

Figure 2: Sectoral Employment Shares in China

Panels (b) and (c) in Figure 2 show that open economy model predictions without wedge are very close to the autarky series. On the other hand, I capture most of the annual changes in Chinese non-agricultural employment shares when I introduce agricultural

[18] According to Srinivasan (1988, p. 7) labor markets are likely to be segmented and imperfect in early stages of development when more than two-thirds of the labor force is employed in agriculture. This was the case in China in the beginning of the economic reforms where the fraction of the labor force engaged in agriculture was more than 70 percent in 1978. In addition, Young (2000) presents evidence that China has become fragmented internally while opening up internationally. See also Dekle and Vandenbroucke 2012 for a model of the Chinese structural transformation.

wedge for China. For example, open economy model with wedge predicts an increase in the service sector share of 12.7 percentage points between 1978 and 2005, which is 75.5 percent of the actual increase in the data.[19]

U.S. Structural Transformation. Figure 3 presents the results for the benchmark open economy as well as the autarky case and compares with the U.S. data between 1978 and 2005. In terms of industrial employment share, the U.S. data shows a 37.4 percent drop (from around 28 percent to around 17 percent). The closed economy model (or autarky) predicts a 0.57 percent annual decline (from around 28 percent to around 24 percent), while the open economy predicts a 1.09 percent annual decline (from around 28 percent to around 21 percent). Hence, the closed economy model accounts for 32.8 percent of the de-industrialization while the open economy accounts for 62.6 percent of the de-industrialization in the U.S. between 1978 and 2005.

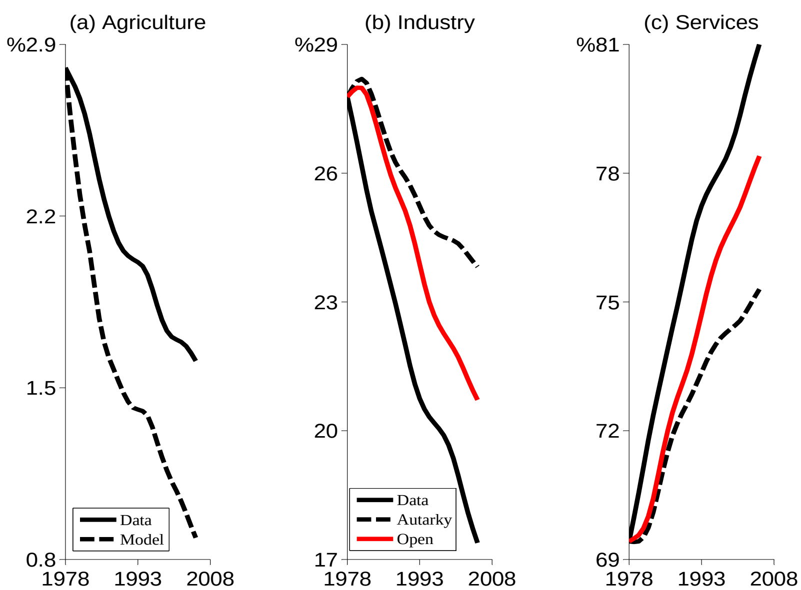

Figure 3: Sectoral Employment Shares in the U.S.

Moreover, the open economy model has more explanatory power to explain the secular declines in the U.S. industrial employment share in the post-1990 period. For example, the U.S. industrial employment share data shows a 1.48 percent annual decline (from about 21 percent in 1992 to around 17 percent in 2005) between 1992 and 2005. The closed economy model predicts a 0.52 percent annual decline, while the open economy predicts a 1.25 percent annual decline. Thus, the open economy model accounts for 83.9

[19]The results for the rest of the paper are based on the model predictions with the so-called time-varying agricultural wedge for China.

percent of de-industrialization while the closed economy accounts for 35.1 percent of the de-industrialization in the U.S. between 1992 and 2005.

The open economy model predicts that the service sector employment share increases by 0.45 percent annually (from 69.4 percent to 78.4 percent) while in the data the annual increase is 0.57 percent (from 69.4 percent to 81.0 percent) between 1978 and 2005. Thus, the open economy model accounts for 78.8 percent of the rise in the service sector employment share between 1978 and 2005. The closed economy predicts that the service sector employment share increases by 0.30 percent annually (from 69.4 percent to 75.3 percent). This suggests that closed economy model accounts for 52.6 percent of the rise in the service sector employment share between 1978 and 2005.

