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

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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 United States 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 percent of the overall labor 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. This paper is the first work that quantitatively explores the role of trade imbalances in the structural change literature, and it supports the argument that persistent trade deficits have a substantial impact on labor markets.

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1 Introduction

The economics literature has documented structural transformation during the industrialization process, which involved a massive reallocation of labor from agriculture 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. This allows for the marginal rate of substitution between different goods changes as an economy grows, and it generates results that are consistent with Engel's law, leading directly to a pattern of uneven growth between 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 (2009) 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.

To solve this puzzle, we revisit the experience of structural change in the United States from 1950 to 2005, and document several factors that could have contribute to the employment contraction in manufacturing sector.

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. As the world economic leader, the United States has been actively involved in international trade, supported the globalization process, and experienced a soaring trade deficit since the 1970s, eventually reaching 6 percent of the GDP in 2005. In addition, the timing of the recent intensive labor movements from the manufacturing to the service sectors in the United States follows the increase of trade deficits quite closely.

Therefore, the poor performance of the model might result from the closed economy assumption. An important question to answer is in regards to how much the labor share movements can be linked to trade factors. Surprisingly, very few studies have investigated the link between structural transformation and international trade. We emphasize that there are two impacts on structural transformation caused

[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.

by international trade.

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. Later, Yi and Zhang (2010) and Teignier (2011) showed that a small country that is good at producing manufactured products can benefit significantly from importing agricultural goods. However, the trade of primary products for manufactured goods consists of only a small volume of global trade.

The other trade factor is the large and persistent trade imbalances, in particular, the trade deficits of 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 inter-sector trade, national trade deficits reflect net imports of manufactured goods, which might also contribute to the allocation of labor across different sectors in the United States.

To evaluate these factors, we first develop a three-sector economy model as a playground for quantitative evaluations. This model inherits features from the traditional literature, including non-homothetic preference, sector-biased technological progress, and heterogeneous capital intensities in sectoral production functions. The quantitative calibration results of this closed economy model can reproduce the labor movements from 1950 to the late 1970s, but show noticeable deviations from the data in the recent period.

For the two trade effects, the inter-sector trade, despite its popularity in theory, has been playing a minor role in the United States. The calibration result show the sectoral trade balances can explain roughly 4.5 percent of the total decline during the sample period, while the trade imbalance effect explains up to 31 percent of the total manufacturing employment share decline.

These results quantitatively fit the historical trends in the data and are robust to various parameter values and alternative measures of structural change. In addition, these findings are in line with the implications of Sachs and Shatz (1994) and Bernard et al. (2006), which support the argument that international competition and trade balances have significant impacts during structural transformation.

The rest of the paper is organized as follows. Section 2 documents some historical evidence of the U.S. economy from 1950 to 2005. Section 3 presents the economy model and characterizes the equilibrium properties. Section 4 calibrates the model to evaluate its performance. Section 5 discusses several relevant issues and checks the robustness of the results. Section 6 concludes the paper.

2 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 et al. (1987), 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 various release of 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 A.

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:[2] 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.

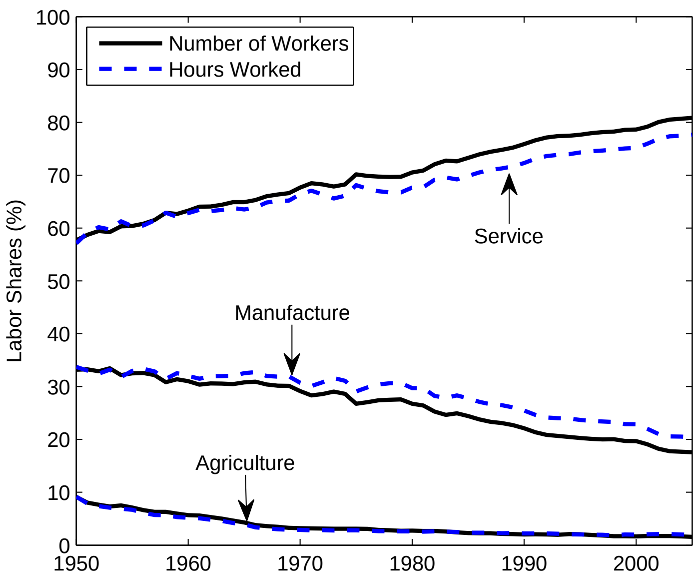

Figure 1: U.S. sectoral employment shares 1950-2005

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.

