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Structural Transformation under Trade Imbalances: The Case of the Postwar U.S.

Abstract A striking feature of the structural change literature is that, even though the U.S. economy is often used as a benchmark for calibration, the traditional models cannot account for the steep decline in manufacturing and rise in services in the U.S. since the late 1970s (Buera and Kaboski, 2009). In order to solve this puzzle, this paper develops a three-sector model to evaluate various factors that could have contributed to the structural transformation process from 1950 to 2005. The results show that, in addition to traditional explanations, such as non-homothetic preference and sector-biased productivity progress, international trade is another major source of structural change and is able to explain about 35.5% of the overall employment share decrease in American manufacturing. The quantitative calibration estimates that the inter-sector trade makes a moderate contribution, while trade imbalances dominate the recent contraction of manufacturing employment share. Our results suggest that calibrated models based on U.S. data have to be adjusted by trade factors.

Keywords trade and structural change, trade imbalance, U.S. manufacture sector

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1 Introduction

Economics literature has documented structural transformation during the industrialization process, which involved a massive reallocation of labor from the agriculture

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sector into manufacturing and service sectors.¹ Kuznets (1966) considered structural change as one of the most prominent features of development.

The literature that develops models of economic growth and development consistent with such structural changes typically starts by positing two assumptions in a closed economy. One is the non-homothetic preference for households, emphasized as the demand-side reason, which allows for the marginal rate of substitution between different goods to vary during economic growth, and generates results that are consistent with Engel's law, leading directly to a pattern of uneven growth across sectors. Another assumption, first proposed by Baumol (1967), is sector-biased technological progress on the supply side. Ngai and Pissarides (2007) showed that with a low (less than one) elasticity of substitution across final goods and identical production functions across sectors, employment shifts to sectors with relatively lower Total Factor Productivity (TFP) growth. Later, Acemoglu and Guerrieri (2008) found that if there are different factor proportions in the production functions, the increase in the capital-labor ratio promotes the output of the capital-intensive sector, while the relative prices move against it and encourage the reallocation of labor to other sectors.

In order to evaluate the performance of these models, a prevalent exercise is to replicate the structural transformation in the United States. Bah (2008) and Buera and Kaboski (2009) found that the predictions of traditional structural change models cannot account for the steep decline in manufacturing and rise in services in the recent data.

The traditional structural change literature, which focuses on long-term industrialization process, often makes the assumption that the economy is in autarky. However, this assumption is unlikely to hold when we investigate the postwar United States, which has experienced a soaring trade deficit since the 1970s, reaching 6% of the GDP in 2005. In addition, the timing of the recent intensive labor movements from the manufacturing to the service sector in the United States follows the increase of trade deficits quite closely.

International trade can affect structural change, because trade allows domestic production to deviate from domestic demand, meaning that the allocation of resources in an open economy has to be different from the pattern in a closed economy. Surprisingly, very few studies have investigated the link between structural transformation and international trade. Our goal in this paper is to provide quantitative evidence on

¹ For the empirical works that document the historical sectoral allocations, see Maddison (1991), Echevarria (1997), Rogerson (2008), and recently Buera and Kaboski (2011), among many others.

the U.S. experience of structural change, and evaluate how much of the employment share movements are associated with the following two trade channels.

The first one is inter-sector trade, which has been investigated in several papers. Echevarria (1995) discussed the impact of trade on structural change in the context of the Ricardian trade model: a country should specialize in producing either agricultural goods or manufactured products, depending on their comparative advantages in the world market. This country will certainly spend more resources, both labor and capital, on the sector with comparative advantages.

The other trade factor is trade imbalance, in particular, the large and persistent trade deficits in the United States. The dominant type of trade, within developed economies and between emerging and developed economies, is the exchange of manufactured products. After controlling the channel of inter-sector trade, national trade deficits reflect net imports of manufactured goods. Since the United States enjoys a large volume of imported manufactured products, it will allocate resources to other sectors, particularly, the service sector. In 2005, the trade deficits of the United States reached 6% of the GDP, thus, we expect a significant contribution of factor movements that are associated with trade imbalance.

We develop a three-sector model to quantitatively evaluate these factors, including non-homothetic preference, sector-biased technological progress, heterogeneous capital intensities in sectoral production functions, and the above two trade factors. The quantitative calibration results show that a closed economy model, which has no trade factor adjustment, can reproduce the labor movements from 1950 to the late 1970s, but deviate from the data evidently in the recent period. Then, we add the two trade channels into our model one by one. The inter-sector trade, despite its popularity in theory, has been playing a minor role in the United States. The calibration results show that the sectoral trade balances can explain roughly 4.5% of the total decline during the sample period, while the trade imbalance explains up to 31% of the total manufacturing employment share decline.

Our results quantitatively fit the historical trends in the data and are robust to various parameter values and alternative measures of structural change. In addition, they are in line with the findings of Sachs and Shatz (1994), Sviekuskas (1995), Bivens (2004) and Bernard, Jensen, and Schott (2006), which support the argument that international competition and trade balances have significant impacts on structural transformation.

The rest of the paper is organized as follows. In section 2, we first briefly review the literature that is related to structural change and trade, and also, in particular, the structural transformation of the United States. Section 3 documents some historical evidence of the U.S. economy from 1950 to 2005. Section 4 presents the economy

model and characterizes the equilibrium properties. Section 5 calibrates the model to evaluate its performance. Section 6 discusses several relevant issues and checks the robustness of the results. Section 7 concludes the paper.

2 Related Literature

This paper is related to two large bodies of literature, the literature of structural transformation that focuses on the allocation of resources during economic development, and the literature that directly evaluates the job destruction by trade in the manufacturing sector.

The literature concerning structural transformation primarily focuses on the long-term development in a particular economy, thus, only a few studies have considered the role of trade in such a process. And most of them have focused on the inter-sector trade in a Ricardian-type model in which a country could make use of its comparative advantages and specialize in producing either agricultural goods or manufactured products (Echevarria, 1995; Teignier, 2011; Uy, Yi, and Zhang, 2013). For example, Teignier (2011) showed that in a small open economy with low agricultural productivity, international trade can promote structural change and stimulate economic growth, since trade allows importing agricultural goods to reduce agricultural employment. However, the trade balances of South Korea might not support this idea. Since 1960, South Korea continued to import food and had persistent trade deficits in the agriculture sector. But the trade balances of the manufacturing sector were also deficits from 1960 to 1981.² It seems that the import of agricultural products helped the economic growth for South Korea, but it is unclear that the food import had been financed by the export of manufactured goods. Therefore, the trade imbalance has to be stressed as an additional channel that affects the process of structural change, which has been ignored almost completely in the literature of structural transformation.

There is another large body of literature that is directly focusing on the impact of trade on the number of workers employed in the U.S. manufacturing sector. For example, Sachs and Shatz (1994) estimated the impacts of trade on manufacturing employment and found that “the increase in net imports between 1978 and 1990 is associated with a decline of 7.2% in production jobs in manufacturing and a decline of 2.1% in non-production jobs in manufacturing”. Sviekaukas (1995) estimated that trade contributed 77,000 jobs in 1977 and 486,000 in 1982, but a loss of 2.5 million

² The overall trade balance of South Korea were deficits before 1985.

jobs in 1985. So on a net basis, trade cost the economy 3 million jobs during the period 1982–1985. And Bivens (2004) estimated that the rising trade deficit in manufactured goods accounted for about 58% of the decline in manufacturing employment between 1998 and 2003 and 34% of the decline from 2000 to 2003.

On the other hand, several authors believed that international trade has played a minor role in the contraction of U.S. manufacturing. Krugman and Lawrence (1994) noted that the share of the U.S. labor force employed in manufacturing, and the share of U.S. output accounted for by value added in manufacturing, both have been falling since 1950. After evaluating several trends in the U.S. data, they argued that foreign competition has played a minor role in the contraction of U.S. manufacturing. Lindsey (2004) found that manufacturing employment dropped by nearly 2.8 million between 2000 and 2003, yet imports of manufactured goods rose only 0.6 percent. Thus, international trade contributed only modestly to this frenetic job turnover. However, in a paper, Krugman (2008) reconsidered the connection between trade and wages that the growing trade with developing countries may have a larger impact on wage inequality in developed countries than that indicated in traditional and posited studies.

One major difficulty to explain employment patterns in the manufacturing sector is that existing models can not properly separate the trade effects from the long-term trend of structural change. In order to deal with this problem, we consolidate two trade channels in a general equilibrium model of structural transformation which is able to decompose the changes in employment dynamics into four key factors: non-homothetic preference, sector-biased technological progress, inter-sector trade, and trade imbalance.