Trade. The first two panels in Figure 4 show "Trade Balance to GDP" and "Trade Volume to GDP" ratios for the U.S. The U.S. trade balance (volume) to GDP is equal to industrial exports to China minus (plus) industrial imports from China divided by GDP, with all variables in U.S. dollars. The model does a good job reproducing the shapes of trade balance and trade volume to GDP. On the other hand, the model predicts higher trade openness compared to the data since model-predicted "Trade Volume to GDP" is bigger than the actual data for each year between 1978 and 2005.

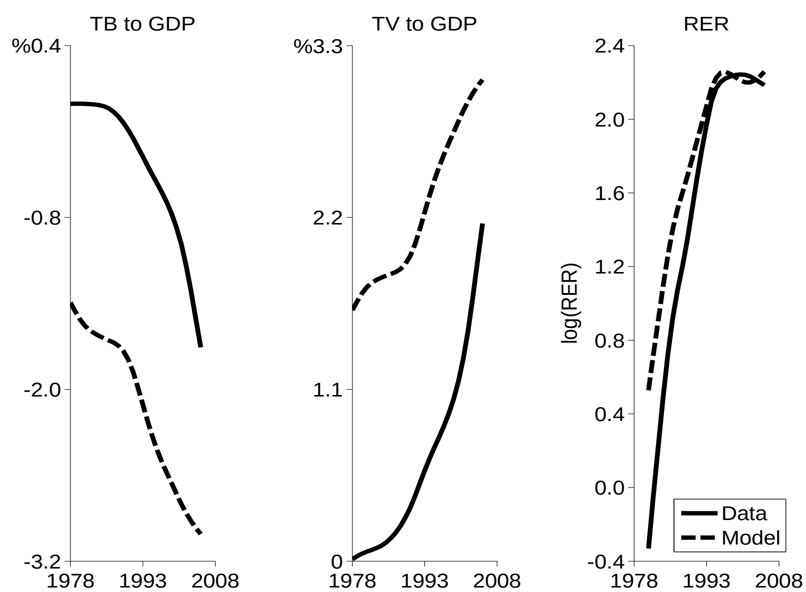

Figure 4: Trade Variables

The last panel in Figure 4 compares the real exchange rate in the data, with real exchange rate simulated form the model between 1981 and 2005. For the data, the market real exchange rate (using the nominal yuan-dollar exchange rate) is defined as the ratio of the weighted GDP deflators in the two countries in terms of dollars.[20] In the model, the real exchange rate is defined as the ratio of the weighted average of the output predicted of three sectors in China and in the U.S., in terms of a common numeraire (industrial sector in the United States). The model-predicted series for the real exchange rate captures the behavior of the time series observed in the data.[21]

3.2.2 Counterfactuals and Sensitivity

Counterfactuals. I conduct several counterfactual experiments in order to understand the impact of different sectoral productivity growth rates across countries on the deindustrialization of the U.S.

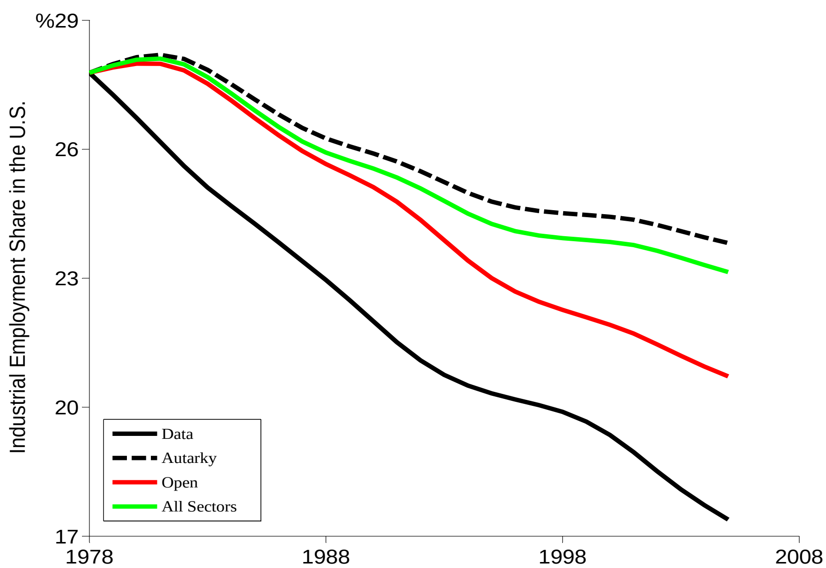

Figure 5: Role of Productivity Differentials

Figure 5 plots the following series: The line "Data" is the industrial employment share in the U.S. between 1978 and 2005. The line "Autarky" represents the closed economy prediction for the U.S. industrial employment share and the line "Open" represents the

[20]Sectoral value added data in terms of dollars are from the United Nations Statistics Division, National Accounts Main Aggregates Database and the nominal yuan-dollar exchange rate data are from the Chinese Statistical Yearbooks.