[2]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.

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 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 percent in the farm sector, compared to 1.2 percent in the non-farm sector.[3] However, within the non-farm sector, the TFP growth rates of manufacturing and services are not directly reported. Jorgenson et al. (1987) estimated relatively low TFP growth rate in manufacturing at 0.6 percent, compared to 0.9 percent in the service sector[4] from 1950 to 1977. The EU KLEMS Growth and Productivity Accounts report that TFP has been growing at 1.03 percent and 0.5 percent 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 percent during 1950-1970 to 0.8 percent during 1971-2005.

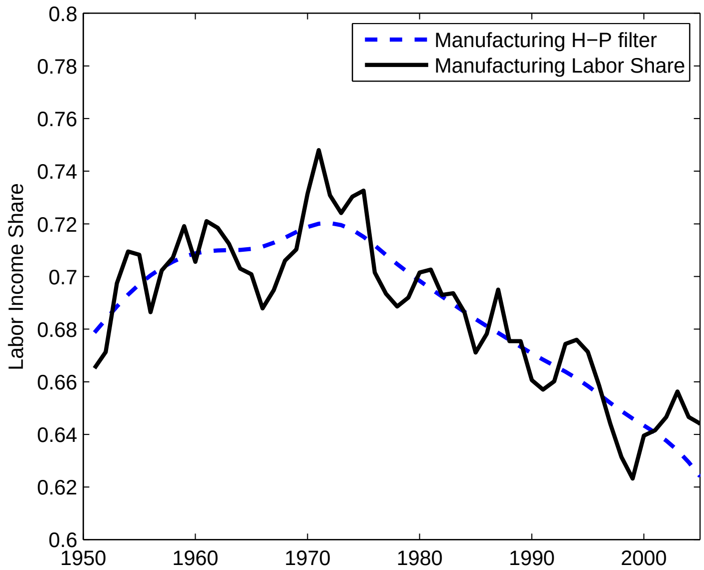

Figure 2: Labor income share in manufacturing

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

[3]See Jorgenson et al. (1987), Jorgenson and Stiroh (2000), and more recently, Alvarez-Cuadrado and Poschke (2011) for the estimations of total factor productivity growth.

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

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 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.[5] 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 Yi and Zhang (2010), are incapable of handling these issues.

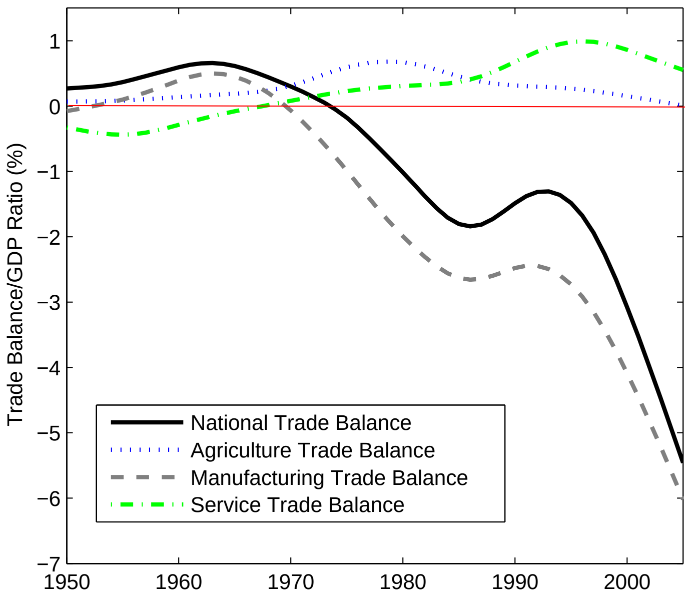

Figure 3: Trade balance/GDP ratio (through H-P filter)

The third, and probably the most ignored, factor is international trade. The traditional models of structural transformation are often restricted to a closed economy, which is an inappropriate assumption for 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 percent 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 balance for the service sector has been persistently positive, while agriculture trade surplus has remained but has become relatively insignificant.

[5]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.

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.

There might be an indirect impact from trade to 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 et al. (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's level response. Since we can not 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.

3 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 literature of modeling structural change, the model adopts three features to achieve this outcome: non-homothetic preference, sector-biased technological growth, and different factor shares in production functions. In addition, we extend this model to include the contribution of international trade.