The two papers most closely related to ours are Świącki (2013) and Kehoe, Ruhl, and Steinberg (2013). Świącki (2013) found that non-homothetic preferences can account for movement of labor out of agriculture in poor countries, while sector-biased technological growth is overall the most important mechanism for understanding experiences of developed countries. Since there is no capital in the model, the role of technology growth can be overestimated. And Kehoe, Ruhl, and Steinberg (2013) focused on the direct impact of U.S. borrowing (saving glut) on the decline in goods-sector employment between 1992 to 2012. Although their models with trade imbalances generated similar results as ours,³ they still focused on the faster productivity growth in the goods sector to explain the shift of employment away from the goods

³ According to Figures 7 and 8 in Kehoe, Ruhl, and Steinberg (2013), models with the saving glut can further explain about 2% drop of manufacturing employment, comparing with the benchmark model in 2005.

sector. Nevertheless, our paper separates the contributions of trade factors from the long-term trend of structural change in the United States from 1950 to 2005, in order to stress the role of international trade in such a process.

3 Structural Change in the United States, 1950-2005

This section documents the process of structural transformation, the total factor productivity (TFP) growth in agriculture, manufacturing, and service sectors, and the trade balances in the United States from 1950 to 2005. The sectoral employment shares during the period come from the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases for numbers of workers and hours worked. For productivity, data sources include Jorgenson (1991), the United States Department of Agriculture (USDA), the Bureau of Labor Statistics (BLS), and the EU KLEMS Growth and Productivity Accounts (Timmer and Vries, 2008). The labor income shares are estimated using the GDP-by-industry accounts from the Bureau of Economic Analysis (BEA). The U.S. trade data comes from the BEA and the United Nation Commodity Trade (UN COMTRADE) database. More details of the data series are given in Appendix B.

Figure 1 reveals the trend of structural change over the period in terms of number of workers and hours worked. Both data series display the same qualitative properties:⁴ the employment share is steadily decreasing in the goods sectors, including agriculture and manufacturing, and is steadily increasing in the service sector. This is consistent with the process of structural transformation as first described by Kuznets (1966): as a country becomes more productive, resources are reallocated from goods-producing sectors to services-producing sectors.

A puzzling feature of the postwar U.S. economy is the rapid decline of the manufacturing labor employment share since the late 1970s. Buera and Kaboski (2009) argued that the traditional models of structural change have failed to match the data in this period. In the following sections of this paper, several possible factors that might contribute to labor reallocation will be evaluated individually.

The first factor is sector-biased productivity growth. As Ngai and Pissarides (2007) and Duarte and Restuccia (2010) proposed, if the elasticity of substitution across final goods is less than one, labor allocation will shift from high productivity growth

⁴ The deviations between the two time-series since the 1960s are due to the change of working hours, especially the shorter working time per worker in the service sector.

Figure 1 U.S. Sectoral Employment Shares 1950–2005

sectors to the sectors with lower TFP growth. Therefore, the structural transformation noted above might come from the faster growth of manufacturing productivity (Brauer, 2004). The Bureau of Labor Statistics reports that the productivity growth in agriculture is higher than in the non-farm sector, from 1948 to 2005, average annual TFP growth at 1.7% in the farm sector, compared to 1.2% in the non-farm sector.⁵ However, within the non-farm sector, the TFP growth rates of manufacturing and services are not directly reported. Jorgenson (1991) estimated relatively low TFP growth rate in manufacturing at 0.6%, compared to 0.9% in the service sector⁶ from 1950 to 1977. The EU KLEMS Growth and Productivity Accounts report that TFP has been growing at 1.03% and 0.5% on average in manufacturing and services, respectively, since 1977. In addition, Englander and Mittelstadt (1988), Jorgenson and Gollop (1992), and the Bureau of Labor Statistics reported a slowdown of TFP growth in the non-farm sector in the early 1970s, from 1.5% during 1950–1970 to 0.8% during 1971–2005.

Second, while different factor income shares across sectors might play an important role in structural transformation, they have received less attention in the literature. Acemoglu and Guerrieri (2008) showed that factor proportion differences and capital deepening across sectors will lead to a factor reallocation. Valentinyi and Herrendorf (2008) found that agriculture has the highest capital share, followed by manufacturing

⁵ See Jorgenson (1991), Jorgenson and Stiroh (2000), and more recently, Alvarez-Cuadrado and Poschke (2011) for the estimations of total factor productivity growth.

⁶ I use industry value-added weights to generate the sector TFP growth rates for this paper.

and the service sectors. Moreover, as shown in Figure 2, from 1950 to 2005, we have observed significant movements on the manufacturing labor income output ratio: it increased from 0.68 to a peak over 0.72 around 1972 and declined to 0.64 in the early 2000s.⁷ Models that consider labor as the only factor of production, or that assume constant and identical capital share across sectors, such as those of Ngai and Pissarides (2007), Buera and Kaboski (2009), Duarte and Restuccia (2010), and Uy, Yi, and Zhang (2013), are incapable of handling these issues.

Figure 2 Labor Income Share in Manufacturing

The third, and probably most ignored, factor is international trade. The traditional models of structural transformation are often restricted to a closed economy, which is an inappropriate assumption to study the postwar U.S. economy. Figure 3 illustrates the historical trends of the trade balances. The aggregate trade balance shifted from surplus to deficit in the early 1970s and continued to deteriorate, reaching 6% of the GDP in 2005.

Trade can influence the process of structural transformation in two direct channels and an indirect channel. First, inter-sector trade might play an important role in structural change. As Mann (2002) documented, the trade balance of the United States for manufacturing sector has been persistently and increasingly negative, and the trade

⁷ This is calculated by the author using the Industry Economic Accounts from Bureau of Economic Analysis (BEA). The data is trended using the Hodrick–Prescott filter with a smoothing parameter of 100.

balance for the service sector has been persistently positive, while agriculture trade surplus has remained but has become relatively insignificant.

The other channel refers to the chronic trade deficits in the United States since the late 1970s. As a persistent feature, rising trade deficits has attracted extensive attention. As illustrated in Figure 3, after controlling for the sectoral trade balances, the net import of manufactured goods dominates the trade deficit of the country. If we consider the net import of manufactured products as a foreign replacement of domestic production, the trade imbalances will contribute directly to the declining manufacturing employment.

Figure 3 Trade Balance/GDP Ratio (through H-P filter)

There might be an indirect impact of trade on structural change. Sachs and Shatz (1994) argued that international competition can drive out low-skilled positions and promote industries with higher skill requirements. They estimated that a substantial decline of manufacturing employment could be associated with the increase of imports between 1978 and 1990, as firms were moving into relatively more capital-intensive industries. Later, Bernard, Jensen, and Schott (2006) found that plant survival and growth in U.S. manufacturing are negatively associated with industry exposure to imports from low-wage countries, implying that firms adjust their production according to trade pressure. Therefore, the rising capital shares in manufacturing sector might reflect such firm-level response. Since we cannot directly measure this factor, we put it into the discussion section.

In the following sections, a formal model of structural transformation will be constructed in order to evaluate these factors in turn.

4 The Model of Structural Change

This section develops a three-sector model of structural transformation that intends to replicate sectoral employment compositions during long-term economic growth. Following the traditional literature of modeling structural change, our model starts with three features: non-homothetic preference, sector-biased technological growth, and different factor shares in production functions across sectors. Then, we extend this traditional model to include trade factors.

4.1 Economic Environment

4.1.1 Firms

There are three consumption goods produced by three sectors in the model: agriculture, manufacturing, and service, denoted by letters a , m , and s , respectively. The manufactured products are also used for investment,⁸ whereas the outputs of the other two sectors are non-durable. Labor and capital are the two factors of production. At time t , the outputs satisfy the following Cobb-Douglas production functions with constant return to scale:

$$Y_{i,t} = B_{i,t} K_{i,t}^{\alpha_i} L_{i,t}^{1-\alpha_i}, \quad (1)$$

where, for sector i ($i \in \{a, m, s\}$), $Y_{i,t}$ is the output, $K_{i,t}$ is the capital input, $L_{i,t}$ is the labor employment, and $\{B_{a,t}, B_{m,t}, B_{s,t}\}$ is the set of sectoral productivity at time t , growing at the following rates,

$$\gamma_{i,t} = \frac{\dot{B}_{i,t}}{B_{i,t}}. \quad (2)$$

There is a continuum of homogeneous firms in each sector, while both goods and factor markets are competitive. Labor and capital are mobile across sectors. Therefore,

⁸ Kongsamut, Rebelo, and Xie (2001) reported manufacturing and construction sectors produced between 90% and 93% of investment in the United States during the period of 1958 to 1987.

at period t , a representative firm in sector i solves,

$$\max_{K_{i,t}, L_{i,t} \geq 0} P_{i,t} Y_{i,t} - w_t L_{i,t} - r_t K_{i,t}, \quad (3)$$

where the price of the output $P_{i,t}$, wage w_t , and interest rate r_t are given for the firm.