[21]Some argue that China's exchange rate policy artificially holds down the value of the yuan to the detriment of U.S. manufacturing output and employment in both import-competing and exporting industries (see, for example, Holtz-Eakin 2003 and Hua 2007). There is some empirical evidence that changes in exchange rate, in terms of appreciation and depreciation of and volatility in exchange rates, have an important influence on domestic employment (see, for example, Gourinchas 1999 and Klein, Schuh, and Triest 2003).

benchmark open economy prediction using the parameters reported in Table 1.[22] The line "All sectors" plots the result of the experiment where the differences in productivity growth rates between the U.S and China are shut down in all sectors setting the sectoral productivity growth rates in China equal to the ones observed in the U.S.

I find a small wedge between autarky and the counterfactual that shuts down productivity differences in all three sectors (see the line "All sectors"). This experiment predicts a decline in the industrial employment share of 4.6 percentage points between 1978 and 2005, which is only 38.9 percent of the actual decline in the data. This result is very close to the autarky prediction, a decline in the industrial employment share of 4.0 percentage points between 1978 and 2005. This experiment, shutting down productivity differences in all three sectors, close down a mechanism of the model that the countries trade due to the sectoral productivity differences. However, there still is a role of trade since the stand-in household in a country has tendency to consume some imported goods governed by the preferences as long as there is no perfect home bias (no foreign goods consumed). This explains the wedge between the lines "Autarky" and "All sectors".

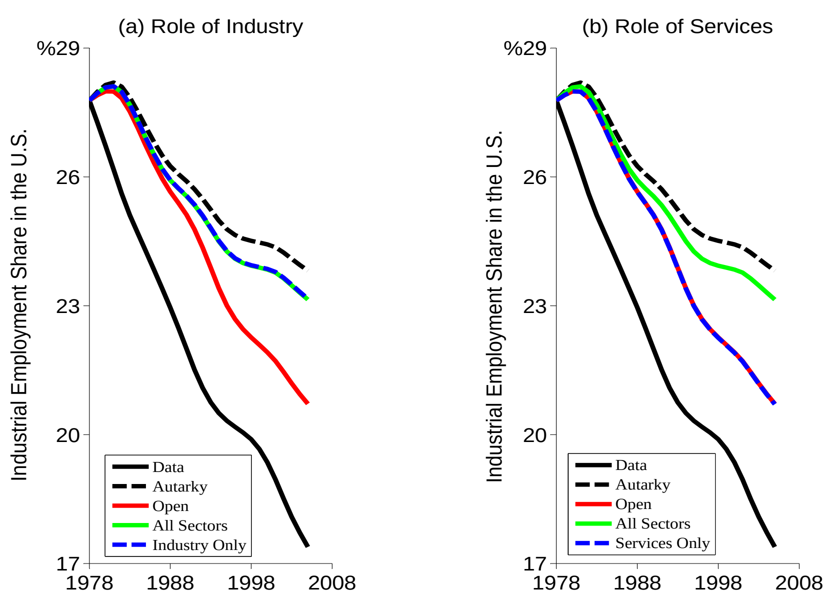

Figure 6: Role of Productivity Differentials in Industry and Services

Then, I focus on the experiments where the differences in productivity growth rates between the U.S and China are shut down only in one sector setting that sector's annual productivity growth rates in China equal to the U.S. productivity growth rates in the same

[22]These three lines are the exact series used in Panel (b) of Figure 3.

sector. The question that guides these experiments for each sector is: What would happened if the Chinese economy had productivity in agriculture/industry/services same as the U.S.? In all these counterfactual experiments, all the sectoral productivity growth rates for the U.S. are kept as in the benchmark case.[23] Figure 6 plots the results of these experiments.

Panel (a) in Figure 6 shows that there are hardly any differences between the line "All sectors" and the line "Industry only". Panel (b) in Figure 6 shows that the line "Services only", mimicking the benchmark open economy, predicts a decline in the industrial employment share of 7.1 percentage points, which is around 63 percent of the actual decline in the data. In sum, Figure 5 suggests that sectoral productivity growth rate differences between China and the U.S are important for the de-industrialization in the U.S. Figure 6 suggests that differences in industrial productivity growth rates between China and the U.S. are, mainly, responsible for the changes in the U.S. industrial employment share.

Sensitivity. I am interested in different values for the elasticities in the model. I vary the elasticity with regard to the imported industrial goods, which is governed by ρ; and the elasticity between industrial goods and services, which is governed by η. Figure 7 presents the sensitivity analysis with respect to these two parameters. I vary only one elasticity parameter at a time, while keeping other elasticity parameter at the value used in benchmark economy.