3.1 Economic Environment

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,[6] 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:

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

[6] Kongsamut et al. (2001) reported manufacturing and construction sectors produced between 90% and 93% of investment in the United States during the period of 1958 to 1987. This ratio, calculated using the World Input-Output Database (Timmer, 2012), is between 77% and 82% from 1996 to 2009.

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,

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

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

$$\max_{K_{i,t}L_{i,t} \geqslant 0} P_{i,t}Y_{i,t} - w_t L_{i,t} - r_t K_{i,t}, \tag{3}$$

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

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 consumptions to maximize the following lifetime utility:

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

where $\sigma > 0$ is the intertemporal elasticity of substitution of consumption, and if $\sigma = 1$, $U(C_t) = \log C_t$, β is a discount factor, and C_t is a composite consumption with three components: the consumption of agriculture goods, manufacturing, and service goods,

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

where $\bar{C}_a \geqslant 0$, is a subsistence level of agricultural consumption that introduces non-homotheticity to the preference which has a long tradition in the literature of development,[7] $\bar{C}_s \leqslant 0$ captures the home-produced services, and θ is the elasticity of substitution across goods. In a recent empirical study, Herrendorf et al. (2009) 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 term 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.

[7] 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 et al. (2001), Gollin et al. (2007), Restuccia et al. (2008), Duarte and Restuccia (2010) and Alvarez-Cuadrado and Poschke (2011).

The budget constraint of the household at time t is

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

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

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,

$$\sum_{i\in\{a,m,s\}} L_{i,t} = L, \qquad \sum_{i\in\{a,m,s\}} K_{i,t} = K_t. \tag{7}$$

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

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

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

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

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,

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

As discussed in Section 2, the trade balance of manufacturing can be divided into two components,

$$NX^{Sector}_{m,t} = \frac{P_{a,t}NX_{a,t} + P_{s,t}NX_{s,t}}{P_{m,t}NX_{m,t}}, \tag{11}$$

$$NX^{TB}_{m,t} = \frac{TB_t}{P_{m,t}}, \tag{12}$$

where $NX^{Sector}_{m,t}$ reflects the manufacturing trade balance that is necessary to keep the overall trade balanced, and $NX^{TB}_{m,t}$ refers to the trade balance that is linked to the aggregate trade position.

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

$$S_t = I_t - NX^{TB}_{m,t}. \tag{13}$$

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.

3.2 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 $\{P_{a,t}, P_{m,t}, P_{s,t}\}_{t\geqslant 0}$, household consumption $\{C_t(C_{a,t}, C_{m,t}, C_{s,t})\}_{t\geqslant 0}$, labor allocations $\{L, L_{a,t}, L_{m,t}, L_{s,t}\}_{t\geqslant 0}$ and capital stocks $\{K_t, K_{a,t}, K_{m,t}, K_{s,t}\}_{t\geqslant 0}$, 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 $\{P_{a,t}, P_{m,t}, P_{s,t}\}_{t\geqslant 0}$ make the markets clear: equation (7), (8) and (9) hold.

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 (Teignier, 2011). 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 et al., 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 B. □

Proposition 1 shows that conditions for jointly having generalized balanced growth and structural transformation become considerably very stringent. Herrendorf et al. (2013) argues that if we want to capture features in reality, the conditions above are too restrictive to be satisfied.

In this paper, the primary target is to capture 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.

Following the strategy of Dekle and Vandenbroucke (2011), instead of investigating the concept of balanced growth, we will focus on studying a sequence of steady states in which the labor allocation and capital are stable at each state, while the exogenous productivity growth shifts the economy from one state to another. 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 household, or to specify how expectations of the future are formed. In addition, this static assumption allows us to introduce trade balances to the model. Therefore, the following definitions of *steady state* and *static growth path* are essential in this exercise.