4.1.2 Households

The economy is populated by an infinitely lived representative household of constant size L . Each member of the household provides one unit of labor inelastically to the market in every period. Therefore, the aggregate labor supply is L , which can be normalized to 1 without loss of generality. The household chooses consumption bundle to maximize the following lifetime utility:

$$U_h = \sum_{t=0}^{\infty} \beta^t U(C_t) = \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma}, \quad (4)$$

where $\sigma > 0$ is the intertemporal elasticity of substitution of consumption, β is a discount factor, and C_t is a composite consumption with three components: the consumption of agriculture goods, manufactured products, and services,

$$C_t = \left(w_a^{\frac{1}{\theta}} (C_{a,t} - \bar{C}_a)^{\frac{\theta-1}{\theta}} + w_m^{\frac{1}{\theta}} C_{m,t}^{\frac{\theta-1}{\theta}} + w_s^{\frac{1}{\theta}} (C_{s,t} - \bar{C}_s)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \quad \sum_i w_i = 1, \quad (5)$$

where $\bar{C}_a \geq 0$ is a subsistence level of agricultural consumption that introduces non-homotheticity to the preference which has a long tradition in the literature of development,⁹ $\bar{C}_s \leq 0$ captures the home-produced services, and θ is the elasticity of substitution across goods. In a recent empirical study, Herrendorf, Rogerson, and Valentinyi (2013) calibrated utility function parameters to be consistent with the U.S. consumption data and found that a Stone-Geary specification ($\theta = 1$) fits the data well in terms of final consumption expenditure, while a preference with low elasticity of substitution, for example, the Leontief specification ($\theta = 0$), fits the value-added sectoral consumption data well. Thus, assuming $\theta \in [0, 1]$ is reasonable.

⁹ It is not literally the “subsistence” food requirement in a modern economy, but this terminology is commonly used to introduce non-homotheticity to the model. See, for instance, Echevarria (1997), Laitner (2000), Kongsamut, Rebelo, and Xie (2001), Gollin, Parente, and Rogerson (2007), Restuccia, Yang, and Zhu (2008), Duarte and Restuccia (2010), and Alvarez-Cuadrado and Poschke (2011).

The budget constraint of the household at time t is

$$\sum_{i \in \{a, m, s\}} P_{i,t} C_{i,t} + P_{m,t} S_t = w_t L + r_t K_t, \quad (6)$$

where S_t is saving, and K_t is the total capital stock.

4.1.3 Trade Balance and Market Clearing Conditions

The market clearing conditions for factor markets require that the demand for labor and capital from firms is equal to the supply of labor and the current capital stock,

$$\sum_{i \in \{a, m, s\}} L_{i,t} = L, \quad \sum_{i \in \{a, m, s\}} K_{i,t} = K_t. \quad (7)$$

In the financial market, given δ as the depreciation rate, the law of motion for capital is,

$$K_{t+1} = (1 - \delta)K_t + I_t, \quad (8)$$

where I_t is the domestic investment, and satisfies the following market clearing conditions,

$$\begin{cases} Y_{i,t} = C_{i,t} + NX_{i,t} & i \in \{a, s\}, \\ Y_{m,t} = C_{m,t} + I_t + NX_{m,t}, \end{cases} \quad (9)$$

where $NX_{i,t}$ is the net export of sector i , and if $NX_{i,t} > 0$, the sector has a trade surplus.

The aggregate trade balance of this economy, TB_t , is given by,

$$TB_t = \sum_{i \in \{a, m, s\}} P_{i,t} NX_{i,t}. \quad (10)$$

As discussed in Section 3, there are two direct channels of trade to influence the domestic economy. First, inter-sector trade might play an important role, as discussed in Teignier (2011) and Uy, Yi, and Zhang (2013). To evaluate this factor, we calculate the net export of manufactured products that is necessary to maintain a balanced trade for the whole economy,

$$NX_{m,t}^{Sector} = - \frac{P_{a,t} NX_{a,t} + P_{s,t} NX_{s,t}}{P_{m,t}}. \quad (11)$$

If the pattern of trade is determined by relative comparative advantages between home and foreign economies, the sectoral trade imbalances, reflecting the gain from trade,

should not cause any concerns. However, we also want to look at the scenario when international trade is not balanced. We calculate the following sectoral trade balance component,

$$NX_{m,t}^{TB} = \frac{TB_t}{P_{m,t}}, \quad (12)$$

where $NX_{m,t}^{TB}$ captures the impact that is linked to the aggregate trade position.

This decomposition exercise separates the two distinct factors of trade,

$$NX_{m,t} = NX_{m,t}^{Sector} + NX_{m,t}^{TB}, \quad (13)$$

which allows us to focus on the impact of trade imbalance. The distribution of trade imbalances across sector will not affect our results.¹⁰

The national saving, measured by manufacturing good, is given by,

$$S_t = I_t - NX_{m,t}^{TB}. \quad (14)$$

For the sake of simplicity, we assume the trade balances are exogenously given. If we set all of the trade balances to zero, this model converges to the closed economy model that has been extensively discussed in the literature.

4.2 Economic Equilibrium

In this section, we start with a closed economy, where $NX_{i,t} = 0$ and $TB_t = 0$. We can define the following competitive equilibrium:

Definition 1. A *competitive equilibrium* is a sequence of prices $\{P_{a,t}, P_{m,t}, P_{s,t}\}_{t \geq 0}$, household consumption $\{C_t(C_{a,t}, C_{m,t}, C_{s,t})\}_{t \geq 0}$, labor allocations $\{L, L_{a,t}, L_{m,t}, L_{s,t}\}_{t \geq 0}$ and capital stocks $\{K_t, K_{a,t}, K_{m,t}, K_{s,t}\}_{t \geq 0}$, such that (i) given prices, firms employ labor and capital to solve the firm's problem in equation (3); (ii) given prices, a household chooses $\{C_t(\cdot)\}$ to solve the intertemporal consumption problem in equation (4); and (iii) the prices $\{P_{a,t}, P_{m,t}, P_{s,t}\}_{t \geq 0}$ make the markets clear: equations (7), (8) and (9) hold.

¹⁰ It will be interesting to consider the distribution effects of trade imbalances. For example, given a national trade deficits worth of 6% of total output, if country A has deficits in both manufacturing and services sectors, 3% each, while country B has balanced trade in services but 6% deficits in manufacturing, the two components for each country will be the following: country A has to maintain a 3% surplus to compensate its deficit in services as in equation (11), thus the second component will be 6% of deficits; for country B, the first component is zero while the second component will still be the same for the other country.

4.2.1 The Balanced Growth Path

The key concept in the literature of economic growth is the balanced growth path where important macroeconomics variables, such as output, consumption, and capital stock, grow at constant but not necessarily common rates. In general, the balanced growth path is not applicable in models with structural change where resources reallocate across sectors. However, with a restrictive set of conditions, structural change is consistent with balanced growth, which is characterized by the following proposition.

Proposition 1. The closed economy with structural change is consistent with balanced growth if and only if

(a) $\gamma_i = \bar{\gamma}$, $\alpha_i = \bar{\alpha}$, $P_{i,t} = \bar{P}_i$, and $(\bar{C}_{a,t}, \bar{C}_{s,t}) \neq 0$, $\sum_i \bar{P}_i \bar{C}_i = 0$ (Kongsamut, Rebelo, and Xie, 2001), or

(b) $\bar{C}_{i,t} = 0$, $\alpha_i = \bar{\alpha}$, and $\gamma_i \neq \bar{\gamma}$, for some $i \neq j$, thus $\dot{p}_{i,t} \neq \dot{p}_{j,t}$ (Ngai and Pissarides, 2007).

Proof. See Appendix A. ■

Proposition 1 shows that conditions for jointly having generalized balanced growth and structural transformation become very stringent. Herrendorf, Rogerson, and Valentinyi (2013) argued that if we want to capture features in reality, the conditions above are too restrictive to be satisfied. It is exactly the challenge to this paper, as we want to capture the complex nature of the structural transformation process in the U.S. economy. Therefore, the model has to be able to deal with different sources of structural change, including the non-homothetic preference, the unbalanced technology growth, different production functions, inter-sector trade, trade imbalances, and so on. With different capital intensities across sectors, the relative prices will change as capital/labor ratio or productivity change. Thus, as discussed in Acemoglu and Guerrieri (2008), the balance growth path is not applicable in this model.