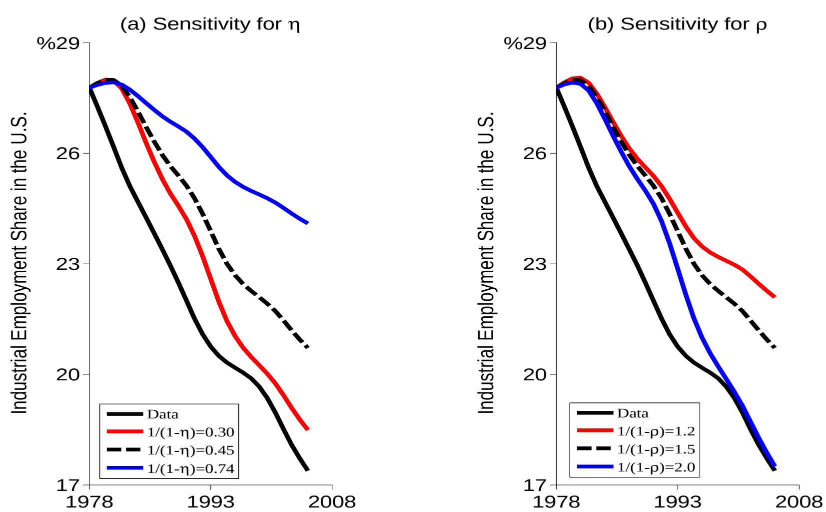

Figure 7: Sensitivity Analysis

[23] I do not plot "Agriculture only" series where I set the agricultural productivity growth rate in the U.S. to the Chinese agricultural productivity growth rate because of the strategy that I match the agricultural employment share in China for each year.

The first elasticity parameter I consider is the elasticity of substitution between traded (industry) and nontraded goods (services). Stockman and Tesar (1995) estimate the elasticity of substitution between traded and nontraded goods in a sample of 30 countries (industrialized and developing countries) regressing the nontraded-good expenditure share on the price index for nontraded goods (including per capita GDP to pick up income effects). They find that the elasticity is 0.44. Mendoza (1995) estimates that the elasticity is 0.74 for industrialized countries following the procedure of Stockman and Tesar (1995). My benchmark choice for $1/(1-\eta)$ is 0.45. Panel (a) in Figure 7 considers alternative elasticities of 0.30 and 0.74. The stand-in household in a country is more willing to substitute between non-agricultural goods with a higher value of the elasticity between industry and services. For example, the experiment where $1/(1-\eta) = 0.3$ predicts 9.3 percent fall in the industrial employment share in the U.S., where the actual fall is 10.4 percentage points.

The second elasticity parameter I consider is the elasticity of substitution between home and foreign goods. This trade elasticity is one of the most debatable parameters in the empirical international trade literature. An elasticity of 1.5 is the value mostly used by the International Business Cycle (IBC) models. According to Backus, Kehoe, and Kydland (1994) and Chari, Kehoe, McGrattan (2002), the most reliable studies seem to indicate that for the U.S. the elasticity is between 1 and 2, and values in this range are generally used in empirical trade models.[24] My benchmark choice $1/(1-\rho)$ is 1.5. Panel (b) in Figure 7 varies the trade elasticity in both directions and consider two alternative elasticities 1.2 and 2. A higher value increases the elasticity between imported and domestic industrial goods. For example, the experiment where $1/(1-\rho) = 2$ predicts 37 percent fall in the industrial employment share in the U.S. Labor in industry falls more than in the benchmark. The more substitutable are imports, the more accelerated de-industrialization in the U.S.

4 Conclusions

This paper has asked, To what extent is de-industrialization in the U.S. the result of the emergence of China in world product markets, and to what extent would this de-industrialization have occurred anyway as the result of secular shifts in sectoral productivity in the U.S.? While employment and output have shifted out of the industrial sector and into services in the U.S., the majority of world manufacturing employment is now

[24]Ruhl (2008) states that the IBC models need small values of the elasticity to generate the volatility of the terms-of-trade and the negative correlation between the terms-of-trade and the trade balance that are found in the data. In contrast, growth models need large Armington elasticity to explain the growth in trade volumes that result from a change in tariffs (see, e.g., Yi 2003).

located in China. China's manufacturing industry is the largest in the world in terms of employment, employing more manufacturing workers than do all of the G7 countries combined. The GDP and the merchandise exports of China account for more than 10 percent of the world GDP and the world merchandise exports.

This paper shows that differences in sectoral productivity growth rates across time and across countries (China and the U.S.) play a major role in accounting for annual changes in the U.S. industrial employment share in the post-1990 period. An open economy model, which allows for trade with China, captures more than 50 percent of secular declines in the U.S. industrial employment share after 1990s due to the differing industrial TFP growth rates in China and the U.S. A comparison of the predictions of open and closed economy models suggests that a common explanation of de-industrialization in the literature, which is based on increased productivity in industry relative to services in a closed economy setting, is not compelling. Counterfactual experiments show that if the Chinese economy had experienced productivity in industry equal to that of the U.S., then the role of openness would have been diminished. The higher the elasticity of substitution between home and foreign industrial goods is, the more accelerated structural transformation in the U.S.

A work in progress includes to embed the capital accumulation to the open economy structural transformation models in the light of Ventura (1997), who argues that the process of structural transformation may also be linked to capital accumulation when the interdependence between different economies is taken into account. Also, a work in modeling more than two-country can provide more answers for many issues debated in current international economics literature, such as current account deficits, global imbalances, etc.

Data Appendix

Sectoral Data for the U.S. Sectoral employment and output data are from Groningen Growth and Development Centre (GGDC) 10-sector database. Timmer and de Vries (2007) provide a detailed discussion of the database. Agriculture includes agriculture, forestry, and fishing. Industry includes mining and quarrying, manufacturing, utilities, and construction. The services aggregate is constructed by summing wholesale and retail trade, hotels and restaurants; transport, storage, and communication; finance, insurance, and real estate; community, social, and personal services; and government services. The database is available at http://www.ggdc.net/dseries/10-sector.html.

Sectoral Data for China. *Sectoral Employment:* Holz (2006, p. 57) and Brandt, Hsieh, and Zhu (2008) discuss the problems regarding the total and sectoral employment series reported in the Chinese Statistical Yearbooks (CSY). Brandt, Hsieh, and Zhu follow Holz's method to get the revised sectoral employment data. Holz (2006, Appendix 13) reports the revised employment values (end-year), where he revises the period 1978-1989. He adjusts pre-1990 sectoral employment values for 1978-1989 are obtained by applying the shares of the individual sectors in official total employment to the adjusted pre-1990 total employment values.

Holz's method is explained as follows. Prior to 1990, the published economy-wide number of laborers constituted the sum of laborers across industrial sectors. Since 1990, the economy-wide number of laborers exceeds the sum across industrial sectors significantly in each year, but continues to, as in all reform years, equal the sum across economic sectors. Since the economy-wide number following the new time series since 1990 is the one compiled according to international definitions of employment, the economy-wide number of laborers in the years prior to 1990 was adjusted following the population censuses of 1982 and 1990 (later-year official values rely on population census data). His data set for the period 1990-2005 coincides with that of the CSY. Sectoral employment shares are the same both in official statistics and in revised data.

Sectoral Output: Holz (2006) offers the following approach. The output series rely on the post-economic census benchmark revision data as far as the revisions reach back. Holz uses real growth rates calculated from the first published implicit deflator and nominal values whenever feasible. First, nominal values are post-economic census values across all sectors after 1993, all other nominal values are not revised, and the earlier published nominal values are used in those instances. Second, the output values are in constant year 2000 prices, which imply applying real growth rates to year 2000 (post-economic census) nominal value added in order to obtain time series of constant price output. First published implicit deflators are available for the primary, secondary, and tertiary sector after 1987.

A Brief Discussion on Sectoral Output Series: There has been a recent discussion on the reliability of the official Chinese GDP numbers as well as the implicit sectoral deflators. Ruoen (1997, p.122) and Young (2003) compare the sectoral implicit GDP deflators with the independent survey based price indices and they suggest alternative price indices instead of the implicit deflators. They choose the index for ”overall farm and sideline products purchasing price” as an alternative for a primary industry index. Ruoen chooses ”industrial products producer index” to serve as the deflator for the secondary industry. Young compares Ruoen's choice with two other possible alternatives: the industrial products rural retail price index and the retail price index. Young argues that the Ruoen's choice is a superior deflator. For tertiary industry, Ruoen uses the index for services from the overall residents' consumer price indices. Young has a similar approach and combines urban service price index and the overall service price index. Chow (2004) argues that Young's method leads to serious errors, and that his findings contradict the alternative estimates of the rates of growth for the periods 1978-1998 and 1988-1989 provided by Young. Dekle and Vandenbroucke (2012) follow Young's methodology to choose the sectoral deflators. On the other hand, Bosworth and Collins (2007) prefer to use the official output data for the primary and tertiary sectors and the alternative (the ex-factory industrial price index) only for the secondary industry.

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