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

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

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. If the capital labor ratio in sector i is defined as $k_{i,t} = \frac{K_{i,t}}{L_{i,t}}$, it will satisfy the following equations:

$$k_{a,t} = m_a k_{m,t}, \qquad k_{s,t=} m_s k_{m,t}, \tag{14}$$

where $m_a = \frac{\alpha_a(1-\alpha_m)}{\alpha_m(1-\alpha_a)}$, $m_s = \frac{\alpha_s(1-\alpha_m)}{\alpha_m(1-\alpha_s)}$.[8]

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

$$\begin{aligned} w_t &= P_{m,t}(1-\alpha_m)B_{m,t}k_{m,t}^{\alpha_m}, \\ r_t &= P_{m,t}\alpha_m B_{m,t}k_{m,t}^{\alpha_m-1}. \end{aligned} \tag{15}$$

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

$$\begin{aligned} p_{a,t} &= \frac{P_{a,t}}{P_{m,t}} = \frac{B_{m,t}(1-\alpha_m)}{B_{a,t}(1-\alpha_a)m_a^{\alpha_a}}k_{m,t}^{\alpha_m-\alpha_a}, \\ p_{s,t} &= \frac{P_{s,t}}{P_{m,t}} = \frac{B_{m,t}(1-\alpha_m)}{B_{s,t}(1-\alpha_s)m_s^{\alpha_s}}k_{m,t}^{\alpha_m-\alpha_s}. \end{aligned} \tag{16}$$

Given relative prices as a function of $k_{m,t}$, the labor 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 B. □

[8] 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 $\frac{k_{s,t}}{k_{m,t}} = \frac{\alpha_s(1-\alpha_m)}{\alpha_m(1-\alpha_s)} \equiv m_S$.

Consumption

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

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \beta\frac{P_t}{P_{t+1}}(r_{t+1}+1-\delta), \tag{17}$$

where P_t is the price index satisfying,

$$P_tC_t = \sum_{i\in\{a,m,s\}} P_{i,t}C_{i,t}. \tag{18}$$

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. (Herrendorf et al., 2009). 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,

$$\begin{aligned} \frac{C_{a,t}-\bar{C}_a}{C_{m,t}} &= \frac{w_a}{w_m}\left(\frac{P_{m,t}}{P_{a,t}}\right)^{\theta}, \\ \frac{C_{m,t}}{C_{s,t}-\bar{C}_s} &= \frac{w_m}{w_s}\left(\frac{P_{s,t}}{P_{m,t}}\right)^{\theta}. \end{aligned} \tag{19}$$

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 (17) can be rewritten as $r_{t+1} = \frac{1}{\rho}+\delta-1$. Thus, the interest rate is determined by the discount factor ρ and the depreciation rate δ.

Proposition 3. *Assuming interior solutions exist, given productivity sequence $\{B_{i,t}\}_{t\geqslant 0}$, if the discount factor β and the depreciation rate δ are held constant, the interest rates on a static growth path are constant,*[9] *as denoted by r_{ss},*

$$r_{ss} = \frac{1}{\beta}+\delta-1. \tag{20}$$

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,

$$k_{m,ss,t} = \left(\frac{P_{m,t}B_{m,t}\alpha_m}{r_{ss}}\right)^{\frac{1}{1-\alpha_m}}, \tag{21}$$

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

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.

Labor Allocations on the Static Growth Path

First, without loss of generality, $P_{m,t}$ can be normalized to one.[10] 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 (16). 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.[11]

3.3 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.

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,

$$\mu_{i,t} = \frac{nx_{i,t}}{gdp_t}, \tag{22}$$

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

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

$$GDP_t = \sum_{i \in \{a,m,s\}} P_{i,t} Y_{i,t}, \tag{23}$$

which is a function of $\{K_t,\ K_{s,t},\ k_{m,t}\}$. Thus, given the trade balance/GDP ratio exogenous by the data,[12] the trade balance in the model is determined by

$$NX_{i,t} = \mu_{i,t} \cdot GDP_t. \tag{24}$$

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

[11]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 fits 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.

[12]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.

Using the market-clearing condition in equation (9), following the same algorithm, we are able to solve the labor 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 et al. (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.

4 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.[13]

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

4.1 Parameter Values

The model period is 1 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 β, θ, w_a, w_m, $\bar{C}_a$,

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

$\bar{C}_s$,[14] and the time series of sectoral productivity $B_{i,t}$ with sectoral TFP growth rates denoted by $\gamma_{i,t}$.

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 sequence of $\{B_{a,t}\}$. The average TFP growth rate, γ_a, was 1.7 percent 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 percent 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 percent.

Case 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 et al. (1987), the TFP growth rate was about 0.77 percent in the manufacturing, and 1.1 percent in the service sector from 1950 to 1970. These estimates would be too low to explain the 1.5 percent 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 percent in the manufacturing and 0.6 percent in the service sector.

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.[15] 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 $\alpha_s = 0.26$.