The household's maximization problem can be broken down into two sub-problems. First, the households have to solve the intertemporal optimization problem, making the saving/investment decision. Second, the households will solve the static distribution problem to maximize consumption across sectors.

To simplify the analysis, instead of investigating the concept of balanced growth, we adopt a static approach that focuses on studying a sequence of steady states which is defined as follows,

Definition 2. A *steady state* is that in which, without productivity shock, the household consumption and capital stock remain constant.

The transition from one steady state to another will be triggered by exogenous productivity growth. And we can define the following static growth path.

Definition 3. The *static growth path* is a sequence of steady states determined by an exogenous productivity sequence $\{B_{i,t}\}_{t \geq 0}$ with $i \in \{a, m, s\}$.

The transition dynamic of this model is more similar to a Solow exogenous growth model, rather than a Ramsey growth model. However, at each state, households make consumption choice to maximize utility.

The advantage of this “static” approach is that we do not have to take a stand on the exact nature of intertemporal opportunities available to the households or to specify how expectations of the future are formed. In addition, this static assumption allows us to easily introduce trade factors into the model. However, this approach is unable to capture the rich dynamic features during these transitions, and the investment rate has to be fixed as constant, meaning that our model has to be further revised to study a country with active changes in investment rates.

4.2.2 The Factor Markets

The first-order conditions of the firm’s problem imply that the marginal productivity of labor must be equal to the wage rate, while the marginal productivity of capital is equal to the interest rate. Assuming perfect factor mobility, the wage rates and interest rates must be the same across sectors at any given time.¹¹ If the capital labor ratio in

sector i is defined by $k_{i,t} = \frac{K_{i,t}}{L_{i,t}}$, it satisfies the following equations:

$$k_{a,t} = m_a k_{m,t}, \quad k_{s,t} = m_s k_{m,t}, \quad (15)$$

where $m_a = \frac{\alpha_a(1 - \alpha_m)}{\alpha_m(1 - \alpha_a)}$, $m_s = \frac{\alpha_s(1 - \alpha_m)}{\alpha_m(1 - \alpha_s)}$.¹²

¹¹ We ignore factor market distortions in this model, which will not affect our main conclusions. Considering wage gaps between sectors will strengthen the puzzle on the rapid decline of employment share in the manufacturing sector. Because the wage rate is higher than the service sector on average, we should expect workers to move into the manufacturing sector, rather than to enter the service sector.

¹² Factor mobility implies that the factor prices must be equal across sectors,

$$r_t = P_{a,t} B_{a,t} \alpha_a k_{a,t}^{\alpha_a - 1} = P_{m,t} B_{m,t} \alpha_m k_{m,t}^{\alpha_m - 1} = P_{s,t} B_{s,t} \alpha_s k_{s,t}^{\alpha_s - 1},$$

$$w_t = P_{a,t} B_{a,t} (1 - \alpha_a) k_{a,t}^{\alpha_a} = P_{m,t} B_{m,t} (1 - \alpha_m) k_{m,t}^{\alpha_m} = P_{s,t} B_{s,t} (1 - \alpha_s) k_{s,t}^{\alpha_s}.$$

Therefore,

$$\frac{w_t}{r_t} = \frac{1 - \alpha_i}{\alpha_i} k_{i,t}$$

implies $\frac{k_{a,t}}{k_{m,t}} = \frac{\alpha_a(1 - \alpha_m)}{\alpha_m(1 - \alpha_a)} \equiv m_A$, and similarly $\frac{k_{s,t}}{k_{m,t}} = \frac{\alpha_s(1 - \alpha_m)}{\alpha_m(1 - \alpha_s)} \equiv m_S$.

Also, the wage rate and interest rate at time t are given by:

$$\begin{aligned} w_t &= P_{m,t}(1 - \alpha_m)B_{m,t}k_{m,t}^{\alpha_m}, \\ r_t &= P_{m,t}\alpha_m B_{m,t}k_{m,t}^{\alpha_m - 1}. \end{aligned} \quad (16)$$

The relative prices, $p_{a,t}$ and $p_{s,t}$, are determined by the relative productivity and capital income shares, such as,

$$\begin{aligned} p_{a,t} &= \frac{P_{a,t}}{P_{m,t}} = \frac{B_{m,t}(1 - \alpha_m)}{B_{a,t}(1 - \alpha_a)m_a^{\alpha_a}}k_{m,t}^{\alpha_m - \alpha_a}, \\ p_{s,t} &= \frac{P_{s,t}}{P_{m,t}} = \frac{B_{m,t}(1 - \alpha_m)}{B_{s,t}(1 - \alpha_s)m_s^{\alpha_s}}k_{m,t}^{\alpha_m - \alpha_s}. \end{aligned} \quad (17)$$

Given relative prices as functions of $k_{m,t}$, the employment shares can be derived as functions of $\{K_t, K_{s,t}, k_{m,t}\}$.

Proposition 2. The market equilibrium labor allocation $\{L_{a,t}, L_{m,t}, L_{s,t}\}$ is determined by $\{K_t, K_{s,t}, k_{m,t}\}$, namely the aggregate capital stock, the capital input in service sector, and the capital labor ratio in domestic manufacturing, respectively.

Proof. See Appendix A. ■

4.2.3 Consumption

Capital accumulation is determined by the intertemporal decision of the household. The first-order conditions for consumption imply the intertemporal Euler equation:

$$\left(\frac{C_{t+1}}{C_t}\right)^\sigma = \beta \frac{P_t}{P_{t+1}}(r_{t+1} + 1 - \delta), \quad (18)$$

where P_t is the price index satisfying:

$$P_t C_t = \sum_{i \in \{a, m, s\}} P_{i,t} C_{i,t}. \quad (19)$$

In general, of course, the non-homotheticity term in the consumption functions can lead to corner solutions. However, this is not relevant for aggregate consumption in a rich country like the postwar U.S. Looking ahead, the calibration results in the following sections show that the household chooses quantities that are far away from corners.

Then, assuming interior solutions, the composition of C_t in equation (5) implies

that, at time t ,

$$\begin{aligned}\frac{C_{a,t} - \bar{C}_a}{C_{m,t}} &= \frac{w_a}{w_m} \left(\frac{P_{m,t}}{P_{a,t}} \right)^\theta, \\ \frac{C_{m,t}}{C_{s,t} - \bar{C}_s} &= \frac{w_m}{w_s} \left(\frac{P_{s,t}}{P_{m,t}} \right)^\theta.\end{aligned}\quad (20)$$

Given the productivity set at time t , in order to reach the steady state, the intertemporal Euler equation should satisfy the restriction that both consumption and capital stock are constant, $C_t = C_{t+1}$ and $K_t = K_{t+1}$. This implies $I_t = \delta K_t$, $k_{m,t} = k_{m,t+1}$, and therefore, $P_t = P_{t+1}$. Equation (18) can be rewritten as $r_{t+1} = \frac{1}{\beta} + \delta - 1$.

Thus, the interest rate is determined by the discount factor β and the depreciation rate δ .

Proposition 3. Assuming interior solutions exist, given productivity sequence $\{B_{i,t}\}_{t \geq 0}$, if the discount factor β and the depreciation rate δ are held constant, the interest rates on a static growth path are constant,¹³ as denoted by r_{ss} ,

$$r_{ss} = \frac{1}{\beta} + \delta - 1. \quad (21)$$

Proof. If δ and β are time invariant, at any time t , the steady state interest rate $r_{t+1} = \frac{1}{\beta} + \delta - 1 \equiv r_{ss}$ is constant. ■

By solving the first order conditions of firms, marginal productivity of capital is equal to interest rate. Then, on the static growth path, the capital labor ratio in manufacturing is given by:

$$k_{m,ss,t} = \left(\frac{P_{m,t} B_{m,t} \alpha_m}{r_{ss}} \right)^{\frac{1}{1-\alpha_m}}, \quad (22)$$

where a productivity growth on $B_{m,t}$ will trigger an increase of the capital/labor ratio in manufacturing. This capital deepening will then lead to structural change along the static growth path.

¹³ The constant return of capital along the economic growth process is supported by the cross-country examination by Caselli and Feyrer (2007).

