Structural transformation under trade imbalances: the case of 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 model cannot account for the steep decline in manufacturing and rise in services in the United States since early 1980s (Buera and Kaboski, 2009). In order to solve the puzzle, this paper develops a three-sector model to evaluate various factors that could contribute to the structural transformation process from 1950 to 2005. The results show that, in addition to the traditional explanations, such as the non-homothetic preferences and sector-biased productivity progress, trade imbalance is another major source of structural change, which is able to explain about 38 percent of the overall labor share decrease in the American manufacturing. The quantitative predictions replicate the labor movements in the U.S. data, especially can properly explain the recent contraction of manufacturing employment share. This result is robust to different parameter values and alternative labor share measure. This paper is so far the first work that considers the intra-industry trade in the structural change literature which might support the argument that trade imbalances have substantial impact on the labor markets.

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1 Introduction

The economics literature has documented the structural transformation during the industrialization process, which is a massive reallocation of labor from agriculture into manufacturing and service sectors[1]. Kuznets (1966) considers the structural change as one of the most prominent features of development.

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

In order to evaluate the performances of these models, a prevalent exercise is to replicate the structural transformation in the United States. Bah (2009), Buera and Kaboski (2009) find that the predictions of traditional structural change models cannot account for the steep decline in manufacturing and rise in services in the recent data. Duarte and Restuccia (2010) attempt to match the magnitude of the overall structural change from 1956 to 2004, but their results have noticeable deviations from the historical trend during the process.

One potential explanation of the puzzle might come from the assumption of closed economy in the traditional literature of structural change, since it is primarily focusing on the long term industrialization process. However, this assumption is a doubtful premise to study the postwar United States which has experienced a soaring trade deficit since 1970s, eventually reaching 6 percent of GDP in 2005. Surprisingly, very few studies have explored the link between structural transformation and international trade. Echevarria (1995) and Yi and Zhang (2010) have discussed the impact of trade on structural change in the context of Ricardian trade: the country should specify to produce either agriculture goods or manufacturing goods depending on their comparative advantages in the world market. This analysis could be helpful to study countries at very early stage of development, which mainly exchange primary goods for manufacturing goods in the world market. However, within the developed economies, or

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

between the emerging and developed economies, the dominant type of trade is the exchange of manufacturing products. This intra-industry trade can not be discussed in the previous framework.

The latter pattern of trade is also a key component of the U.S. economy. Therefore, one contribution of this paper to the structural change literature is to provide a new framework to consider the role of intra-industry trade, which is able to explain the postwar structural transformation of United States.

In this paper, the first exercise is to develop a three-sector closed economy model to reveal the puzzle. This model inherits those features in the traditional literature of structural change, 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 could reproduce the labor movements across sectors from 1950 to early 1980s, but show noticeable deviations from the data in the recent period.

As discussed early, the poor performance of the model might come from the closed economy assumption, since the recent labor reallocation process has an interesting statistical relationship with the deterioration of trade balances in the United States. At the aggregate level, the timing of the recent intensive labor movements from manufacturing to service sectors follows quite closely that of the increase of trade deficits. For simplicity, I assume only manufacturing products are tradable, because the trade deficits come from the net import of consumer goods and automobiles (Mann, 2002). Next, I set the trade balance/GDP ratio in the model exogenously given as in the data, meaning that a portion of total output will be net imported for either consumption or investment. This model, denoted as a trade balance augmented model, will estimate the optimal response of the domestic labor market, and predict the labor movements. The result quantitatively fits the historical trends in the data, and is robust to various parameter values and alternative measure of labor shares. These findings are in line with the implications of Sachs and Shatz (1994), Bernard, Jensen, and Schott (2006), which might support the argument that international competition and trade have significant impacts on the labor market.

The rest of the paper is organized as follows. Section 2 documents some historical evidences of the U.S. economy from 1950 to 2005. Section 3 presents the benchmark closed economy model and characterizes the equilibrium properties. Section 4 calibrates the model to evaluate its performance and reveals the puzzle between the model predictions and the data. Then, in section 5, I introduce trade balance positions into the model, and recalibrate such a trade-balance-augmented model to predict the labor movements. Section 6 discusses several relevant issues and checks the robustness of the results. Section 7 concludes the paper.

2 The Structural Change in the United States, 1950-2005

This section documents the process of structural transformation and labor productivity growth in agriculture, manufacturing, and service in the United States from 1950 to 2005. The sectoral employment shares during the period are come from the Groningen Growth and Development Centre (GGDC) 10-sector and Historical National Accounts databases(Timmer and Vries, 2008), in term of number of workers and hours worked. The labor income shares are available as Unit Labor Cost (ULC) from the OECD statistics since 1970. For the productivity, data sources include Jorgenson, Gallop, and Fraumeni (1987), the United States Department of Agriculture (USDA), the Bureau of Labor Statistics (BLS), and the EU KLEMS Growth and Productivity Accounts. The trade balances of U.S. are from Lees (1965) for 1950 to 1955, Branson (1971) for 1956 to 1969, and IMF International Financial Statistics since 1970. More details of the data series are explained in Appendix A.

Figure 1 reveals the trend of structural change over the period in term of number of workers and in term of hours worked. Both data series display the same qualitative properties[2]: the employment share is steadily decreasing in the goods sector, including agriculture and manufacturing, and 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 good-producing sectors to service-producing sectors.

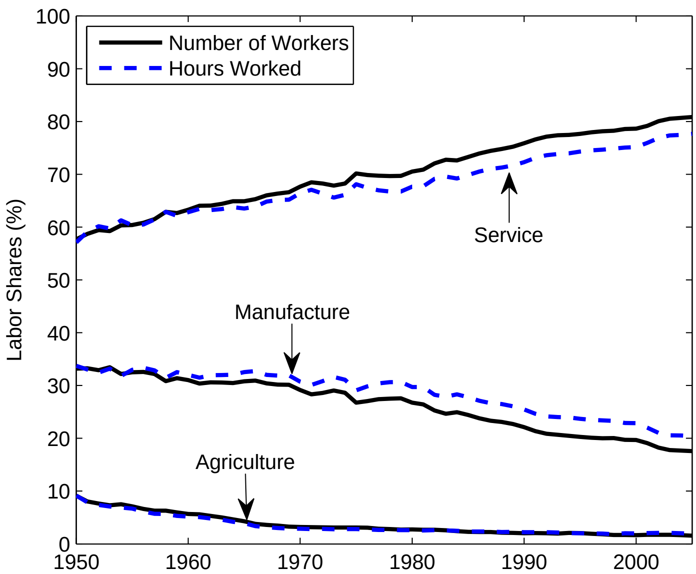

Fig. 1: U.S. Sectoral Employment Shares 1950-2005

A puzzling feature of the postwar U.S. economy is the rapid decline of the manufacturing labor employment share since early 1980s. Buera and

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

Kaboski (2009) argue that the traditional models of structural change have failed to match the data in this period. In this paper, three possible factors that might contribute to the labor reallocation will be evaluated one by one in the following sections.

The first factor is the sector-biased productivity growth. As Ngai and Pissarides (2007) and Duarte and Restuccia (2010) propose, 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 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 the non-farm sector, average annual TFP growth at 1.7 percent in the farm sector, compared with 1.2 percent in the non-farm sector from 1948 to 2005[3]. In addition, in the non-farm sector, Englander and Mittelstadt (1988), Jorgenson and Gollop (1992) report a slowdown of TFP growth in the early 1970s, from 1.5 percent during 1950-1970 to 0.8 percent during 1971-2005, according to the Bureau of Labor Statistics. However, the TFP growth rates of manufacturing and service are not directly reported. Jorgenson, Gallop, and Fraumeni (1987) estimate relatively low level of TFP growth rate in manufacturing at 0.6 percent, comparing with 0.9 percent in service sector[4] from 1950 to 1977, while EU KLEMS Growth and Productivity Accounts report that TFP has been growing at 1.2 percent and 0.5 percent on average in manufacturing and service respectively since 1977.

Second, the different factor proportions across sectors and their fluctuations might play an important role in the structural transformation, which have received less attention in the literature. Valentinyi and Herrendorf (2008) find that agriculture has the highest capital share, following by manufacturing, and service sector. And Acemoglu and Guerrieri (2008) show that factor proportion differences and capital deepening across sectors will lead to a factor reallocation. Moreover, as a measure of labor income output share, Unit Labor Cost (ULC)[5] in the U.S. manufacturing sector felt from 0.71 in 1970 to 0.53 in 2005[6], as shown in figure 2. This finding is confirmed by using the EU KLEMS database, and is consistent with Glyn (2007). Therefore, models with only labor as factor of production, or assuming identical capital share across sectors, such as Ngai and Pissarides (2007), Buera and Kaboski (2009), Duarte and Restuccia (2010), and Yi and Zhang (2010), have ignored some important features.

The third, also probably the most ignored factor, is the international trade. The traditional models of structural transformation are often re-

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

[4] The author uses industry value-added weights to generate the sector TFP growth rates of this paper.

[5] Unit labor costs (ULC) measure the average cost of labor per unit of output and are calculated as the ratio of total labor costs to real output.

[6] The labor income share is trended using the Hodrick–Prescott filter with a smoothing parameter 100.

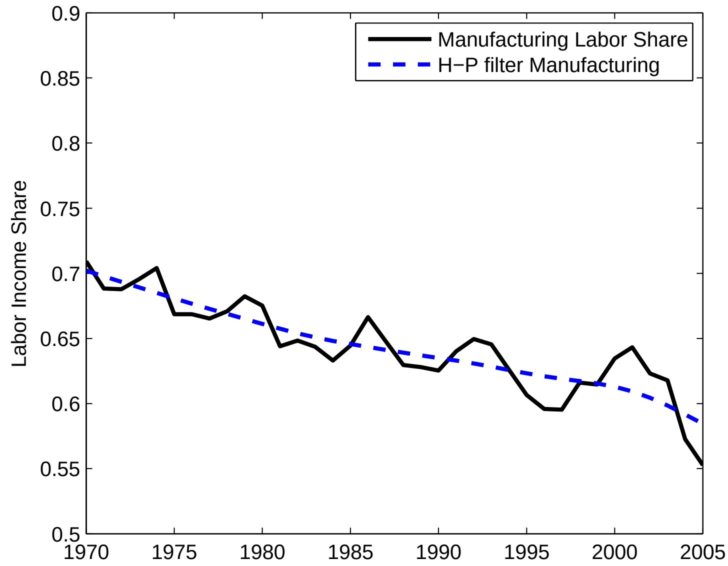

Fig. 2: The Labor Income Share in Manufacture Sector

stricted to closed economy, which is an inappropriate assumption for the postwar U.S. economy. As shown by Lees (1965), Branson (1971) and IMF International Financial Statistics, the U.S. trade balance, has been in the deficit since the early 1970s, and reached 6 percent of GDP in 2005 (figure 3).

Since manufacture products are generally considered as tradable goods, the competition in the international market and the net import into U.S. would contribute to the decline of employment share of the manufacturing sector. Sachs and Shatz (1994) estimate the impacts of trade on manufacturing employment and find that "the increase in net imports between 1978 and 1990 is associated with a decline of 7.2 percent in production jobs in manufacturing and a decline of 2.1 percent in non-production jobs in manufacturing". They also find that the international competition drives out the positions of low skill workers and promotes industries with higher skill requirement, which is somehow consistent with the rising capital income share in manufacturing sector. Later, Bernard, Jensen, and Schott (2006) find that plant survival and growth in the U.S. manufacturing are negatively associated with industry exposure to low-wage country imports, implying that firms adjust their production according to the trade pressures. However, Krugman and Lawrence (1994) and Lindsey (2004) believe that international trade has played a minor role in the contraction of U.S. manufacturing.

In the following sections, a formal model of structural transformation will be constructed in order to evaluate the impacts of the three factors presented above.

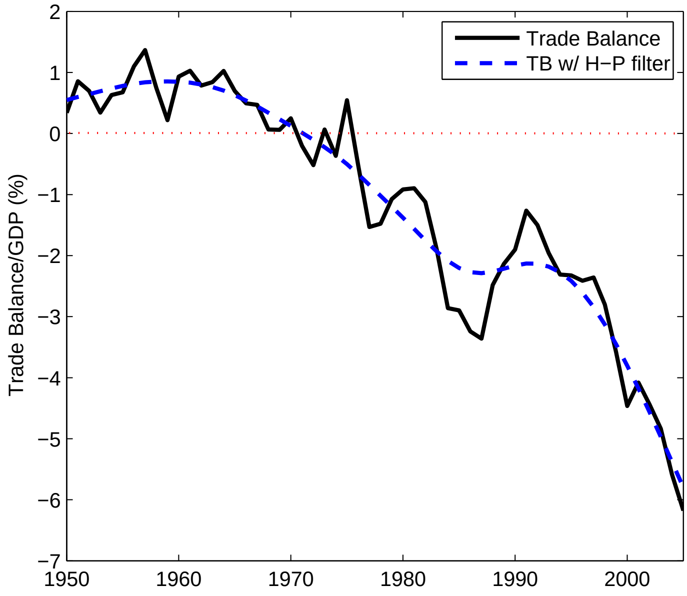

Fig. 3: Trade Balance/GDP Ratio

3 The Model of Structural Change

This section develops a three-sector model of structural transformation which intends to replicate the labor relocation process during economic growth. Following the literature of modeling structural change, the model has three features to achieve this outcome: non-homothetic preference, sector-biased technological growth, and different factor shares in the production functions.

To simplify the analysis, I start with a closed economy which is a very popular scenario considered in the literature. Trade factors will be introduced in section 5.

3.1 Economic Environment

Firms

There are three sectors in the model: agriculture, manufacturing, and service, denoted by capital letter A, M, and S, respectively. All three goods are consumption goods, though manufacture products are also used for investment. Labor and capital are the only two factors of production. At time t, the outputs satisfy the following Cobb-Douglas production functions with constant return to scale:

$$\begin{aligned} Y_{A,t} &= A_t K_{A,t}^{\alpha} L_{A,t}^{1-\alpha} \\ Y_{M,t} &= B_t K_{M,t}^{\beta} L_{M,t}^{1-\beta} \\ Y_{S,t} &= G_t K_{S,t}^{\gamma} L_{S,t}^{1-\gamma} \end{aligned} \quad (1)$$

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. The capital intensities in the three sectors are different - α, β, γ, and $\{A_t, B_t, G_t\}$ is the set of productivity at time t, starting from some initial values - A_0, B_0, G_0.

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,

$$\max_{K_{i,t}L_{i,t}\geqslant 0} P_{i,t}Y_{i,t} - w_t L_{i,t} - r_t K_{i,t} \tag{2}$$

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 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:

$$U_h = \sum_{t=0}^{\infty} \rho^t U(C_t) = \sum_{t=0}^{\infty} \rho^t \frac{C_t^{1-\sigma} - 1}{1-\sigma} \tag{3}$$

where $\sigma > 0$, of course, if $\sigma = 1$, $U(C_t) = \log C_t$, ρ is a discount factor, and C_t is a composite consumption with two components: the consumption of agriculture goods, $C_{A,t}$, and the non-agriculture consumption including manufacturing and service goods, $C_{I,t}$,

$$C_t = (C_{A,t} - \overline{c_A})^{w_A} C_{I,t}^{1-w_A} \tag{4}$$

$$C_{I,t} = \left(w_M^{\frac{1}{\theta}} C_{M,t}^{\frac{\theta-1}{\theta}} + (1-w_M)^{\frac{1}{\theta}} C_{S,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \qquad w_M \in (0,1) \tag{5}$$

where $w_A \in (0,\, 1)$, and $\overline{c_A}$, assuming to be positive, 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] as an important feature leading to the movement of labor away from agriculture during structural transformation. θ is the elasticity of substitution between manufacturing and service products[8]. In a recent empirical study, Herrendorf, Rogerson, and Valentinyi (2009) calibrate utility function parameters

[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, Rebelo, and Xie (2001), Gollin, Parente, and Rogerson (2007), Restuccia, Yang, and Zhu (2008), Duarte and Restuccia (2010) and Alvarez-Cuadrado and Poschke (2011).

[8] Introducing non-homotheticity between service and manufacturing is also popular in the literature. Using a term for non-market/home service goods, $\overline{c_S}$, the total consumption in service is given by, $C_{S,t} = Y_{S,t} + \overline{c_S}$. This constant term $\overline{c_S}$ will help the model to generate further labor movements into service sector as household income grows. However, because of the following two reasons, in this paper, $\overline{c_S}$ is set to 0: (i) the impact of

to be consistent with the U.S. consumption data, and find 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, especially like the Leontief specification ($\theta = 0$) fits the value added sectoral consumption data well. Thus, assuming $\theta \in (0,\ 1)$ is reasonable.

The budget constraint of the household at time t is

$$\sum_{i=A,M,S} P_{i,t}C_{i,t} + P_{M,t}S_t = w_tL + r_tK_t \tag{6}$$

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

Market clearing

In the factor markets, at any period t, the demand for labor and capital from firms should be equal to the supply of labor and the current capital stock,

$$L_{A,t} + L_{M,t} + L_{S,t} = L, \qquad K_{A,t} + K_{M,t} + K_{S,t} = K_t \tag{7}$$

The financial market of this closed economy requires $S_t = I_t$ in every period, where I_t is the domestic investment. Depreciation rate is denoted by δ. Then, the law of motion for capital is,

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

In addition, at each date t, the market for each good produced must clear:

$$Y_{A,t} = C_{A,t}, \qquad Y_{M,t} = C_{M,t} + I_t, \qquad Y_{S,t} = C_{S,t}. \tag{9}$$

3.2 Economic Equilibrium

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 allocation $\{L,\ L_{A,t},\ L_{M,t},\ L_{S,t}\}_{t\geqslant 0}$ 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 (2); (ii) given prices, household chooses $\{C_t(\cdot)\}$ to solve the intertemporal consumption problem in equation (3); and (iii) the prices $\{P_{A,t},\ P_{M,t},\ P_{S,t}\}_{t\geqslant 0}$ make markets clear: equation (7), (8) and (9) hold.

The key concept in the literature of economic growth is the balanced growth path in which the fraction of capital and labor allocated to different industries remain constant over time (Kongsamut, Rebelo, and Xie, 2001). In order to evaluate the productivity growth differential across sector, Ngai and Pissarides (2007) define the concept, "aggregate balanced growth," as aggregate output, consumption, and capital grow at the same

this non-homothetic term will fade off as $Y_{S,t}$ increases, thus it cannot explain the rapid increase of service employment share in the recent data; (ii) in the calibration exercise, extra assumptions are required to estimate the value of $\overline{c_S}$, which might not be necessary.

For more discussions on the home service production and structural change, see Rogerson (2008), Herrendorf, Rogerson, and Valentinyi (2009), Buera and Kaboski (2011), and many others.

rate. They show under certain conditions, including identical production function across sectors, those aggregate ratios can be constant even with ongoing structural change. However, when production functions across sectors have different factor shares, Acemoglu and Guerrieri (2008) show that the growth will be unbalanced, since output, capital, and employment in the sectors will grow at different rates.

The primary target of this model is to capture the structural transformation process in the U.S. economy. Therefore, following the strategy of Herrendorf, Rogerson, and Valentinyi (2009), instead of investigating the concept of balanced growth, this paper will focus on studying a sequence of steady states in which the labor allocation and capital stock 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. Therefore, the following definitions of *steady state* and *static growth path* are essential in this exercise.

Definition 1. A *steady state* is that, without productivity shock, the household consumption and capital stock remain constant.

The steady state is typical as in the macroeconomics textbook, when the population and productivity are hold as constant (Ljungqvist and Sargent, 2004).

Definition 2. The *static growth path* is a sequence of steady states determined by an exogenous productivity sequence $\{A_t, B_t, G_t\}_{t\geqslant 0}$.

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 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,

$$k_{A,t} = m_A k_{M,t}, \qquad k_{S,t=} m_S k_{M,t}. \tag{10}$$

where $m_A = \frac{\alpha(1-\beta)}{\beta(1-\alpha)}$, $m_S = \frac{\gamma(1-\beta)}{\beta(1-\gamma)}$[9].

[9] The factor mobility implies the factor prices must be equal across sectors, such as,

$$r_t = P_{A,t}A_t\alpha k_{A,t}^{\alpha-1} = P_{M,t}B_t\beta k_{M,t}^{\beta-1} = P_{S,t}G_t\gamma k_{S,t}^{\gamma-1}$$

$$w_t = P_{A,t}A_t(1-\alpha)k_{A,t}^{\alpha} = P_{M,t}B_t(1-\beta)k_{M,t}^{\beta} = P_{S,t}G_t(1-\gamma)k_{S,t}^{\gamma}.$$

Therefore,

$$\frac{w_t}{r_t} = \frac{1-\alpha}{\alpha}k_{A,t} = \frac{1-\beta}{\beta}k_{M,t} = \frac{1-\gamma}{\gamma}k_{S,t}$$

implies $\frac{k_{A,t}}{k_{M,t}} = \frac{\alpha(1-\beta)}{(1-\alpha)\beta} \equiv m_A$, and similarly $\frac{k_{S,t}}{k_{M,t}} = \frac{\gamma(1-\beta)}{(1-\gamma)\beta} \equiv m_S$.

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

$$\begin{aligned} w_t &= P_{M,t}(1-\beta)B_t k_{M,t}^{\beta}, \\ r_t &= P_{M,t}\beta B_t k_{M,t}^{\beta-1}. \end{aligned} \tag{11}$$

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

$$\begin{aligned} p_{A,t} &= \frac{P_{A,t}}{P_{M,t}} = \frac{B_t\,(1-\beta)}{A_t\,(1-\alpha)\,m_A^{\alpha}} k_{M,t}^{\beta-\alpha}, \\ p_{S,t} &= \frac{P_{S,t}}{P_{M,t}} = \frac{B_t\,(1-\beta)}{G_t\,(1-\gamma)\,m_S^{\gamma}} k_{M,t}^{\beta-\gamma} \end{aligned} \tag{12}$$

Given the 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 1. *The market equilibrium labor allocation* $\{L_{A,t}, L_{M,t}, L_{S,t}\}$ *is determined by* $\{K_t, K_{S,t}, k_{M,t}\}$*, which are the aggregate capital stock, the capital input in service sector, and the capital labor ratio in domestic manufacturing respectively.*

Proof. see the Appendix B. □

Consumptions

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

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \rho \frac{P_t}{P_{t+1}}(r_{t+1}+1-\delta) \tag{13}$$

where P_t is the price index satisfying,

$$P_t C_t = \sum_{i=A,M,S} P_{i,t} C_{i,t}. \tag{14}$$

In general, of course, the non-homotheticity terms in the consumption functions can lead to corner solutions. However, this is not relevant for aggregate consumption in a rich country such as the postwar U.S.(Herrendorf, Rogerson, and Valentinyi, 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 (4) and (5) implies that, at time t,

$$\begin{aligned} \frac{C_{A,t}-\overline{c_A}}{C_{I,t}} &= \frac{w_A}{1-w_A}\cdot\frac{P_{I,t}}{P_{A,t}}, \\ \frac{C_{M,t}}{C_{S,t}} &= \frac{w_M}{1-w_M}\left(\frac{P_{S,t}}{P_{M,t}}\right)^{\theta}, \end{aligned} \tag{15}$$

where $P_{I,t} = \left(w_M P_{M,t}^{1-\theta} + (1-w_M) P_{S,t}^{1-\theta}\right)^{\frac{1}{1-\theta}}$.

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 $K_t = K_{t+1}$. It implies $I_t = \delta K_t$, $k_{M,t} = k_{M,t+1}$, and therefore, $P_t = P_{t+1}$. Then equation (13) 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 2. *Assuming interior solutions exist, given productivity sequence $\{A_t, B_t, G_t\}_{t \geqslant 0}$, if the discount factor ρ and the depreciation rate δ are held constant, the interest rates on a static growth path are constant*[10]*, denoted by r_{ss},*

$$r_{ss} = \frac{1}{\rho} + \delta - 1. \tag{16}$$

Proof. As shown above, if δ and ρ are time invariant, at anytime t, the steady state interest rate $r_{t+1} = \frac{1}{\rho} + \delta - 1 \equiv r_{ss}$ is constant. □

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

$$k_{M,ss,t} = \left(\frac{P_{M,t} B_t \beta}{r_{ss}}\right)^{\frac{1}{1-\beta}} \tag{17}$$

where a productivity growth on B_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[11]. Then, $k_{M,ss,t}$ is solely determined by B_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 A_t, B_t, G_t and $k_{M,ss,t}$, according to equation (12). Then, the relative prices will help to estimate the consumptions and solve the capital stock $K_{ss,t}$ and capital input of service sector $K_{S,ss,t}$. Therefore, when the technology path is given, the model is able to simulate the labor movements of the sectoral transformation on the static growth path.

One major drawback of this approach is that the analysis of steady states might underestimate the employment in manufacturing, since investment is restricted to replace the capital depreciation. The later calibration results show that even with this downward bias, the challenge to the model is still the rapid decline of manufacturing shares. Therefore, it won't change the conclusion.

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

[11] If $P_{M,t} = 1$, $p_{i,t} = \frac{P_{i,t}}{P_{M,t}} = P_{i,t}$, $i \in \{A, S\}$.

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 shares of total hours worked in the three sectors[12]. In order to consider the factors discussed in section 2, the model will consider the following three scenarios, which will be updated to include the trade balance effect later in section 5.

1. This is the *benchmark* case. The TFP growth rates are kept constant over the whole period in all there sectors, where manufacturing and service sector share the same growth rate as reported by the Bureau of Labor Statistics.
2. The second case, in addition, will consider different growth rates in the non-farm sectors.
3. In the third case, there are two more factors introduced to the model starting from early 1970s: the slowdown of the productivity growth in the non-farm sectors, and the capital income share increase in manufacturing.

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 capital income share in the production function, α, β, γ, the depreciation rate δ, the preference parameter ρ, θ, w_A, w_M, $\overline{c_A}$[13], and the time series of sectoral productivity A_t, B_t, and G_t, where the sectoral TFP growth rates are denoted by $\{\Delta A_t\}$, $\{\Delta B_t\}$ and $\{\Delta G_t\}$.

Multifactor Productivity Growth

The United States Department of Agriculture calculates the rate of total factor productivity growth in agriculture every year from 1948 to 2008, which provides the sequence of $\{A_t\}$. The average TFP growth rate is 1.7 percent during 1950 to 2005, confirmed by Alvarez-Cuadrado and Poschke (2011).

Case 1, the Bureau of Labor Statistics report 1.2 percent TFP growth rate from 1950 to 2005 in the non-agriculture business sector, which is the rate of sectoral TFP growth $\{\Delta B_t\}$ and $\{\Delta G_t\}$.

[12] The data series has been filtered to focus on low frequency time series. And the labor shares in term of number of workers employed will be discussed in section 6.2.

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

Case 2, the TFP growth rates in manufacturing and service have various estimates among different researchers. For example, based on the estimates of industry level TFP growth in Jorgenson, Gallop, and Fraumeni (1987), the TFP growth rate was about 0.77 percent in manufacturing, and 1.1 percent in service sector from 1950 to 1970. Those estimates wouldn't explain the aggregate productivity growth at 1.5 percent during 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 and the average growth rate of per capita real GDP in the data. The corresponding values are: 2.2 percent in manufacturing and 0.5 percent in service.

Case 3, the growth accounting literature has documented the slowdown of TFP growth in the early 1970s[14]. Therefore, I construct a break in the manufacturing TFP growth at 1970. The manufacturing productivity growth, $\{\Delta B_t\}$, is set to 2.2 percent before 1970 (as in Case 2), and down to 1.2 percent[15] after the break.

Factor Intensities

Case 1, and Case 2, the shares of capital and labor, and the growth rates of productivity are held constant in sectors at any moment in the sample period. As a measure of factor (labor) income shares, the OECD labor statistics provide the average unit labor cost[16] in manufacturing and service, which are 0.63 and 0.74 respectively. Therefore, the capital shares in the productivity function are chosen as $\beta = 0.37$, and $\gamma = 0.26$. Unfortunately, the ULC data is not available for agriculture. Valentinyi and Herrendorf (2008) estimates 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[17]. Therefore, α is set at 0.54.

Case 3, in addition to the above cases, the capital share in the manufacturing production function is allowed to vary over time which might explain the paradox between the TFP growth slowdown in the early 1970s and the steady real output growth over the whole sample period. The rising capital shares in manufacturing since 1970. Due to the data availability of the OECD Statistics, from 1950 to 1970, β is kept at 0.29, the level of 1970, and follows the the values from the ULC data[18] to 0.47 in 2005 .

[14] See Englander and Mittelstadt (1988), and Jorgenson and Gollop (1992).

[15] It is estimated by using EU KLEMS data since 1977.

[16] Since the data is only available from 1970 to 2005, I use the sub-period average for the whole study period. However, the main results of this paper are not sensitive to these parameters.

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

[18] It is adjusted through the Hodrick–Prescott filter with parameter 100.

Depreciation Rate

A number of the early papers, such as Mankiw, Romer, and Weil (1992), assumed a depreciation rate of 3 percent per year. Mankiw, Phelps, and Romer (1995) explain that this is approximately the figure obtained from US national accounts when the value of depreciation was divided by the value of the capital stock. However, the Department of Commerce has significantly revised its capital stock estimates since the mid-1990s, with its new estimates on updated empirical evidence on depreciation for various types of assets. Based on this revision, McQuinn and Whelan (2007) estimate the depreciation rate δ in the United States at 6 percent.

Preference

The labor employment share in agriculture converges to w_A in the long run. The workers in agriculture are only 1.6 percent of the labor force in 2005 and have been decreasing over time, w_A set to 0.01 could be acceptable. Although this target is somewhat arbitrary, our main results are not sensitive to this choice.

Acemoglu and Guerrieri (2008), Herrendorf, Rogerson, and Valentinyi (2009) and others find the elasticity of substitution θ should be less than unity. I follow Buera and Kaboski (2009) to set θ at 0.5. And as part of the robustness check, various values of θ will be evaluated in section 6.2. The discount factor, ρ, is set at 0.97, similar to Echevarria (1997).

The other parameters, $\overline{c_A}$ and w_M, would be selected to match the initial employment shares in 1950.

Initial Parameters

The initial efficiency parameters A_0, B_0 and G_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 that I use is summarized in table 1. The values of $\overline{c_A}$ and w_D are calculated to match the initial labor employment shares in 1950, the corresponding values are in table 2, which also summarizes other case specific parameters.

Tab. 1: Calibrated Parameters

A_0	B_0	G_0	$\{\Delta A_t\}$	α	γ	δ	ρ	θ	w_A
1	1	1	1.7%	0.54	0.26	0.06	0.97	0.5	0.01

Tab. 2: The Case Specific Parameter Values for Calibrations

Parameter	Case 1	Case 2	Case 3
$\{\Delta B_t\}$	1.2%	2.2%	2.2% until 1970, 1.2% after
$\{\Delta G_t\}$	1.2%	0.5%	
β	0.37		0.29 until 1970, as data after
$\overline{c_A}$	0.39		0.34
w_M	0.22		0.19

4.2 Structural Transformation of the U.S. Economy

This section provides some insights on how well the calibrated model fits the data. I use the calibrated model to compute the sectoral shares of employment of the US economy from 1950 to 2005, and compare them with the data series. Table 3 shows some statistics of both the data and the model.

Tab. 3: Statistics in the Data and the Model

Statistics, average 1950-2005	Data	Case 1	Case 2	Case 3
Per Capita GDP Growth Rate	2.15%	1.8%	2.12%	2.13%
Capital to Output Ratio	3.21	3.50	3.43	3.30
Investment to Output Ratio	20.2%	21.0%	20.6%	20.0%

In the benchmark (case 1) model, there are only modest structural changes predicted in the model (figure 4), which are mainly caused by the non-homothetic preference. The employment share in manufacturing remains almost constant during the period, from 33 percent to 31 percent, while the service employment share slightly increases from 58 percent to 66 percent, mainly due to the decline of labor share in agriculture from 9 percent to less than 3 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 share in agriculture that is close to the data. However, it is clear that the above structural transformation can not explain the trend in the non-farm sectors[19], which reported 20 percent employment share in manufacturing and 78 percent in service in 2005. One thing worth noting is that the real per capita GDP growth rate is lower than the data in the benchmark case. According to equation (17), the capital labor ratio in manufacturing is determined by the productivity B_t. The TFP growth in manufacturing 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.

[19] As discussed early, an additional non-homotheticity might improve the performance of this basic model, for example, the non-market/home produced service goods. However, it cannot explain the recent rapid decline of manufacturing employment, since its impact fades out over time.

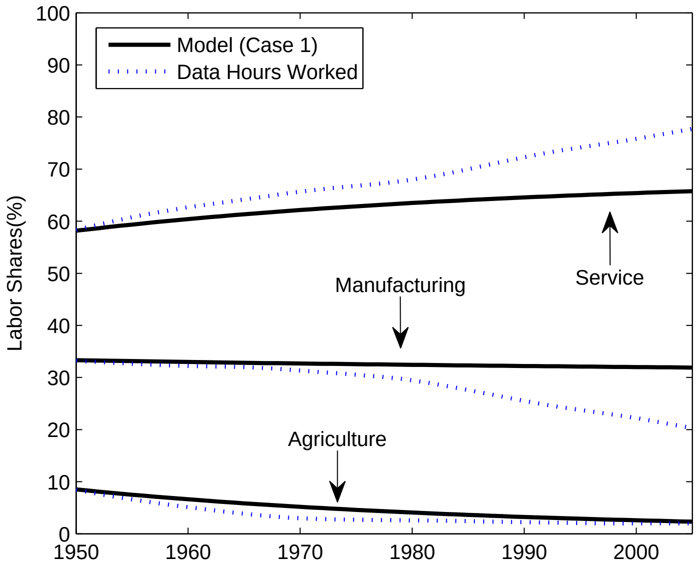

Fig. 4: Benchmark Model (Case 1) vs U.S. Data

According to Ngai and Pissarides (2007), workers will move out from sectors with high productivity growth rates to the low growth sectors. In addition to the benchmark case, the case 2 model intends to explore the scenario when the manufacturing has a relatively higher TFP growth rate. As illustrated in figure 5, 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 26.5 percent in 2005 (20 percent in the data), whereas the share of workers in services increases from about 58 percent to 72 percent (78 percent in the data). Of great interest is the fact that since 1980, the predictions of the model have deviated from the data, and are failed to match the further reduction of labor share in manufacturing and a corresponding increase in the service sector over the last three decades.

As discussed in section 2, there are two additional factors that might contribute to the structural transformation since early 1970s: the increase of capital income share, and the slowdown of TFP growth in manufacturing sector. First, these two factors have opposite impacts. A higher capital share β leads to a higher capital-labor ratio according to equation (17), which will increase the output in manufacturing and encourage workers to move into service sector. On the contrary, a lower productivity growth in manufacturing requests more people working in the sector. Thus, in order to explore these effects separately, in the case 3 model, I first allow β to vary as in the OECD ULC data, and then introduce the TFP slowdown.

The figure 6 compares the result of case 3 model with the U.S. labor share data, and also reports the result of case 2 model for reference. Without TFP slowdown, the increase of capital share in the production function leads to a faster decline in the manufacturing employment share. However, after considering the adjustment in the productivity growth, the over-

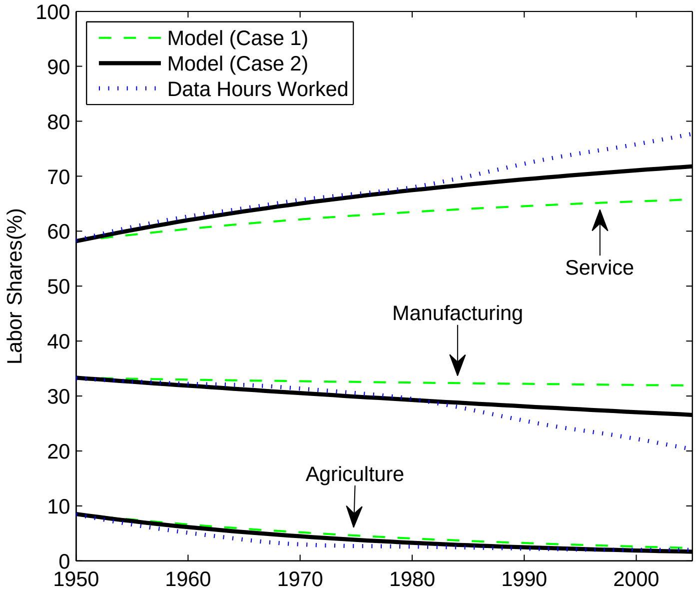

Fig. 5: Case 2 Model vs U.S. Data

all structural transformation calibrated in the case 3 model only provides minor improvement toward the data, increasing 1 percent to 73 percent for service, and in manufacture it decreases by the equivalent 1 percent to 25.5 percent, compared to the case 2 model.

Moreover, the case 3 model generates the following results: the real output growth is stable over the period, invariant to the shifts of productivity growth; the manufacturing output per worker grows relatively slowly during the rapid technology improvement period in 1950s and 1960s, and increases quickly since 1980 while the total factor productivity growth slowed down. This is consistent with the observation in the data. From 1950 to 1979, the output per worker in manufacture was increasing at 2.4 percent and the multifactor productivity in non-farm business grew at 1.46 percent. Since 1980, the annual progress of multifactor productivity has been around 0.75 percent, while the output per worker in manufacture sector was increasing at 3.8 percent every year, as reported by Brauer (2004) from the Congressional Budget Office.

Nevertheless, significant portions of employment share changes, roughly a five-percent decline in manufacturing and a simultaneous rise in services in the later data, are still lack of a convincing explanation. One possibility is that, this puzzle which is proposed in Buera and Kaboski (2009), is beyond any closed economy models. As the data shows, since late 1970s, the U.S. economy has experienced persistent trade deficits, which might contribute to the structural changes, since the majority of tradable goods is manufacture products. Therefore, to deal with globalization and trade imbalances, a further extension of the model should be presented.

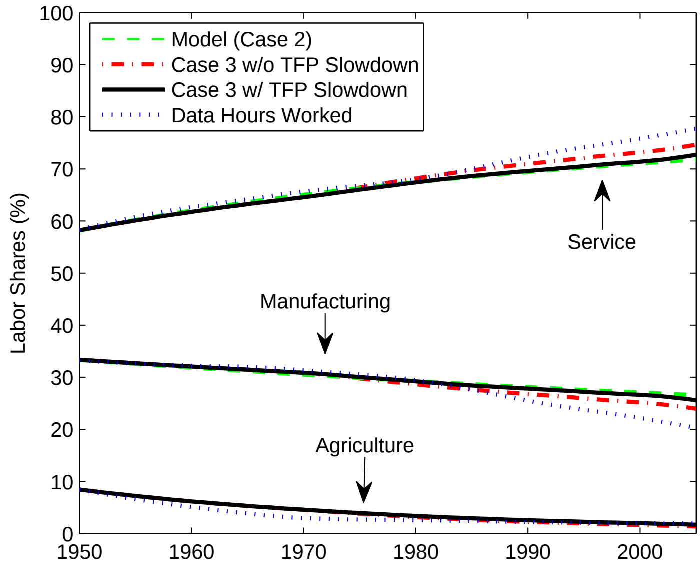

Fig. 6: Case 3 Model vs U.S. Data

5 An Extension for Open Economy

The chronic trade deficit is a persistent feature of the the U.S. economy since the late 1970s, which attracts extensive attentions in the literature. Early explanations focus on the exchange rate adjustment. Feldstein (1987) argues that the deterioration of trade balances is due to the rise of the U.S. dollar in the early 1980s. Krugman, Baldwin, Bosworth, and Hooper (1987) find significant lags on the effects of exchange rate adjustment, and relative faster demand growth in the United States than other countries, which can explain up to two thirds of the change of trade deficit. Recently, the trade deficit is part of the discussion on the U.S. current account imbalances. Dooley, Folkerts-Landau, and Garber (2004) argue that the current account deficit in the U.S. is necessary to generate collateral in the global financial markets and allow more efficient capital reallocation (in term of FDI) to the developing countries. Moreover, Caballero, Farhi, and Gourinchas (2008) and Cooper (2008) propose that the development of the U.S. financial markets, and financial globalization play a crucial role in sustaining the current account deficit. Other economists argue these foreign financed deficits should be unsustainable. For example, Feldstein (2008), and Wolf (2008) discuss the precautionary saving of Asian countries as a response to the Asian financial crises, which might not be sustainable due to the motivation of portfolio diversification in the future.

Discussion on the persistent deficits requires extended analysis that would make the paper unwieldy. An interesting question that is relevant to this paper is, whether the trade deficits will help to explain the employment share adjustments in the United States.

Since the early 1990s, economists have paid attention to the controversial relationship between the decline of manufacture sector and the soaring trade deficit in the United States. However, the precise role of international trade in these trends remains unclear. In the view of some leading trade economists, the effects of internationalization have been minimal (Lawrence, Slaughter, Hall, Davis, and Topel, 1993, Krugman, 1994, and Lindsey (2004)). These observers point to technological change rather than internationalization as the major force behind the labor market trends. On the contrary, Sachs and Shatz (1994) report that increased internationalization is having a substantial effect on U.S. labor markets, as firms are moving into relatively more capital intensive industries, which is supported by the rising capital income shares in the data. And recently, Bernard, Jensen, and Schott (2006) provide evidence that firms adjust their production in response to trade pressures, since plant survival and growth in the U.S. manufacturing are negatively associated with industry exposure to low-wage country imports. This branch of literature focuses on the industry level trade data to discuss the role of trade in the domestic labor market, such as inequality between skilled and unskilled workers. And these results have not been extended into the structural change literature.

On the other hand, economists who are working on theories of structural transformation have expressed few interest to evaluate the impact of international trade, except only a few exceptions. Echevarria (1995) and Yi and Zhang (2010) look at the interrelationship between trade and the process of structural change. However, the pattern of trade in their discussions is Ricardian type in which each country should specify to produce either primary goods or manufacturing goods, according to their comparative advantages in the world market. The application of this kind of analysis is quite limited to study the trade impact on countries at very early stage of development that are exporting primary goods to the rest of the world for manufacturing products. These models are not available to study the trade between countries that are mainly involved in the exchange of manufacturing products.

United States, has been absorbing the rising supply from the rest of the world and experiencing huge trade deficits since the early 1980s. Mann (2002) separates the U.S. trade imbalances into "end-use" categories, and finds that the trade balance for consumer goods and autos has been persistently and increasingly negative, whereas that for services, persistently positive[20]. The net export of services and net import of manufacturing products should contribute to the structural transformation. Therefore, a new framework of structural change should be introduced in the open economy context. In this section, I propose an intuitive modification to the previous theoretic model, which can effectively solve this problem.

5.1 A Trade Balance Augmented Model

For simplicity, I assume that only manufacturing products are considered as tradable goods. This assumption is different with early works from Echevar-

[20] The third category, according to Mann (2002), is the capital goods and non-energy industrial supplies which fluctuate with the business cycle. This cyclical component might have limited contribution to the structural changes in the long run.

ria (1995) and Yi and Zhang (2010), but is consistent with the major features of the U.S. trade with the rest of the world[21].

The trade deficit, therefore, reflects a replacement of manufacture production by foreign countries, which will be used domestically either for consumption or investment. Net import increases the quantity of manufacturing products available in the domestic economy, and is equivalent to an endowment increase in manufacture sector in the closed economy. Hence, the market clear condition in equation (9) for manufacturing should be updated to deal with the trade imbalances,

$$Y_{M,t} - TB_t = C_{M,t} + I_t. \tag{18}$$

where TB_t is the trade balance position at time t, $TB_t > 0$ if it is surplus. But it is not the nominal value of trade balance in the data, since the measurement is different between the model and real economy. One way to construct a comparable trade balance sequence is considering the trade balance/GDP ratio calculated from the data, given by,

$$\mu_t = \frac{tb_t}{gdp_t} \tag{19}$$

where tb_t and gdp_t are the trade balance and output in the data.

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

$$GDP_t = \sum_{i=A,M,S} P_{i,t} Y_{i,t} \tag{20}$$

which is a function of $\{K_t,\ K_{S,t},\ k_{M,t}\}$. Thus, exogenously given the trade balance/GDP ratio from the data[22], the trade balance in the model is determined by $TB_t = \mu_t \cdot GDP_t$. Then, using the new market clear condition in equation (18), the calibration will follow the same procedure as in the previous section.

5.2 Calibration of the Trade Balance Augmented Model

Corresponding to section (4), the last two cases (case 2 and 3) are updated to evaluate the effects of trade imbalances: case 4 is an augmented version of case 2, and case 5 is extended from case 3. The parameter values are the same as shown in table 1, except w_M is slightly adjusted

[21] Mann (2002) show that the major component of the persistent and increasing trade deficits come from the manufacturing sector, such as consumer goods and autos, while the trade balance for services are increasingly positive. Thus, if the trade deficit is considered as only from manufacturing, the model underestimated the impact of trade on structural change, since more services have been consumed abroad. For the agriculture sector, even though U.S. is one of the major exporters of agriculture products, its share in total trade is quite small.

[22] In the trade literature, the trade balance position will be endogenously determined by various factors of trade, such as the 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.

to 0.22 and 0.18 respectively to match the initial labor shares in 1950. The results are summarized in table 4, and illustrated in figure 7 and figure 8.

Tab. 4: Statistics in the Data and the Model with Trade Imbalances

Statistics, average 1950-2005	Data	Case 4	Case 5
Per Capita GDP Growth Rate	2.15%	2.08%	2.07%
Capital to Output Ratio	3.21	3.42	3.36
Investment to Output Ratio	20.2%	20.5%	20.2%
Saving to Output Ratio (1990-2005)	16.1%	16.5%	17.0%

The introduction of trade balance significantly improves the performance of the model. In both case 4 and case 5, the model predicted labor movements are close to the values in the data. The case 5 model is able to reach almost exactly the employment share in service (78 percent) and manufacturing (20.4 percent) in 2005 in term of hours worked from the data, while the case 4 model reports very similar trends, but predicts one percent less in the scale of shifts. In addition, these trade-balance-augmented models report lower domestic saving rates similar to the data from 1990 to 2005, as shown in the last row[23] of table 4.

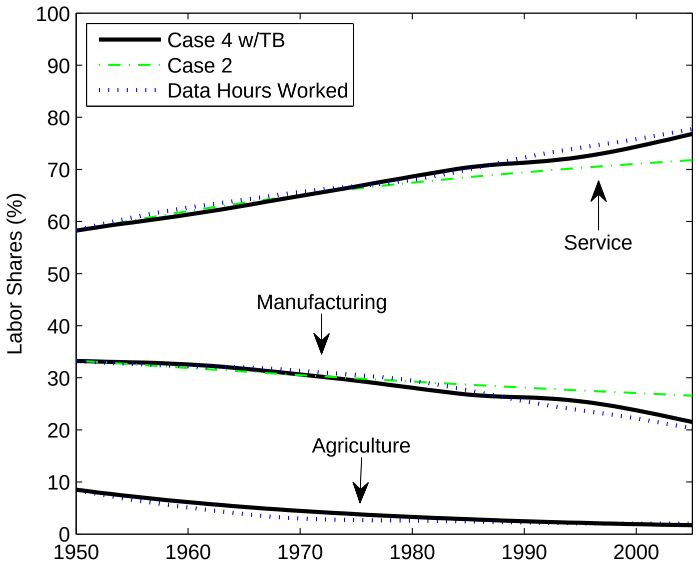

Fig. 7: Case 4 Model vs U.S. Data

[23] This is intuitive as the model assumes a portion of investment has been directly financed by foreign countries in term of import.

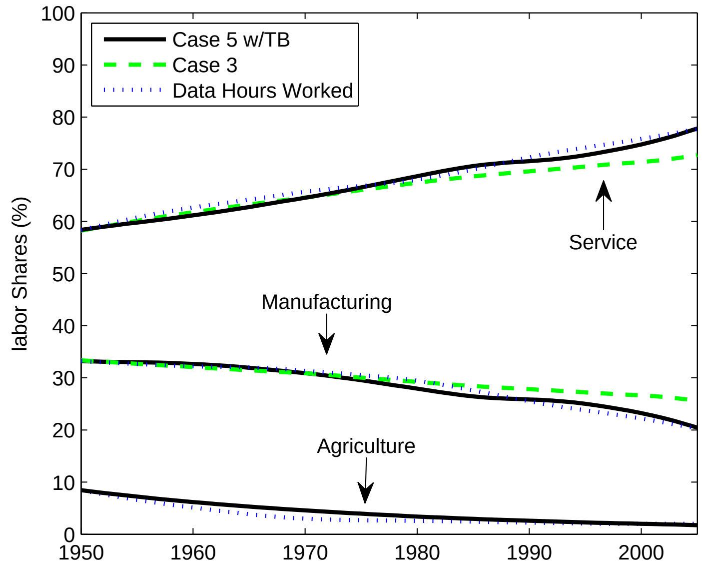

Fig. 8: Case 5 Model vs U.S. Data

The structural change model, therefore, is able to link a large portion of labor movements to the chronic trade deficits. It provides some support for the argument that trade imbalances have a substantial impact on the structural transformation.

6 Discussions

6.1 Decomposition of the Structural Transformation

The analysis in the previous sections have shown that a structural change model in the open economy context can explain the labor allocation across sectors, especially the recent rapid decline in the manufacturing employment. Base on the different constructions of the models, the post-war structural transformation in the United States can be separated into different sources in the literature, as summarized in table 5.

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

Model #	NetΔ	CumulativeΔ	Sources
Case 1	1.5 %	1.5 %	Differential capital shares, non-homothetic utility.
Case 2	5.5 %	7 %	Higher TFP growth in manufacturing.
Case 3	2.5 %	9.5 %	Higher capital intensity in manufacturing.
Case 3	-1.5 %	8 %	Slowdown of TFP growth in manufacturing.
Case 5	5 %	13 %	Trade imbalance effects.
Data		13 %	The decline of labor share from 1950 to 2005.

The most important factors that would contribute to the structural change are the higher productivity growth in manufacturing, and the trade deficits, accounting for 5.5 and 5 percentage points respectively. But due to the possible TFP growth slowdown in the early 1970s, the overall contribution of productivity growth difference would be 4 percentage points. Further, one implicit assumption of this counterfactual exercise, similar to Herrendorf, Rogerson, and Valentinyi (2009), is that the home country might use the same production function to produce the "imports", if it were a closed economy. According to Sachs and Shatz (1994), Bernard, Jensen, and Schott (2006), the higher income share of capital in manufacturing is actually one of the consequences of the international competition, as low-skill manufacturing industries (possibly more labor intensive) are exposed more to the competition[24]. Thus, the rise of labor intensity considered in case 3 model might originate from trade factors.

Therefore, the trade related factors can explain more than 38 percent of the labor share decline in the U.S. manufacturing sector, which actually is the most important factor that contributes to the structural transformation of the postwar U.S. economy. Unfortunately, it has been almost ignored in the structural change literature.

These results are in line with the findings of Sachs and Shatz (1994), Bernard, Jensen, and Schott (2006). However, due to the identification problem, the causality relationship during the whole process is unclear. As mentioned by Krugman and Lawrence (1994), the structural change process, even the 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 the some unknown shock. There are still plenty of issues need to be clarified to fully understand the structural change in the United States, especially the extraordinary decline in manufacture sector since 1980s.

6.2 Robustness

Alternative Measure of Labor Allocation

In section 2, figure 1 shows the evolution of labor employment shares in term 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 from manufacturing to service, comparing with 13 percent reported in term of working hours. The deviations between the two measures of labor distribution come from the decline of working time in the service sector. However, it is not obvious that which one is more appropriate as the target of the calibration.

[24] 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 discussion on elasticity of substitution and structural change process, by using CES type of production functions.

The Preference Parameter

The calibration exercises depend on the assumptions of household preference and the choices of parameter values. One core parameter worth revisiting is the elasticity of substitution between manufacturing and service goods, 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, Rogerson, and Valentinyi (2009) find a Leontief utility (θ= 0) fits the value added sectoral consumption data for U.S. households[25]. Therefore, robustness checks on the values of θ, especially a preference closed to the Leontief specification, would be crucial for the calibration.

Tab. 6: Robustness Analysis of the Structural Change Model

	Labor Share Change in Data		Case 5 Model		
	Employment	Hours worked	$\theta = 0.5$	$\theta = 0.25$	$\theta = 0.01$
Agriculture	-7 %	-6.9 %	-6.7 %	-6.7 %	-6.7 %
Manufacturing	-16 %	-13 %	-13 %	-14.8 %	-16.5 %
Service	23 %	19.9 %	19.7 %	21.5 %	23.2 %

Table 6 summarizes the model (Case 5) predictions with different values of θ, 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 service sector will be 19.7 percent for $\theta = 0.5$, 21.5 percent for $\theta = 0.25$, and reach 23.2 percent if $\theta = 0.01$, which is close to the Leontief preference. The aggregate difference between various parameter values is less than 4 percent which is less than a quarter of the total structural change. Moreover, the labor allocation from number of workers reports a larger decline (increase) in manufacturing (service) sector, the quantitative magnitude is still less than the predictions from the model with Leontief specification.

In conclusion, the model presented in this paper can explain a large portion of the labor reallocation in the postwar U.S. economy. And it is not sensitive to the measure of employment and the elasticity of substitution parameter θ.

6.3 Economic Growth

Comparing the results in table 3 and 4, an interesting finding is that the growth rates are lower in the trade balance augmented models with trade deficits. Using the same parameter values summarized in table 1 and 2, the real output growth rates are 2.08 percent in case 4 model versus 2.12 percent in its closed economy version case 2 model, and 2.07 percent in

[25] Buera and Kaboski (2009) also report that Leontief preference will provide better fit in their model.

case 5 model versus 2.13 percent in case 3 model. Therefore, the labor movements explained by the trade imbalances might lead to a lower output growth rate, which is one of the disadvantages of having persistent trade deficits.

To fully estimate the impact of trade imbalances on the output growth, I compare the output growth rates of a closed economy model, case 2, with a special version of case 4 model in which the trade deficits are set at 5 percent of total output. Therefore, due to 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)[26].

7 Concluding Remarks

This paper uses a three-sector model to replicate the structural transformation of the United States from 1950 to 2005, which features a steep decline in the manufacturing employment shares. According to Buera and Kaboski (2009), those intensive changes can not be explained by the traditional theories of structural change. However, after introducing the trade balance effects, the model presents a plausible explanation for the historical trends. Therefore, the first contribution of this paper is to show that the limitation of the traditional theories on the U.S. data is mainly due to the assumption of close economy. In the era of globalization, traditional structural models should be updated to accommodate the trade factors.

The second contribution of this paper is to present an intuitive modification to the three-sector closed economy model, which is a very first attempt in the structural change literature to consider the intra-industry trade of manufacturing products. The international trade provides a channel through which sectoral expenditure can deviate from the sectoral output, or vice versa. Therefore, if a share of output is net imported into the economy (in term of trade deficit), the domestic labor market would response passively to accommodate this trade shock. The optimal labor allocation is equivalent to the counterfactual scenario in the closed economy model when manufacturing endowment has increased. The prediction of this exercise is intuitive that fewer labor will be employed in manufacturing sector, since the production has been replaced by foreign countries. The quantitative result of this trade-balance-augmented model fits the labor employment movements in the data, and is robust to different preference parameter values and alternative labor share measure.

These findings are consistent with Sachs and Shatz (1994) and Bernard, Jensen, and Schott (2006) that the international trade have significant im-

[26] The model also reports the output growth, at 2.21 percent, in the same economy with trade surplus (5 percent of GDP).

pact on the tradable good production sectors, firms either move to more capital intensive industries, or close their plant sooner due to the competition. The labor market will response accordingly that labor moves out of the tradable sector, manufacturing, to non-tradable sector, such as service.

Third, the model predicts slightly lower growth rate when the country has trade deficit. This is possible one kind of those expenses when a country spends beyond its means.

Appendix

A Data Sources

The calibration of the model to the US economy requires data for GDP per capita, sectoral shares of hours worked, investment to output and capital to output. The data for GDP per capita, comes from the benchmark studies of the Penn World Table (version 6.3).

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[27] where the economy is disaggregated into 10 sectors. I aggregate those sectors into the 3 sectors used throughout this paper. Manufacturing includes mining, manufacturing, utilities and construction. The value-added of each sector is given in both constant and current prices. For the United States, both the labor shares in term of number of workers and in term of hours worked are available for the whole sample period.

I obtain investment, nominal GDP series from the NIPA tables, and use the H-P filter to focus on low frequency trends. The unit labor cost data is available from 1970 to 2008 from the OECD statistics. The data on trade balance comes from Lees (1965) for 1950 to 1955, Branson (1971) for 1956 to 1969, and IMF International Financial Statistics from 1970 to 2005. The productivity growth rates in agriculture come from the United States Department of Agriculture (USDA)[28]. And the detailed import/export information comes from the U.S. Census Bureau [29].

B Proofs

Proof. for Proposition 1,

According to equation (7) and (10), 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,

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

[28] http://www.ers.usda.gov/ Data/AgProductivity/

[29] Data is available at http://www.census.gov/

$$m_A k_{M,t} L_{A,t} + k_{M,t}(L - L_{A,t} - \frac{K_{S,t}}{m_S k_{M,t}}) = K_t - K_{S,t}$$

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

$$\begin{aligned} L_{A,t} &= \frac{K_{S,t} - K_t + k_{M,t}\left(L - \frac{K_{S,t}}{m_S k_{M,t}}\right)}{k_{M,t}(1-m_A)} \\ L_{M,t} &= L - L_{A,t} - L_{S,t} \\ L_{S,t} &= \frac{K_{S,t}}{m_S k_{M,t}} \end{aligned} \tag{21}$$

which depend on a three-variable set, $\{K_t, K_{S,t}, k_{M,t}\}$, the aggregate capital stock, the capital stock in service sector, and the capital Labor share in domestic manufacture respectively. □

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