Depreciation Rate

The Department of Commerce has significantly revised its capital stock estimates since the mid-1990s, with its new estimates on updated empirical evidence on de-

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

[15]The EU KLEMS Growth and Productivity Accounts only cover the post 1977 period.

preciation for various types of assets. Based on this revision, McQuinn and Whelan (2007) estimate the annual depreciation rate δ in the United States at 6 percent.

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 percent in 2009[16], so setting w_a to 0.01 is acceptable. I also calibrate the consumption share of manufacturing goods, w_m, at around 14.5 percent.

Acemoglu and Guerrieri (2008), Herrendorf et al. (2009) and others have found 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 5.3. 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.

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	0.06	McQuinn and Whelan (2007)
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
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

[16]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.

Table 3: The Case Specific Parameter Values

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

4.2 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.

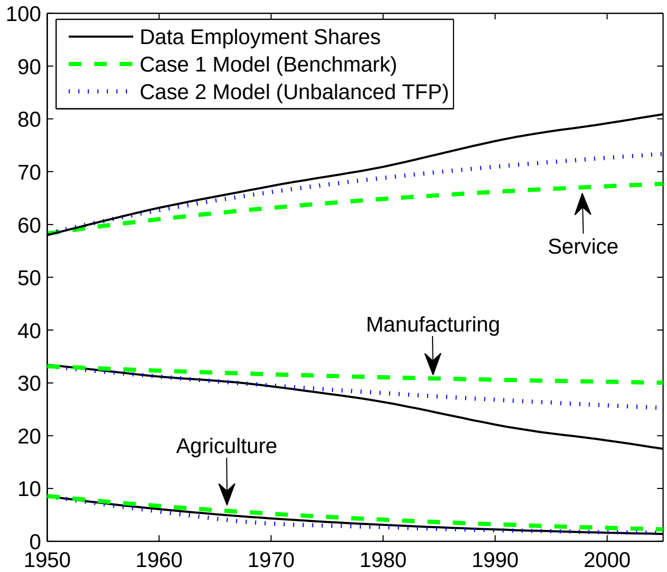

Figure 4: Closed Economic Models vs U.S. Data

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 percent to 30 percent, while the service employment share increases from 58 percent to 67.8 percent, mainly from the decline of employment in agriculture, down from 9 percent to just above 2 percent. 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 labor 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 percent employment share in the manufacturing and 80.9 percent 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 (21), 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.

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 labor shares in the data, showing a steady decline in the share of manufacturing employment from about 33 percent in 1950 to 25.2 percent in 2005 (17.5 percent in the data), whereas the share of workers in the service sector increases from about 58 percent to 73.4 percent (80.9 percent in the data). Nevertheless, since 1980, the model predictions have deviated from the data. A significant parts of the employment composition change, roughly a five-percent decline in manufacturing and a simultaneous rise in services over the last three decades, still lack a convincing explanation. These calibration results match the works of Bah (2009), and Buera and Kaboski (2009).

4.3 Trade-augmented Model

As discussed earlier, persistent trade deficits could contribute to the structural changes through two direct channels: inter-sector trade effect and trade imbalance effect. We will consider them in turn.

In the Case 3 model, we investigate the factor of inter-sector trade. If the trade surplus in the agriculture and service sectors in the U.S. reflects comparative advantages in these sectors, the economy can have a corresponding trade deficits in manufacturing. This channel of structural change has been discussed in Yi and Zhang (2010) and Teignier (2011). We estimate counterfactual manufacturing trade balances that can keep the economy-wide trade balanced. And we solve for the labor shares, using these sectoral trade balances as exogenously given. The numerical results of the Case 3 model, as reported in Figure 5, show only moderate contribution, compared to the case 2 model. Numerically, the predicted manufacturing employment share in 2005 decreases by 1 percent to 24 percent, while the service share increases to 74.3 percent.

In the Case 4 model, actual sector trade balance/GDP ratios are used to evaluate the total 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 percent to 19.6 percent, while the employment share for the service sector increases 4.8 percent to 78.8 percent. These estimates lie between the two measures of employment shares. The predicted manufacturing share (19.6 percent) is lower than the share in terms of hours worked (20.3 percent in 2005), but higher than the share in terms of the number of workers (17.5 percent in 2005).