4.2.4 Labor Allocations on the Static Growth Path

First, without loss of generality, $P_{m,t}$ can be normalized to one.¹⁴ Then, $k_{m,ss,t}$ is solely determined by $B_{m,t}$, the productivity level of the domestic manufacturing sector. Further, the relative prices $p_{a,ss,t}$ and $p_{s,ss,t}$ are given by the productivity $B_{a,t}$, $B_{m,t}$, $B_{s,t}$, and $k_{m,ss,t}$, according to equation (17). The relative prices will help to estimate the consumption and solve the capital stock $K_{ss,t}$ and capital input of the service sector $K_{s,ss,t}$. Therefore, when the technology path is given, the model is able to simulate the labor movements on the static growth path.¹⁵

4.3 A Trade Balance Augmented Model

The previous section has been dealing with a closed economy. Hereafter, we will introduce trade balance effect into the model. The trade factors are considered as exogenous external supply¹⁶ to the economy.

Since the nominal trade balances reported in the data are not comparable with the real sectoral net exports in the model, we have to transform the information of the data into the model. The link we choose is the trade balance/GDP ratio, which can be calculated from the data as follows,

$$\mu_{i,t} = \frac{nx_{i,t}}{gdp_t}, \quad (23)$$

where $nx_{i,t}$ and gdp_t are sectoral trade balances and nominal output in the data, respectively.

¹⁴ If $P_{m,t} = 1$, $p_{i,t} = \frac{P_{i,t}}{P_{m,t}} = P_{i,t}$, $i \in \{a, s\}$.

¹⁵ One drawback of this approach is that the analysis of steady states might underestimate the employment in manufacturing, since investment is restricted to replacing capital depreciation. However, in the U.S. data, the historical investment output ratio is roughly constant over the period. And our calibrated models quantitatively fit the investment output ratio in the data. Further, even with this possible downward bias, the challenge to the model is still the rapid decline of manufacturing shares. Therefore, it does not effect the conclusion.

¹⁶ We do not want to address the endogenous mechanism that might determine this trade balances, especially the huge trade deficits in the manufacturing sector. Despite the relative price dynamics in the domestic economy, a large portion of the net trade position depends on external exogenous sources, such as the term of trade shifts, the foreign currency devaluation and so on. Therefore, we assume exogenous trade balances and focus on the response of the domestic labor market.

The nominal gross domestic output in the model is given by,

$$GDP_t = \sum_{i \in \{a, m, s\}} P_{i,t} Y_{i,t}, \quad (24)$$

which is a function of $\{K_t, K_{s,t}, k_{m,t}\}$. Thus, given the trade balance/GDP ratio exogenous by the data,¹⁷ the trade balance in the model is determined by

$$NX_{i,t} = \mu_{i,t} \cdot GDP_t. \quad (25)$$

Using the market-clearing condition in equation (9), following the same algorithm, we are able to solve the employment shares while the sectoral trade balances/GDP ratio are fixed to their values in the data.

One potential drawback of this exercise is that it implicitly assumes that the value-added shares in the data can be quantitatively transformed into the model. Both Buera and Kaboski (2009) and Herrendorf, Rogerson, and Valentinyi (2013) found that traditional models have difficulties in matching the similar, but distinctive, trends between employment shares and value-added shares. However, as part of the robustness check, we show that this issue is negligible and does not change our main conclusion.

5 Calibration

In this section, the model presented above will be calibrated to match the postwar labor movements and real economic growth in the United States from 1950 to 2005. The labor allocation over the period is measured by the employment shares in the three sectors.¹⁸

We start with a benchmark model, denoted as Case 1, which includes a non-homothetic preference and different capital income shares in production func-

¹⁷ In the trade literature, the trade balance position will be endogenously determined by various factors of trade, such as transportation cost, relative prices, trade barriers, international finance conditions, etc. This exogenous assumption in this model is only valid to evaluate the counterfactual response in the domestic labor market.

¹⁸ The data has been filtered to focus on low frequency time series, using Hodrick–Prescott filter with a smoothing parameter of 100.

tions.¹⁹ The TFP growth rates are kept constant over the whole period in all sectors, where the manufacturing and service sectors share the same growth rate as reported by the Bureau of Labor Statistics. We, then, consider different technology growth rates in the model, denoted as Case 2. The trade effects are divided into the inter-sector trade effect and total trade balance effect. In Case 3 model, the trade balances of agriculture and services are used to calculate the corresponding manufacturing trade balance that is necessary to keep the total trade balance balanced. Case 4 model will use data from all sectors, where the trade imbalance effect will be the net change on top of Case 3.

Table 1 Model Details

Model #	Factors
Case 1	Differential capital shares, non-homothetic utility
Case 2	Higher TFP growth in manufacturing
Case 3	Inter-sector trade effects
Case 4	Total trade effects

5.1 Parameter Values

The model period is one year. The measure of labor input in the model is the sectoral shares of hours worked. The parameter values to determine are the sector capital intensity, α_i , the depreciation rate δ , the preference parameter $\beta, \theta, w_a, w_m, \bar{C}_a, \bar{C}_s$,²⁰ and the time series of sectoral productivity $B_{i,t}$ with sectoral TFP growth rates denoted by $\gamma_{i,t}$.

5.1.1 Multifactor Productivity Growth

The United States Department of Agriculture has calculated the rate of total factor productivity growth in agriculture every year from 1948 to 2008, which provides the

¹⁹We set Case 1 to include both non-homothetic preference and different capital intensities across sectors, because if we only include non-homothetic preference, we have to choose different initial parameter values in order to match the initial employment shares in 1950, which makes these results incomparable. However, we want to do an exercise to see how important is the non-homothetic preference. The results show that, with common production function ($\alpha_A = \alpha_M = \alpha_S = 0.35$) and no trade, the model only predicts 0.7 percentage decline in the manufacturing sector. It shows that as a developed country at 1950, the non-homothetic preference is not a very important source that leads the labor movements over the sample period.

²⁰ The intertemporal substitution rate σ is not relevant for the calibration of the static growth path.

sequence of $\{B_{a,t}\}$. The average TFP growth rate, γ_a , was 1.7% during the period from 1950 to 2005, as confirmed by Alvarez-Cuadrado and Poschke (2011).

Case 1: The Bureau of Labor Statistics reports 1.2% TFP growth rate from 1950 to 2005 in the non-agriculture business sector, thus setting both γ_m and γ_s to be 1.2%.

Cases 2, 3, and 4: The TFP growth rates in the manufacturing and service sectors have various estimates among different researchers. For example, based on the estimates of industry level TFP growth in Jorgenson (1991), the TFP growth rate was about 0.77% in the manufacturing, and 1.1% in the service sector from 1950 to 1970. These estimates would be too low to explain the 1.5% aggregate growth rate in the non-farm sector over the period, according to the Bureau of Labor Statistics. Therefore, I will calibrate them jointly in order to match two targets: the average TFP growth rate in the non-agriculture sector and the average growth rate of real GDP per capita. The corresponding values are 2.5% in the manufacturing and 0.6% in the service sector.

5.1.2 Factor Intensities

The income shares of capital and labor are held constant in all three sectors at any moment in the sample period. For agriculture, Valentinyi and Herrendorf (2008) estimated the capital income share to be 0.54 in the U.S. agriculture sector, which is also confirmed by the EU KLEMS Growth and Productivity Accounts.²¹ Therefore, α is set at 0.54. The manufacturing labor income share, as in Figure 2, provides two distinctive patterns: from 1950 to 1970, the labor income share slightly increased with an average around 0.705, and it has been decreasing monotonically since the early 1970s. The service labor income share has been relatively stable, remaining at about 0.74 over the periods. Thus, the capital shares in the productivity function are set as $\alpha_m = 0.295$ and $\alpha_s = 0.26$.

5.1.3 Depreciation Rate

In the model, the capital depreciation reflects the demand of capital for investment. Thus, we use the investment/capital ratio to match the capital depreciation rate, δ . The Bureau of Economic Analysis reports a roughly constant investment/capital stock ratio for the U.S. at about 6.3% on average. It is consistent with the estimate of 6% from McQuinn and Whelan (2007). Therefore, δ is set at 0.063.

²¹ The EU KLEMS Growth and Productivity Accounts only cover the post 1977 period.

5.1.4 Preference

The real consumption share in agriculture converges to w_a in the long run. The value-added share of agriculture goods in consumption was only 0.6% in 2009,²² so setting w_a to 0.01 is acceptable. I also calibrate the consumption share of manufacturing goods, w_m , at around 14.5%.

Acemoglu and Guerrieri (2008), Herrendorf, Rogerson, and Valentinyi (2013) and others have found that the elasticity of substitution θ should be less than unity. I follow Buera and Kaboski (2009) and set θ at 0.5. As part of the robustness check, various values of θ will be evaluated in Section 6.3. The discount factor, β , is set at 0.97, similar to the value used in Echevarria (1997).