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

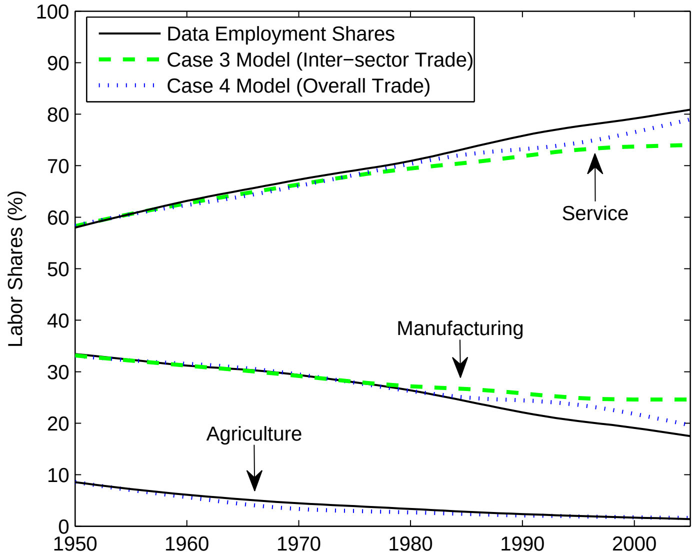

Figure 5: Trade-augmented Model vs U.S. Data

argument that trade imbalances have a substantial impact on the composition of employment.

5 Discussion

5.1 Technology Slowdown and Rising Capital Intensity

There are several facts in the data 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 put 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 percent between 1950 and 1973, to 0.6 percent after 1973. If the slowdown had not been balanced between the manufacturing and service sectors, it might have affect 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 et al. (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.[17] Thus, the rise of labor intensity and its impact on

[17] Another explanation of the capital income share change comes from the limitation of the Cobb-Douglas type production function. Long and Alvarez-Cuadrado (2011) provide a more general

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 percent for the manufacturing sector and 0.5 percent 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 0.47 in 2005.

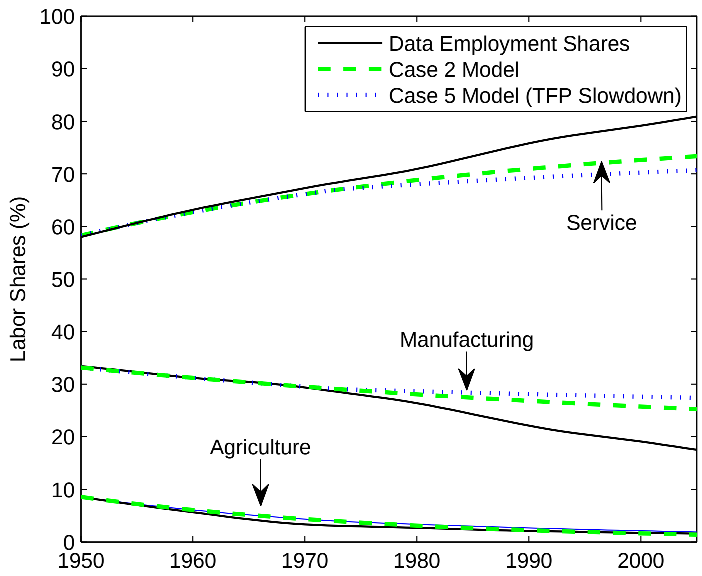

Figure 6: Case 5 (TFP Slowdown) vs Case 2, with U.S. Data

Figure 6 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 percent in 2005, 2.2 percent higher than 25.2 percent reported by Case 2 model.

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

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 percent and the multifactor productivity in nonfarm business grew at 1.46 percent. Since 1980, the annual progress of multifactor productivity was around 0.75 percent, while the output per worker in the manufacturing sector increased at

discussion on elasticity of substitution and structural change process by using the CES type of production functions.

3.8 percent 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.

5.2 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.

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%

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 the different constructions of the models, the postwar structural transformation in the United States can be separated into different sources that have been discussed in the literature, as summarized in Table 5.

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

Model #	NetΔ	CumulativeΔ	Sources
Case 1	3 %	3 %	Differential capital shares, non-homothetic utility
Case 2	4.8%	7.8%	Unbalanced TFP growth rates
Case 3	0.7 %	8.5 %	Inter-sector trade effect
Case 4	4.8 %	13.3 %	Trade imbalance effect
Data		15.5 %	The decline of labor share from 1950 to 2005

The key drivers that contribute most to structural change are the sector-biased productivity growth rates and the trade imbalance effect, each of which account for 4.8 percentage points in the model. But taking the inter-sector trade effect into account, which adds another 0.7 percentage points, the trade-related factor can explain at least 35.5 percent (5.5 out of 15.5) of the labor 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.

These results are in line with the findings of Sachs and Shatz (1994) and Bernard et al. (2006). However, because of the identification problem, the causality relationship during the whole process is unclear. As mentioned by Krugman and Lawrence (1994), the structural change process, including trade balance deterioration, could come from the slowdown of the technology change. Therefore, the correlation found in the model between trade balance and labor movement might be caused by unknown shocks. There are still many issues that need to be clarified to fully understand the structural change in the United States, especially the extraordinary decline in the manufacturing sector since the early 1980s.

5.3 Robustness

Alternative Measure of Structural Change

Buera and Kaboski (2009) and Herrendorf et al. (2013) argued that traditional models have difficulty simultaneously matching the structural change in terms of labor employment and value-added. Figure 7 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 sector, we can partially capture the change of relative prices.

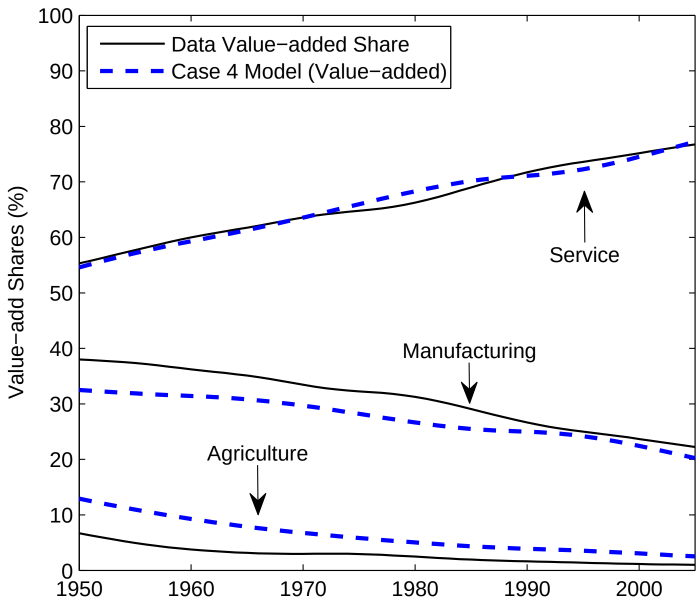

Figure 7: Case 4 Model vs U.S. Data in terms of Value-added Shares

In addition, Figure 1 in section 2, shows the evolution of labor employment shares in terms of number of workers and number of hours worked. Although both data series display similar trends in general, the number of workers shows larger labor movements (16 percent in the manufacturing sector), compared to 13 percent reported in terms of working hours. The deviations between the two measures of labor distribution come from the decline of working time in the service sector. We hope that within a reasonable range of parameter choice, the model can account for the structural change in both measures.

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 relative low elasticity of substitution (θ= 0.5) across industry goods, following Buera and Kaboski (2009). But Herrendorf et al. (2009) find that a Leontief utility (θ= 0) fits the value-added sectoral consumption data for U.S. households.[18] Therefore, robustness checks on the values of θ, especially a preference close to the Leontief specification, would be crucial for the calibration.

Table 6: Robustness Analysis of the Structural Change Model

	Labor Share Change in Data		Case 4 Model		
	Employment	Hours worked	$\theta = 0.75$	$\theta = 0.25$	$\theta = 0.01$
Agriculture	-7 %	-6.9 %	-6.9 %	-7 %	-7 %
Manufacturing	-16 %	-13 %	-11.2 %	-15.2%	-16.5 %
Service	23 %	19.9 %	18%	22.2 %	23.5 %

Table 6 summarizes the model (Case 5) predictions with different values of θ, and the elasticity of substitution between manufacturing products and services, and compares those results with the two labor share measures in the data. It shows that a smaller θ leads to larger labor movements across sectors. For example, the labor share increase in the service sector will be 18 percent for $\theta = 0.75$, 20.4 percent for $\theta = 0.5$, 22.2 percent for $\theta = 0.25$, and will reach 23.5 percent if $\theta = 0.01$, which is close to the Leontief preference.

In conclusion, the model presented in this paper can explain a significant part of the labor reallocation in the postwar U.S. economy. In addition, this result is not sensitive to the measure of employment and the elasticity of the substitution parameter θ.

5.4 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. By using the same parameter values summarized in Tables 2 and 3, the real per capita output growth rate is 2.12 percent in the Case 4 model versus

[18]Buera and Kaboski (2009) also report that Leontief preference provides a better fit in their model.

2.15 percent 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 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 construct a special version of the Case 4 model in which only the manufacturing sector maintains a trade deficit at 5 percent of the total GDP. This model reports a slightly lower real output growth rate, around 2.02 percent. Therefore, 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 percent in the closed economy (Case 2) versus 2.02 percent in the open economy (Case 4 with trade deficit at 5 percent of GDP). Thus, according to the model, the real economic growth rate is just slightly affected by the large trade deficit (5 percent of GDP).[19]

6 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. We mainly focus on two channels, the inter-sector trade and trade imbalances.

Second, this paper quantifies the roles of different factors on the composition of labor employment, especially the decreasing manufacturing employment share. The 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 percent of the overall labor 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.

These findings are consistent with those of Sachs and Shatz (1994) and Bernard et al. (2006) that international trade have a significant impact on the production

[19] The model also reports the output growth, at 2.24 percent, in the same economy with a trade surplus (5 percent of GDP).

sector of tradable goods: firms either move to more capital intensive industries or close their plants sooner because of the competition. The labor market responds accordingly. As a result, labor moves out of the sectors of tradable goods, such as manufacturing, and into the non-tradable sectors, such as services.

The policy applications, based on the model and related calibration exercises, provide a better understanding on the current structural problem in the United States. For example, in our quantitative exercise, persistent trade deficits can explain 31 percent of the recent contraction of the manufacturing sector, or roughly 5 percent of total employment. As many economist argued,[20] this trade balance position can not 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 one of the reasons to explain the sluggish recovery from the recent great recession. In addition, the model shows that the countries have trade deficits will achieve a slightly lower growth rate, while countries can maintain a 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.

Appendix

A Data Sources

A.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 databases[21] 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, both the labor shares in terms of number of workers and in terms of hours worked are available for the whole sample period. The value-added of each sector is given in both constant and current prices.

A.2 Production Function and Productivity

The Economic Research Service of the United States Department of Agriculture (USDA) reports agriculture productivity from 1948 to 2009.[22]For the the non-

[20]See, for example, Feldstein (2008).

[21]Data is available at http://www.ggdc.net.

[22]http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx

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 the estimates in Valentinyi and Herrendorf (2008).

A.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 are reported by the BEA since 1929. Within the trade of goods, the United Nation Commodity Trade (UN COMTRADE) database provides estimates from 1961.

B Proofs

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 et al., 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

$$\sum_{i\in\{a,m,s\}} \bar{P}_{i,t}(C_{i,t} - \bar{C}_i) + \bar{P}_{m,t} I_t = \sum_{i\in\{a,m,s\}} \bar{P}_{i,t} Y_i. \tag{25}$$

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

$$\dot{K}_t + \delta K_t + C_{m,t} + \bar{P}_{a,t}(C_{a,t} - \bar{C}_a) + \bar{P}_{s,t}(C_{s,t} - \bar{C}_s) = B_{m,t} K_t^{\bar{\alpha}}. \tag{26}$$

or

$$\frac{\dot{K}_t + \delta K_t + C_{m,t} + \bar{P}_{a,t}(C_{a,t} - \bar{C}_a) + \bar{P}_{s,t}(C_{s,t} - \bar{C}_s)}{B_{m,t}^{\frac{1}{1-\bar{\alpha}}}} = \left(\frac{K_t}{B_{m,t}^{\frac{1}{1-\bar{\alpha}}}} \right)^{\bar{\alpha}}. \tag{27}$$

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 et al. (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. for Proposition 2,

According to equations (7) and (14), 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,

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

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

$$\begin{aligned} L_{a,t} &= \frac{K_{s,t} - K_t + k_{m,t}\left(L - \frac{K_{s,t}}{m_s k_{m,t}}\right)}{k_{m,t}(1 - m_a)} \\ L_{m,t} &= L - L_{a,t} - L_{m,t} \\ L_{s,t} &= \frac{K_{s,t}}{m_s k_{m,t}} \end{aligned} \tag{28}$$

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 labor share in domestic manufacturing, respectively. □

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