The other parameters, $\bar{C}_a$ and $\bar{C}_s$, are selected to match the initial employment shares in 1950.

5.1.5 Initial Parameters

The initial efficiency parameters $B_{i,0}$ affect the unit of measurement of the three goods. As usual, these parameters are normalized to one and the units of the three goods are chosen accordingly.

The set of parameters used is summarized in Table 2. The values of $\bar{C}_a$ and $\bar{C}_s$ are calculated to match the initial labor employment shares in 1950, and the corresponding values are in Table 3 which also summarizes other case specific parameters.

Table 2 Common Parameters

Parameter	Value	Source
β	0.97	Echevarria (1997)
δ	0.063	McQuinn and Whelan (2007) and BEA
θ	0.5	Buera and Kaboski (2009)
w_a	0.01	World Input-Output Database
w_m	0.145	World Input-Output Database
α_a	0.54	Valentinyi and Herrendorf (2008)
α_m	0.29	BEA Industry Economic Accounts

(To be continued)

²² This is derived from the national table of the United States in the World Input-Output Database, and only includes consumption under the category of Agriculture, Hunting, Forestry and Fishing.

(Continued)

Parameter	Value	Source
α_s	0.26	BEA Industry Economic Accounts
γ_a	0.017	United States Department of Agriculture
$\bar{C}_a$	0.35	Industry employment share in 1950
$\bar{C}_s$	-0.27	Industry employment share in 1950
$B_{i,0}$	1	Normalization

Table 3 The Case Specific Parameter Values

Parameter	Case 1	Cases 2-4
γ_m	1.2%	2.5%
γ_s	1.2%	0.6%

5.2 Closed Economy Model

This section provides some insights on how well the model fits the data. Starting with a closed economy, we use the calibrated model to compute the sectoral shares of employment of the U.S. economy from 1950 to 2005 and compare them with the data series.

In the benchmark (Case 1) model, there are only modest structural changes predicted by the model (Figure 4), which are mainly caused by the non-homothetic preference. The employment share in manufacturing remains almost constant during the period, slowly decreases from 33% to 30%, while the service employment share increases from 58% to 67.8%, mainly from the decline of employment in agriculture, down from 9% to just above 2%. Notice that even though the calibration only targets the initial employment share in agriculture in 1950, the model implies a time path of the equilibrium employment shares in agriculture that is close to the data. However, it is clear that the above structural transformation cannot explain the trends in the non-farm sectors, which reported 17.5% employment share in the manufacturing and 80.9% in the services in 2005. One matter worth noting is that the real per capita GDP growth rate is lower than the data in the benchmark case. According to equation (22), the capital labor ratio in manufacturing is determined by the productivity $B_{m,t}$. The TFP growth in the manufacturing sector not only increases the output at any given inputs, but also triggers a capital accumulation process. Therefore, the results above imply that the productivity growth rate might be underestimated in the benchmark case.

Figure 4 Closed Economic Models vs U.S. Data

The Case 2 model is meant to explore the scenario when the manufacturing sector has a relatively higher TFP growth rate. As illustrated in Figure 4, the model does a better job on replicating the sectoral employment shares in the data, showing a steady decline in the share of manufacturing employment from about 33% in 1950 to 25.2% in 2005 (17.5% in the data), whereas the share of workers in the service sector increases from about 58% to 73.4% (80.9% in the data). Nevertheless, since 1980, the model predictions have deviated from the data. A significant change of the employment composition roughly a five-percent decline in manufacturing and a simultaneous rise in services over the last three decades, still lacks a convincing explanation. These calibration results match the works of Bah (2008), and Buera and Kaboski (2009).

If we calculate the gap between this traditional closed economy model and the data as residuals, and plot them along with sectoral trade balances in the manufacturing sector, a strong pattern of co-movement between these two sequences emerges, which is consistent both in timing and magnitude. This pattern has been summarized by Figure 5. Since we can reasonably argue that imported manufacturing products are substitutes of domestic manufacturing products, this correlation between trade balance and sectoral employment gap has to be carefully evaluated.

Figure 5 Predication Residuals of Case 2 Model and Sectoral Trade Balances in the U.S. Manufacturing Sector

5.3 Trade-Augmented Model

We consider that trade factors affect structural transformation through two channels: inter-sector trade effect and trade imbalance effect.

The Case 3 model investigates the channel of inter-sector trade, which has been discussed in Teignier (2011) and Uy, Yi, and Zhang (2013). If the trade surplus in the agriculture and service sectors in the U.S. reflects comparative advantages in these sectors, the economy can experience corresponding trade deficits in the manufacturing sector. We use equation (11) to estimate counterfactual manufacturing trade balances that can keep the economy-wide trade balanced. Then we solve for the employment shares, taking these sectoral trade balances as exogenously given. The numerical results of the Case 3 model, as reported by Figure 6, show only moderate contribution from this inter-sector trade, compared to the Case 2 model. Numerically, the predicted manufacturing employment share in 2005 decreases by additional 1% to 24%, while the service share increases to 74.3%.

In the Case 4 model, actual sector trade balance/GDP ratios are used to evaluate the overall contribution of trade on the labor redistribution. Compared to the results in Case 3 model, the predicted employment share for the manufacturing sector decreases by roughly 5% to 19.6%, while the employment share for the service sector increases 4.8% to 78.8%. These estimates lie between the two measures of employment shares. The predicted manufacturing share (19.6%) is lower than the share in terms of hours worked (20.3% in 2005), but higher than the share in terms of the number of workers

(17.5% in 2005).

Figure 6 Trade-Augmented Model vs U.S. Data

The employment share in the agriculture sector is largely unaffected after controlling for trade factors. There are two reasons. First, the trade balances in the agriculture sector were relatively small, which were less than 1% of GDP in our sample. Thus, we shouldn't expect a significant change in the agriculture sector after including trade balances. Second, the preference weight on agriculture consumption is small ($w_a = 0.01$), meaning that the income effect is negligible: even the economy enjoys a large volume of imported manufactured goods, only a small portion of resources will go to agriculture sector. Therefore, the changes of employment shares in the agriculture sector are determined by the traditional factors, such as the non-homothetic preference and the improvement of TFP.

Taking trade factors into account, the calibration exercises have explained a large portion of labor movements in the sample period, where a significant part can be related to the chronic trade deficits. This result provides some support for the argument that trade imbalances have a substantial impact on the composition of employment.

6 Discussion

6.1 Technology Slowdown and Rising Capital Intensity

There are several facts in the data that have not been covered in the previous discussion: a slowdown of productivity growth in the early 1970s, and a rising capital

income share in manufacturing over the same period.

The recession during the 1970s puts an end to the post-World War II economic boom. The Bureau of Labor Statistics reports a sharp decline of TFP growth in the nonfarm business sector. The annual TFP growth rates dropped from 1.7% between 1950 and 1973, to 0.6% after 1973. If the slowdown had not been balanced between the manufacturing and service sectors, it might have affected the structural transformation process, as we have seen in the Case 2 model presented above.

Interestingly, around the same time, the manufacturing capital income shares stopped a moderate decline from 1950 to 1973, and started to rise steadily. According to Sachs and Shatz (1994) and Bernard, Jensen, and Schott (2006), the higher income share of capital in manufacturing is actually one of the consequences of international competition, as low-skill (possibly more labor intensive) manufacturing industries are more exposed to competition.²³ Thus, the rise of labor intensity and its impact on labor allocation might be indirectly linked to trade factors.

To consider the TFP slowdown in 1973, we estimated the sectoral productivities from 1977 to 2005 to be 1.03% for the manufacturing sector and 0.5% for the service sector by using the EU KLEMS database. This model, denoted as Case 5, does not account for trade balances and is directly comparable to the Case 2 model.

On top of the TFP slowdown in Case 5, in the Case 6 model, we allow the capital intensities in the manufacturing sector to vary, which increased from 0.29 in 1970 to 0.37 in 2005.

Figure 7 illustrates the calibration results of the Case 5 model. As we predicted, the relatively larger drop of TFP growth in the manufacturing sector leads to a higher employment share comparing to the Case 2 model. Quantitatively, the manufacturing employment share predicted by Case 5 model is around 27.4% in 2005, 2.2% higher than 25.2% reported by Case 2 model.

In Case 6, after we add the rising capital share to our numerical exercise, the calibrated manufacturing employment share returns to 25%. Therefore, productivity slowdown and higher capital share have opposite contributions with equivalent magnitudes. These two factors do not change any of the above conclusions.

²³ Another explanation of the capital income share change comes from the limitation of the Cobb-Douglas type production function. Alvarez-Cuadrado, Long, and Poschke (2014) provided a more general discussion on elasticity of substitution and structural change process by using the CES type of production functions.

Figure 7 Case 5 (TFP Slowdown) vs Case 2, with U.S. Data

In addition, the Case 6 model can explain an interesting feature in the data. From 1950 to 1979, the output per worker in the manufacturing sector increased at 2.4% and the multifactor productivity in nonfarm business grew at 1.46%. Since 1980, the annual progress of multifactor productivity was around 0.75%, while the output per worker in the manufacturing sector increased at 3.8% every year. It shows that per worker output in the manufacturing sector grew relatively slowly during the period of rapid technology improvement in the 1950s and 1960s, but has increased quickly since 1980, when the TFP growth had slowed down. When we take the rising capital intensity in the manufacturing sector into consideration, we find that industry that is becoming more capital-intensive, can increase per worker output through capital deepening. Thus, even the technology growth might have slowed down, the overall output growth can be maintained.

6.2 Decomposition of the Structural Transformation

Table 4 shows some statistics of both the data and the model. In general, the models have been able to mimic several key aspects of the U.S. economy.

The analysis in the previous sections has proved that a structural change model in the open economy context can explain labor movements across sectors, especially the recent rapid decline in manufacturing employment. On the basis of our numerical

results, the postwar structural transformation in the United States can be separated into the following sources that have been discussed in this paper, as summarized in Table 5.

Table 4 Statistics in the Data and the Model

Statistics, average 1950–2005	Data	Case 1	Case 2	Case 3	Case 4
Per Capita GDP Growth Rate	2.15%	1.67%	2.15%	2.14%	2.12%
Capital to Output Ratio	3.21	3.20	3.15	3.16	3.156
Investment to Output Ratio	20.2%	19.2%	18.9%	18.9%	18.9%

Table 5 Decomposition of the Structural Transformation in U.S. Manufacturing

Model #	Net Δ	Cumulative Δ	Sources
Case 1	3.7 %	3.7 %	Differential capital shares, non-homothetic utility
Case 2	4.8 %	8.5 %	Unbalanced TFP growth rates
Case 3	0.7 %	9.2 %	Inter-sector trade effect
Case 4	5 %	14.2 %	Trade imbalance effect
Data		16 %	The decline of employment share from 1950 to 2005

The key driver that contributes most to structural change is the trade imbalance effect, which accounts for 5 percentage points in the model. And taking the inter-sector trade effect into account, which adds another 0.7 percentage points, the trade-related factor can explain at about 5.7 percentage points, or 35.5% (5.7 out of 16) of the employment share decline in the U.S. manufacturing sector. Therefore, international trade has become the most important factor that contributes to the structural transformation of the postwar U.S. economy.

The relative contributions of these factors have been evolving over time, as illustrated in figure 8. The traditional motivations, such as the non-homothetic preference and different capital intensities across sectors, and the unbalanced productivity growth have been the key drivers in the early periods. However, their relative shares have been decreasing since the late 1960s. The contributions of trade-related factors changed significantly and became more and more important. The inter-sector trade, in most of the time, contributes positively to the decline of U.S. manufacturing as the trade surplus in the agriculture and service sector reflects some of the comparative advantages of the U.S. economy. The impact from trade imbalances provides a more compelling trend, turned from a dragging factor to one of the most important driving factor to push down the manufacturing employment.

Figure 8 Relative Contributions on Structural Change

6.3 Robustness

6.3.1 The Preference Parameter

The calibration exercises depend on the assumption of household preferences and the choice of parameter values. One core parameter worth revisiting is the elasticity of substitution between the manufacturing and service sectors, denoted by θ . In the main body of the calibration, I use a relatively low elasticity of substitution ($\theta = 0.5$) across industry goods, following Buera and Kaboski (2009). But Herrendorf, Rogerson, and Valentinyi (2013) found that a Leontief utility ($\theta = 0$) fits the value-added sectoral consumption data for U.S. households.²⁴ Therefore, robustness checks on the values of θ , especially a preference close to the Leontief specification, would be crucial for the calibration.

Table 6 summarizes the model (Case 4) predictions with different values of θ , the elasticity of substitution between manufacturing products and services, and compares those results with the employment shares in the data. It shows that a smaller θ leads to

²⁴ Buera and Kaboski (2009) also reported that Leontief preference provides a better fit in their model.

larger labor movements across sectors. For example, the employment share increase in the service sector will be 18% for $\theta = 0.75$, 20.4% for $\theta = 0.5$, 21.2% for $\theta = 0.5$, and will reach 23.5% if $\theta = 0.01$, which is close to the Leontief preference.

Table 6 Robustness Analysis of the Structural Change Model

	Change of employment	Case 4 Model		
	share in data	$\theta = 0.75$	$\theta = 0.5$	$\theta = 0.01$
Agriculture	−7 %	−6.9 %	−7 %	−7 %
Manufacturing	−16 %	−11.2 %	−14.2%	−16.5%
Service	23 %	18%	21.2 %	23.5 %

In addition, we break down the employment share change in the manufacturing sector to identify the relative contributions of different factors when the preference parameters are adjusted. Table 7 shows that as the rate of substitution across sectors decreases, the different growth rates of productivity become more and more important. However, trade factors are still one of the key drivers behind the structural transformation in the United States, among which the trade imbalance channel dominates.

Table 7 Robustness of Relative Contributions in Manufacturing

	$\theta = 0.75$	$\theta = 0.5$	$\theta = 0.01$
Preference & capital intensity	29.3%	26.0%	23.8%
Unbalanced TFP growth	23.3%	34.0%	43.2%
Inter-sector trade effect	7.1%	4.7%	3.5%
Trade imbalance	40.2%	35.3%	29.5%

6.3.2 Value-Added Trends

The structural transformation across sectors can also be measured in terms of value-add shares. However, it seems that the traditional models have difficulties in matching the two trends simultaneously. Buera and Kaboski (2009) argued that their model exhibits large deviation between value-added shares and employment shares, and Herrendorf, Rogerson, and Valentinyi (2013) argued that using common production functions across sector they can connect the production measures to the data either in terms of employment shares, or in terms of value-added shares. However, in our model, since the manufacturing sector is considered to be more capital intensive, the relative price of service will increase as the country becomes richer.

Figure 9 reports the value-added share of the Case 4 model. Qualitatively, the model, which is only set to fit the employment share in 1950, makes a plausible prediction for the trends of value-added shares. Even though we are using a static approach to approximate the long-run growth path, by using production functions with different capital intensity across sectors, we can partially capture the change of relative prices.

Figure 9 Case 4 Model vs U.S. Data in Terms of Value-Added Shares

6.4 Counterfactual Exercises

Following our numerical results, we turn to conduct two counterfactual exercises. First, we would like to show if the manufacturing sector has had a constant trade deficit over the sample period. Second, we discuss briefly whether trade imbalance could affect economic growth by influencing structural transformation.

6.4.1 Trade Deficit in the Manufacturing Sector

In order to match the historical data, we allow sectoral trade balances to vary over time when we calibrate our trade-augmented models. However, it would be helpful to conduct a counterfactual analysis to show how trade deficit in the manufacturing sector affects structural transformation in our model.

To fully estimate the impact of trade deficits in the manufacturing sector, we construct a special version of the Case 4 model in which only the manufacturing sector

maintains a constant trade deficit at 6% of the total GDP. We calculate the corresponding employment allocations over time, which are illustrated in Figure 10. The solid lines represent the employment shares in our data, the dash lines stand for our results from the Case 2 model, while the dot lines demonstrate this counterfactual exercise with constant trade deficits. Compared with our closed economy model (Case 2), having a 6% trade deficit in the manufacturing sector shifts the manufacturing employment downward, and the trends that come from the data are bounded by these two curves.

Figure 10 A Constant Trade Deficit in the Manufacturing Sector (6% of GDP)

6.4.2 Economic Growth

When the results in Table 4 are compared, one thing worth noting is that the average per capita output growth rate is slightly lower in the Case 4 model with trade deficits. With the same parameter values summarized in Tables 2 and 3, the real per capita output growth rate is 2.12% in the Case 4 model versus 2.15% in Case 2 model for the closed economy. Therefore, trade deficits might lead to a lower output growth rate, which is one of the disadvantages of having persistent trade deficits. The explanation is intuitive. Since net import of manufactured products can be considered as a foreign replacement of production, workers have to find positions in other sectors. Most of them will move to the service sector. As a result, the TFP growth in the whole economy will be dragged down, since the productivity growth is relatively lower in the service sector than in the manufacturing sector.

To fully estimate the impact of trade imbalances on output growth, we continue to use the counterfactual version of the Case 4 model with a 6% trade deficit in the manufacturing sector. This model reports a slightly lower real output growth rate, around 2.02%. Because of the foreign replacement of manufacturing production, the employment shares of domestic manufacturing are lower in the open economy model, leading to lower real output growth rates. However, the magnitude of the slowdown is insignificant, 2.12% in the closed economy (Case 2) versus 2.02% in the open economy (Case 4 with trade deficit at 6% of GDP). According to the model, the real economic growth rate is just slightly affected by the large trade deficit (6% of GDP).²⁵

7 Concluding Remarks

According to Buera and Kaboski (2009), the steep decline in manufacturing employment shares cannot be explained by the traditional theories of structural change. Therefore, in this paper, we intend to answer such a quantitatively motivated question: how much could a unified model of structural change with trade factors explain the contraction of the manufacturing employment shares in the United States?

The first contribution of this paper is to introduce trade factors to the traditional models of structural change. International trade provides a channel through which sectoral expenditures can deviate from the sectoral output, or vice versa, providing a new important cause of structural change on the demand side. We mainly focus on two direct channels of trade, the inter-sector trade and trade imbalance.

Second, this paper quantifies the roles of different factors on the composition of labor employment, especially the decreasing manufacturing employment share. Our results show that, in addition to traditional explanations, such as a non-homothetic preference and sector-biased productivity progress, international trade is another key driving force of structural change. The calibrated models show that about 35.5% of the overall employment share decrease in American manufacturing from 1950 to 2005 can be linked to trade factors. We estimate that the inter-sector trade makes only a moderate contribution, while trade imbalances dominate the recent contraction of manufacturing employment share.

Third, our results suggest that directly fitting models without trade factors with U.S. data can be misleading, which generate parameters that can be seriously miss-

²⁵ The model also reports the output growth, at 2.26%, in the same economy with a trade surplus (6% of GDP).

specified. We encourage future research to specify their model or adjust the data properly to achieve valid numerical results.

Finally, our framework separates the trade factors from the long-term trends of structural change in a closed economy, and helps to clarify the role of trade in the decline of manufacturing employment in the United States. Our findings are consistent with those of Sachs and Shatz (1994) and Bernard, Jensen, and Schott (2006) that international trade has a significant impact on the production sector of tradable goods, and the labor market responds accordingly: workers move out of the sectors of tradable goods, such as manufacturing, and into the non-tradable sectors, such as services.

The model and related calibration exercises provide a few insights into the current structural problem in the United States. For example, in our quantitative exercise, persistent trade deficits can explain 31% of the recent contraction of the manufacturing sector, or roughly 5% of total employment. As many economists have argued,²⁶ this trade balance position cannot be maintained forever. When the trade deficits shrink, the U.S. economy will need some of these manufacturing jobs back again. However, this renaissance of American manufacturing might take a longer time to restore, since a portion of job-specific human capital could have been destroyed during the last two or three decades. This might be one of the reasons to explain the sluggish recovery from the recent great recession. In addition, the model shows that the countries with trade deficits will achieve a slightly lower growth rate, while countries with trade surplus can enjoy a higher rate of economic growth. Although the magnitude of this loss/benefit is not large, it can accumulate over time.

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Appendix

A Technical Details

Proposition 1. The closed economy with structural change is consistent with balanced growth if and only if

(a) $\gamma_i = \bar{\gamma}$, $\alpha_i = \bar{\alpha}$, $P_{i,t} = \bar{P}_i$, and $(\bar{C}_{a,t}, \bar{C}_{s,t}) \neq 0$, $\sum_i \bar{P}_i \bar{C}_i = 0$ (Kongsamut, Rebelo, and Xie, 2001), or

(b) $\bar{C}_{i,t} = 0$, $\gamma_i \neq \bar{\gamma}$, $\alpha_i = \bar{\alpha}$, for some $i \neq j$, thus $\dot{p}_{i,t} \neq \dot{p}_{j,t}$ (Ngai and Pissarides, 2007).

Proof. (a) Using $\sum_i \bar{P}_i \bar{C}_i = 0$, the budget constraint in equation (6) rewrites as

$$\sum_{i \in \{a, m, s\}} \bar{P}_{i,t} (C_{i,t} - \bar{C}_i) + \bar{P}_{m,t} I_t = \sum_{i \in \{a, m, s\}} \bar{P}_{i,t} Y_i. \quad (\text{A1})$$

Plugging the market clear conditions and law of motion for capital to the budget constraint,

$$\dot{K}_t + \delta K_t + C_{m,t} + \bar{P}_{a,t} (C_{a,t} - \bar{C}_a) + \bar{P}_{s,t} (C_{s,t} - \bar{C}_s) = B_{m,t} K_t^{\bar{\alpha}}, \quad (\text{A2})$$

or

$$\frac{\dot{K}_t + \delta K_t + C_{m,t} + \bar{P}_{a,t} (C_{a,t} - \bar{C}_a) + \bar{P}_{s,t} (C_{s,t} - \bar{C}_s)}{B_{m,t}^{\frac{1}{1-\bar{\alpha}}}} = \left(\frac{K_t}{B_{m,t}^{\frac{1}{1-\bar{\alpha}}}} \right)^{\bar{\alpha}}. \quad (\text{A3})$$

As $B_{m,t}$ increases at a constant rate $\bar{\gamma}$, the whole economy is able to evolve at a constant rate, $\frac{\bar{\gamma}}{1-\bar{\alpha}}$. For more details about this generalized balance growth path, see

Kongsamut, Rebelo, and Xie (2001).

(b) See Ngai and Pissarides (2007) Proposition 4. ■

Proposition 2. The market equilibrium labor allocation $\{L_{a,t}, L_{m,t}, L_{s,t}\}$ is determined by $\{K_t, K_{s,t}, k_{m,t}\}$, namely the aggregate capital stock, the capital input in service sector, and the capital labor ratio in domestic manufacturing, respectively.

Proof. According to equation (7) and (15), first get $L_{s,t} = \frac{K_{s,t}}{m_s k_{m,t}}$, then, $K_{a,t} + K_{m,t} + K_{s,t} = K_t$ can be written as,

$$m_a k_{m,t} L_{a,t} + k_{m,t} \left(L - L_{a,t} - \frac{K_{s,t}}{m_s k_{m,t}} \right) = K_t - K_{s,t}.$$

Therefore, the labor employment shares across sectors are given by,

$$\begin{cases} L_{a,t} = \frac{K_{s,t} - K_t + k_{m,t} \left(L - \frac{K_{s,t}}{m_s k_{m,t}} \right)}{k_{m,t}(1 - m_a)}, \\ L_{m,t} = L - L_{a,t} - L_{s,t}, \\ L_{s,t} = \frac{K_{s,t}}{m_s k_{m,t}}, \end{cases} \quad (\text{A4})$$

which depend on a three-variable set, $\{K_t, K_{s,t}, k_{m,t}\}$, the aggregate capital stock, the capital stock in the service sector, and the capital employment share in domestic manufacturing, respectively. ■

B Data Sources

B.1 Share of Employment by Sector

The shares of sectoral hours worked and the price of services relative to manufacturing are from the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases²⁷ where the economy is disaggregated into 10 sectors.

We aggregate those sectors into the 3 sectors used throughout this paper. Agriculture sector includes agriculture and fishery, manufacturing includes mining, manufacturing, utilities and construction, and service sector covers the rest industries. For the United States, the employment shares both in terms of number of workers and in terms

²⁷ Data is available at <http://www.ggdc.net>.

of hours worked are available for the whole sample period. The value-added of each sector is given in both constant and current prices.

B.2 Production Function and Productivity

The Economic Research Service of the United States Department of Agriculture (USDA) reports agriculture productivity from 1948 to 2009.²⁸ For the non-agriculture business sector, the Bureau of Labor Statistics reports multifactor productivity growth rate from 1950 to 1976,. And EU KLEMS provides detailed sectoral productivity estimates since 1977.

The sectoral labor/capital income shares are calculated using various release of the BEA's GDP-by-industry accounts, tables in 72SIC, 87SIC, and 02NAICS. The labor income shares are also available as Unit Labor Costs (ULC) in the OECD statistics since 1970. In addition, we refer to the estimates in Valentinyi and Herrendorf (2008).

B.3 National Income Accounts and Trade Balances

The real GDP per capita comes from the Penn World Table (version 6.3), while BEA reports investment to output, capital to output ratios.

Net export of goods and services is reported by the BEA since 1929. Within the trade of goods, the United Nation Commodity Trade (UN COMTRADE) database provides estimates from 1961.

²⁸<http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx>