The Decline of the U.S. Manufacturing: An Explanation from Structural Change

Zongye Huang

McGill University

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Department of Economics, McGill University

Email : Zongye.Huang@mcgill.ca

This is a preliminary draft.

Abstract

In this paper, I develop a three-sector model that is able to fully explain the postwar structural transformation process experienced by the United States from 1950 to 2005. The model have multiple consumption goods which are produced using different factor intensities. The closed economy version of the model estimates the trends from 1950 to 1980 very well, but is not able to traces the labor movements since 1980s. An intuitive idea that would improves the performance of the model is to connect the soaring trade deficits with the decline of manufacture sector since then. The modification to the model is simple: keeping the trade balance/GDP ratio as in the data, I evaluate the model to estimate the labor allocations. The results of this trade balance augmented model replicate the structural change over the whole sample period at great accuracy. This result might support the argument that trade imbalances have a substantial effect on the labor markets.

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Keyword: Structural Change, Trade Balance, Labor Allocation

1 Introduction

The economics literature has documented the structural transformation during the industrialization process, which is a massive reallocation of labor from agriculture into manufacture and service sectors. This is one of the most prominent features of development, and is closely related to the level of economic growth.

The early empirical works show that the agriculture shares of output and employment decline, while the manufacture and service shares of output and employment rise, as a country develops. In light of this pattern, most models of structural change developed at that time were two sector models. In more recent years, Maddison (1991), Buera and Kaboski (2008), Rogerson (2008) have shown clearly that there are three distinct sectoral allocation patterns: agriculture declines, services rises, and manufacturing follows a hump pattern, first rising, then falling. Therefore three-sector models have become more prevalent, including Echevarria (1997), Kongsamut, Rebelo, and Xie (2001), Ngai and Pissarides (2007), Bah (2009), and Duarte and Restuccia (2010), despite these models are all set in a closed economy.

Some recent works, such as Echevarria (1995) and Yi and Zhang (2010), introduce international trade into the three-sector framework, but only consider a cross sector trade in which one country has to specify to produce either agriculture goods or manufacturing goods. This type of analysis is quite helpful to study the structural transformation at very early stage of development or look at some Least Developed Countries (LDC) who are mainly exporting primary goods to and importing manufacturing goods from the rest of the world. But, they are not eligible to study the trade effects of emerging markets who are intensively trading in the manufacturing products.

The primary target of this paper is to develop a three-sector model that is able to fully explain the postwar structural transformation process in the United States.

Starting with a closed economy model, there are three consumption goods: agriculture, domestic manufactures, and services, which are produced using two inputs, labor and capital, with different factor intensities. Manufacturing products can be used as an investment good as well. Then, I calibrate the model respect to parameters that are consistent with U.S. historical data. The model can closely reproduce the labor movements from 1950 to early 1980s, but can not completely replicate the sectoral transformation since 1980. This result is quite robust, after controlling the capital income share adjustments and introducing a productivity slowdown in 1970.

Another significant change in U.S. economy during the same period is the soaring trade deficits which eventually reaches 6% in 2005. In order to evaluate the potential impact from the trade balance to the labor employment, I assume only manufacture product is tradable. The trade balance/GDP ratio is fixed as in the data. Then I evaluate the model to solve for the optimal labor allocation given this portion of manufacture good is net exported. The prediction of this trade balance augmented model matches the data with surprising accuracy. This result supports the argument that international competition and trade have impacts in the labor market(Sachs and Shatz, 1994).

The rest of the paper is organized as follows. In the next section, I document some facts about the process of structural transformation in the United States from 1950 to 2005. Section 3 constructs a three-sector closed economy model and characterizes the competitive equilibrium. In section 4, I evaluate the performance of the model by calibrating the U.S. transformation process during the sample period, and I find the limitations for the closed economy model. Then, Section 5 introduces modification in order to take into account the impacts from the trade balances. And section 6 concludes.

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

This section documents the process of structural transformation and labor productivity growth in agriculture, manufacture, and service for the United States from 1950 to 2005. The sources and detail 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: the employment rate is steadily decreasing in the goods sector, including agriculture and manufacture, 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.

One feature to note is that the deviation between the two time-series since 1960s. The share of employment in service is higher than the share calculated by the hours worked, which implies that workers in the tertiary sector work less hours than manufacture workers. The average working hours since 1950 are illustrated in figure 2.

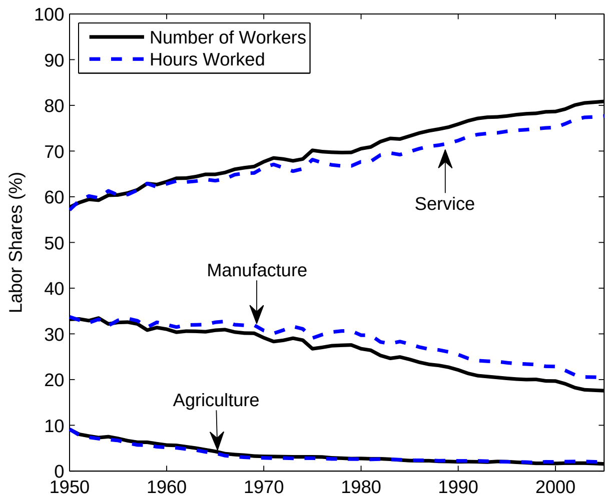

Figure 1: U.S. Sectoral Employment Shares 1950-2005

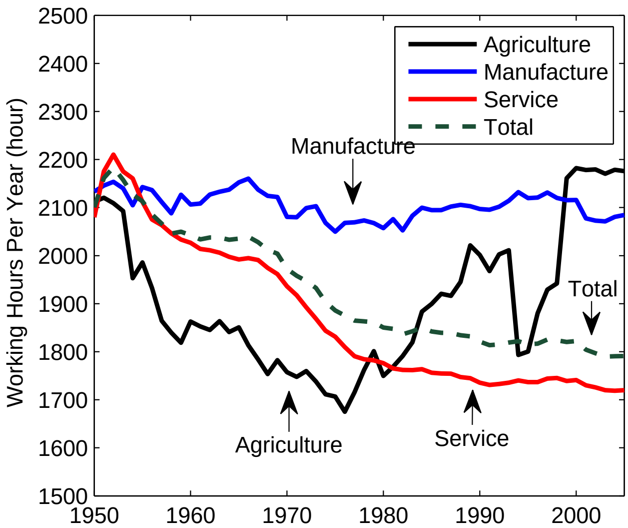

Figure 2: Average Working Hours in U.S.

The rapid decline of the manufacturing labor share since early 1980s is another feature worth noticing. As Ngai and Pissarides (2007), Duarte and Restuccia (2010) and other economists propose, if the elasticity of substitution across final goods is less than one, labor allocation will shift from high productivity growth sector to the low TFP growth. Therefore the structural transformation above might come from a faster growth in manufacture productivity.

From 1979 to 2002, the per worker output growth rate in manufacture is 3.3% which is higher than the 2% average output per unit of labor growth in non-farm business sector, as reported by Brauer (2004) from the Congressional Budget Office. In contrast, Englander and Mittelstadt (1988) show a slowdown on total productivity growth from late 1960s to mid-1980s. In addition, the real output growth in the United States is quite stable over the whole sample period, around 2.2% every year, no matter the slowdown of TFP. These observations generate a puzzle: how to connect the break of total factor productivity growth with the higher growth rate of per worker output in manufacture. One potential explanation comes from the falling labor income share in manufacture or more broadly the industrial production sector. According to the OECD Unit Labor Cost (ULC) statistics, the industry labor compensation to output share felt from 0.71 in 1950 to 0.53 in 2005, as shown in figure 3, the labor income share is trended using the Hodrick–Prescott filter with a smoothing parameter 100. Therefore, the output per worker can grow at a higher rate, due to the capital intensity deepening, even the TFP growth slows down. Models with only labor as factor of production might not be able to take into account of the changes of labor (capital) income share, such as Duarte and Restuccia (2010), Yi and Zhang (2010).

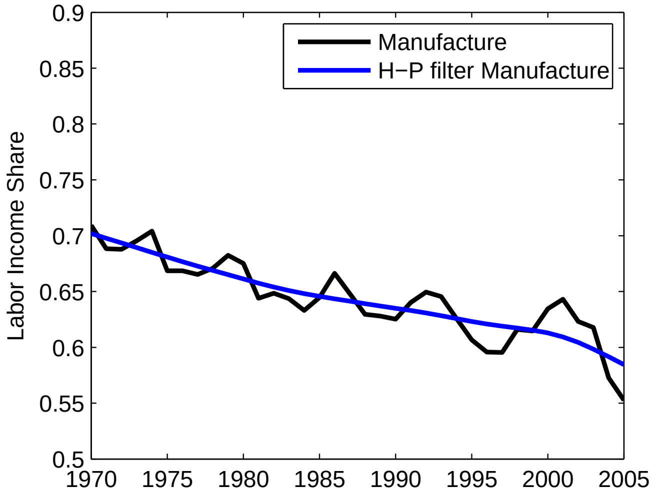

Figure 3: The Labor Income Share in Manufacture Sector

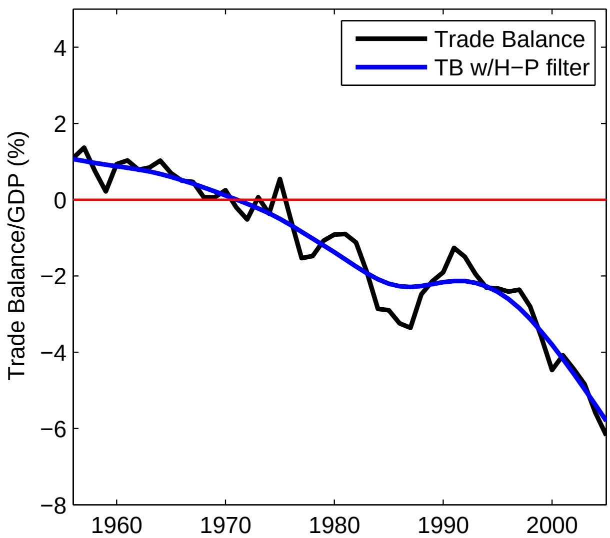

Figure 4: Trade Balance/GDP Ratio

According to the U.S. trade balance data (figure 4), the trade deficit increases rapidly since 1980s, reaches 6 percent of GDP in 2005. Therefore, researchers attempt to link this soaring U.S. trade deficit to the contemporary decline of the manufacturing industry. Sachs and Shatz (1994) find that internationalization has indeed contributed to this trend, "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 identify that the U.S. trade with high-wage countries is intra-industry, and is interindustry with low-income countries. And the international competition drive out the position of low skill workers and promote industries with higher skill requirement. This result can somehow explain the lower of the labor income share in manufacturing sector. However, Krugman and Lawrence (1994) argue that "competition from abroad has played a minor role in the contraction of U.S. manufacturing".

In the next section, in order to evaluate the factors presented above, I should first setup a formal model of structural transformation.

3 The Model of Structural Change

This section develops a three-sector model of structural transformation which is intend to replicate the labor relocation process during growth. Following Rogerson (2008) and Duarte and Restuccia (2010), the model has two features to achieve this outcome: non-homothetic preferences and technological growth differential across sectors. If income elasticities are not all unitary, then resources are reallocated to more preferred sectors as the income increases. Examples emphasizing this feature include Echevarria (1997), Laitner (2000), Kongsamut, Rebelo, and Xie (2001), Gollin, Parente, and Rogerson (2007), and Bah (2009). Technological growth differential and non-unitary elasticities of substitution across goods lead to resource reallocation. For example, Ngai and Pissarides (2007) show that a low (below one) elasticity of substitution across final goods leads to shifts of employment shares to sectors with low TFP growth.

To simplify the analysis, I first assume closed economies. And later, in section 5, I extend the model to capture the trade effect.

3.1 Economic Environment

Firms

The model includes three sectors: agriculture (A), domestic manufactures (D), and services (S). All three goods are consumption goods, although 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:

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

where for sector i ($i \in\{A,\ D,\ S\}$), $Y_{i,t}$ 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 in each period, starting at 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.

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. 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 overtime, and C_t is a composite consumption with two components, the consumption of agriculture good (A) and industry product (I),

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

where $\overline{c_A} > 0$ is a subsistence level of agricultural consumption which is crucial for the household to survive, and $w_A \in (0,1)$.

The composite consumption of industry product $C_{I,t}$ includes the consumption from manufacture and service,

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

where $\theta \in (0,1)$ is the elasticity of substitution between the two goods, $w_M \in (0,1)$. When $0 < \theta < 1$, manufacturing goods and services are complements.

The budget constraint of the household at time t is

$$\sum_{i=A,D,S} p_{i,t} C_{i,t} + S_t = w_t L + r_t K_t \tag{6}$$

where S_t is saving, K_t is the capital stock.

Market clearing

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

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

The financial market of this closed economy requires $S_t = I_t$ in every period, where I_t is the domestic investment. Depreciation rate denotes as 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:

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

3.2 Economic Equilibrium

A *competitive equilibrium* is a sequence of prices $\{p_{A,t},\ p_{D,t},\ p_{S,t}\}$, consumption $\{C_t(C_{A,t},\ C_{D,t},\ C_{S,t})\}$ of the household, labor employments $\{L,\ L_{A,t},\ L_{D,t},\ L_{S,t}\}$ and capital allocations $\{K_t,\ K_{A,t},\ K_{D,t},\ K_{S,t}\}$ of firms, 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 (3); and (iii) the prices $\{P_{A,t},\ P_{D,t},\ P_{S,t}\}$ make markets clear: equation (7), (8) and (9) hold.

In addition, following Kongsamut, Rebelo, and Xie (2001), I introduce the generalized balanced growth path.

Definition. A *generalized balanced growth path* is a trajectory along which the real interest rate is constant.

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The first-order condition from the firm's problem implies that the marginal productivity of labor must be equal to the wage rate while the marginal productivity of capital equals the interest rate. And since both labor and capital are perfectly mobile, the wage rates and interest rates must be the same across sectors at any time. And the capital labor ratio in sector i, is defined as $k_{i,t} = \frac{K_{i,t}}{L_{i,t}}$ and satisfies the following equation,

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

where $m_A = \frac{\alpha(1-\beta)}{\beta(1-\alpha)}$, $m_S = \frac{\gamma(1-\beta)}{\beta(1-\gamma)}$[1]. Therefore, the relative prices $p_{A,t}$ and $p_{S,t}$ [2] are determined by the relative productivities and capital income share parameters such as:

$$\begin{aligned} p_{A,t} &= \frac{P_{A,t}}{P_{D,t}} = \frac{B_t(1-\beta)}{A_t(1-\alpha)m_A^{\alpha}} k_{D,t}^{\beta-\alpha}, \\ p_{S,t} &= \frac{P_{S,t}}{P_{D,t}} = \frac{B_t(1-\beta)}{G_t(1-\gamma)m_S^{\gamma}} k_{D,t}^{\beta-\gamma} \end{aligned} \tag{11}$$

And the wage rate and interest rate at time t are:

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

Proposition 1. *The market equilibrium labor allocation $\{L_{A,t},\ L_{D,t},\ L_{S,t}\}$ is determined by $\{K_t,\ K_{S,t},\ k_{D,t}\}$, which are the aggregate capital stock, the capital stock in service sector, and the capital labor share in domestic manufacture respectively.*

Proof. see the Appendix B. □

The first-order conditions for consumption implies the Euler equation:

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \rho \frac{P_t}{P_{t+1}}(r_{t+1} + 1 - \delta) \tag{12}$$

where P_t is the price index satisfying

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

The composition of C_t in equation (4) and (5) imply that,

$$\frac{C_{A,t} - \overline{c_A}}{C_{I,t}} = \frac{w_A}{1-w_A}\frac{P_{A,t}}{P_{I,t}},$$

$$C_{D,t} = \frac{w_D}{1-w_D} C_{S,t} P_{S,t}^{\theta},$$

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

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

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

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

Therefore,

$$\frac{P_{A,t} A_t \alpha}{P_{D,t} B_t \beta} = \frac{k_{D,t}^{\beta-1}}{k_{A,t}^{\alpha-1}}, \qquad \frac{P_{A,t} A_t (1-\alpha)}{P_{D,t} B_t (1-\beta)} = \frac{k_{D,t}^{\beta}}{k_{A,t}^{\alpha}}$$

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

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

Proposition 2. *If the discount factor ρ and the depreciation rate δ are kept constant, an exogenous productivity sequence $\{A_t,\ B_t,\ G_t\}$ determines a sequence of long run competitive equilibrium that satisfies the definition of generalized balanced growth path.*

Proof. At period t, given productivities $\{A_t,\ B_t,\ G_t\}$, a long run equilibrium requests the consumption path and price level to be stable. It implies that $C_t = C_{t+1}$ and $P_t = P_{t+1}$ in equation (12) which indicates that

$$k_{D,ss,t} = \left(\frac{P_{D,t} B_t \beta}{r_{ss}}\right)^{\frac{1}{1-\beta}} \tag{13}$$

where r_{ss} is the real return to capital. Since the deprecation rate δ and the discount factor ρ are constant over time, from equation (12), the interest rate satisfies,

$$r_{ss} = \frac{1}{\rho} + \delta - 1. \tag{14}$$

which is constant. Therefore, it is a generalized balanced growth path. □

Without lost of generality, I normalize $P_{D,t}$ to 1 in equation (13). Then, $k_{D,ss}$ 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 productivities A_t, B_t, G_t and $k_{D,ss,t}$, according to equation (11). Then the relative prices will help to estimate relative consumptions and solve the capital stock $K_{ss,t}$ and capital in service sector $K_{S,ss,t}$. Therefore, when the technology path is given, on the generalized balance growth path, the model is able to simulate the labor relocation in the sectoral transformation.

4 Calibration

In this section, I will calibrate the model to match the postwar labor relocation and real economic growth in the United States, from 1950 to 2005. Because of the discussion in section 2, there are two scenarios: 1) a benchmark model with constant growth in sectoral TFP; 2) a model with adjusted capital income share, β, and a slowdown in TFP in manufacture since since 1970.

In section 5, I will update the two scenarios to include the trade balance effect on structural change.

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_D, $\overline{c_A}$[3], and the time series of sectoral productivities A_t, B_t, and G_t.

Factor Intensities

Case 1, the shares of capital and labor are hold at any moment in the three sectors. To calibrate factor intensities and rates of technological change for the three sectors, I look into the OECD labor statistics, and use the average unit labor cost[4] (ULC) in manufacture and service sectors as estimates on labor income share, where are 0.63 for manufacture and 0.74 for service sector. Therefore, the capital shares in the productivity function are estimated as $\beta = 0.37$, and $\gamma = 0.26$. Unfortunately, the

[3]The intertemporal substitution rateσ is not relevant for the calibration on a generalized growth path.

[4]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.

ULC data is not available for agriculture. Valentinyi and Herrendorf (2008) estimates the capital income share is 0.54, while the empirical findings of Echevarria (1997) show that the capital share in agriculture is about 0.79 during 1976-1988. I choose $\alpha = 0.7$ in the calibration.

Case 2, In addition to the benchmark case, I allow the capital income share in manufacture to vary to match the trend in the data, increasing steadily from 0.29 in 1970 to 0.47 in 2005. During 1950 to 1970, I set the capital share at 0.29, the level of 1970 as my best guess.

Multifactor Productivity Growth

Case 1, 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% during 1950 to 2005, as the same as Alvarez-Cuadrado and Poschke (2011).

The TFP growth rate in the rest two sectors have various estimates among different researchers. Therefore, I will calibrate them jointly in order to match the average growth rate of per capita real GDP in the data. The corresponding values are: 2.4% in manufacture and 0.5% in service.

Case 2, The real output growth in the U.S. is surprisingly stable during the sample period, while the TFP experiences slowdown and the capital share in the manufacture increases since 1970. I construct a break in the model at 1970. Then, the total productivity in manufacture grows at 2.4% before 1970, and slows down to 1.4% after, while the the capital share in the production function raises as shown in the OECD ULC data series which is adjusted through the Hodrick–Prescott filter.

Depreciation Rate

A number of the early papers, such as Mankiw, Romer, and Weil (1992), assumed a depreciation rate of 3% per year. Mankiw (1995) explains 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%.

Preference

The labor employment share in agriculture converges to w_A in the long run. The workers in agriculture are only 1.6% 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. The subsistence level of agricultural consumption, $\overline{c_A}$, and w_D would be selected to match the initial employment shares in 1950.

Manufacture and serves goods are considered as compliments. Then, the elasticity of substitution θ should be less than 1. In order to match the labor transformation over the time, it is set at 0.7.

From 1950 to 2005, the average gross investment rate is 20.1%, according to the Bureau of Economic Analysis national account database. The discount factor, ρ, is selected to match the investment rate, set at 0.96.

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. Since $\overline{c_A}$ and w_D are calculated to match the initial labor employment share in 1950, the corresponding values are in table 2.

Table 1: Calibrated Parameters

A_0	B_0	G_0	$\{A_t\}$	$\{G_t\}$	α	γ	δ	ρ	θ	w_A
1	1	1	0.017	0.005	0.7	0.26	0.06	0.96	0.7	0.01

Table 2: The Case Specific Parameter Values for Calibrations

Parameter	Description	Case 1	Case 2
$\{B_t\}$	TFP growth in manufacture	2.4%	2.4% before 1970, 1.4% after
β	Capital share in manufacture	0.37	0.31 before 1970, as data after
$\overline{c_A}$	Subsistence agricultural consumption	0.95	0.83
w_D	Preference on manufacture goods	0.19	0.16

4.2 Structural Transformation of the US 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.

Table 3: Statistics in the Data and the Model

Statistics, average 1950-2005	Data	Case 1	Case 2
Per Capita GDP Growth Rate	2.15%	2.2%	2.2%
Investment to Output Ratio	20.2%	20.2%	20.1%
Capital to Output Ratio	3.21	3.30	3.29

Figure 5 shows the structural transformation predicted by the benchmark model. The model implies a fall in the share of employment in manufacturing from about 33% in 1950 to 26% in 2005 (20% in the data), whereas the share of workers in services increases from about 53% to 73% (78% in the data) during this period. Notice that even though the calibration only targets the initial employment share in agriculture which is 9% in 1950, the model implies a time path of the equilibrium labor share in agriculture that is remarkably close to the data, declining to about 1% (1.5% in the data) in 2005.

The benchmark model (Case 1) does a good job on replicating the sectoral labor shares in the data. In particular, the model traces very well the relocation of labor among the three sectors until the early 1980s. Of greater interest is the fact that the prediction of the model deviates from the data since then, and couldn't explain the rapid decline in the manufacture and sharp increase in the service sector during the last three decades.

As discussed in section 2, one potential response lies in the intensive change of the capital income share in manufacture sector, which is considered in the Case 2 model, but excluded in the benchmark case. The figure 6 compares the result of

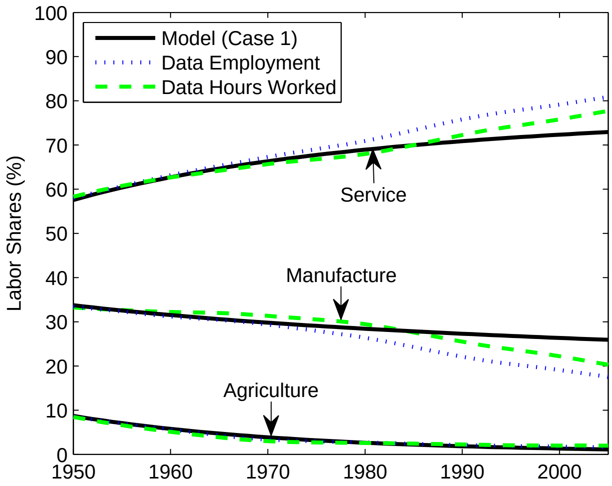

Figure 5: Benchmark Model (Case 1) vs U.S. Data

case 2 model with the U.S. labor share data, and also with the benchmark model. After adjustment, the case 2 model improves the model predictions to the data: the predicted labor share in service increases two percent to 75%, and in manufacture it decreases by the equivalent two percent to 24%.

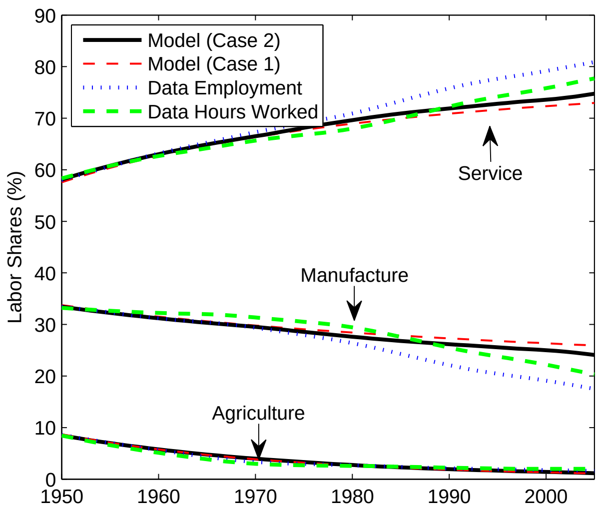

Figure 6: Case 2 Model vs U.S. Data

Moreover, the case 2 model generates the following result: the manufacture 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 slows down. This is consistent with the observation in the data. From 1950 to 1979, the output per worker in manufacture increases at 2.4% and the multifactor productivity in non-farm business grows at 1.46%. Since 1980, the annual progress of multifactor productivity is about 0.75%, while the output per worker in manufacture sector increases at 3.8% every year.

Although the case 2 model performances better than the benchmark model, the drop in manufacturing share of hours worked starting in the mid-1980s, is still lack of a convincing explanation. One possibility is that this phenomenon is beyond the region of a closed economy model. Therefore, a further extension of the model to deal with globalization and trade should be presented. This is the mission for the next section.

5 An Extension for Open Economy

In the 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, and Krugman, 1994). These observers point to technological change rather than internationalization as the major force behind the labor market trends. Other economists, such as Sachs and Shatz (1994), report that increased internationalization is having a substantial effect on U.S. labor markets. This branch of literature focuses in the industry level trade data to discuss the role of trade in the domestic labor market, such as inequality between skilled and unskilled workers. However, it seems that they are not willing to extend the debate into the literature about the long run structural change.

One the other hand, economists who are working on theories of structural transformation express few interest to evaluate the impact of international trade, with 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, due to their comparative advantages in production. The application of this kind of analysis is quite limited to study the trade of countries at very early stage of development or those Least Developed Countries (LDC) who are mainly exporting primary goods to and importing manufacture goods from the rest of the world. These models are hardly eligible to study the trade of emerging markets, since they are intensively trading in the manufacturing sectors. Therefore, the impacts of those emerging markets in the world economy attract most attention and request new models.

United States, of course, is not an emerging market, but is a key player in the international trade, which is absorbing the rising supply from the rest of the world and experiencing huge trade deficits since the early 1980s. Any model that attempts to capture the trade effects on industrialization and growth of those emerging markets should also be ready to deal with the U.S. economy, which is the other side of the game. The three-sector closed economy model in the previous section that replicates the structural change before 1980s, should be rearmed to accommodate the trade imbalances in the data. Surprisingly, the modification required is simple but very effective.

A Trade Balance Augmented Model

First, I should make some assumptions on the pattern of trade that the model is trying to capture. Different with early works from Echevarria (1995) and Yi and Zhang (2010), there is only one sector that is tradable, the manufacturing industry[5]. Therefore, the trade deficit reflects a replacement of manufacture production by foreign countries, used either for consumption or investment.

A benefit of working with a complicated model is that we can always ask counterfactual questions to see what will happen. Since trade deficit is a net increase in the quantity of manufacture product available in the domestic economy, the trade

[5]Although U.S. is one of the major exporters of agriculture products, its share in total trade is less than 5%.

impacts on structural change and labor allocation can be treated as to an endowment increase in manufacture sector in the closed economy. Hence, only the market clear condition in equation (9) for manufacture sector should be updated as the following,

$$Y_{D,t} + TB_t = C_{D,t} + I_t. \tag{15}$$

where TB_t is the trade balance at time t, and $TB_t = \mu_t GDP_t$, μ_t is the trade balance/GDP ratio calculated from the data.

The gross domestic output,

$$GDP_t = \sum_{i=A,D,S} P_{i,t} Y_{i,t}$$

is a function of $\{K_t,\ K_{S,t},\ k_{D,t}\}$. Therefore, the computation is very similar to the previous cases.

Corresponding to section (4), there are also two cases: case 3 is calibrated based on the benchmark case 1, and case 4 is extended from case 2, which includes the adjustments in the capital share. The parameter values are the same as shown in table 1. The results are summarized in table 4, and illustrated in figure 7 and figure 8.

Table 4: Statistics in the Data and the Model with Trade Imbalances

Statistics, average 1950-2005	Data	Case 3	Case 4
Per Capita GDP Growth Rate	2.15%	2.19%	2.15%
Capital to Output Ratio	3.21	3.29	3.27

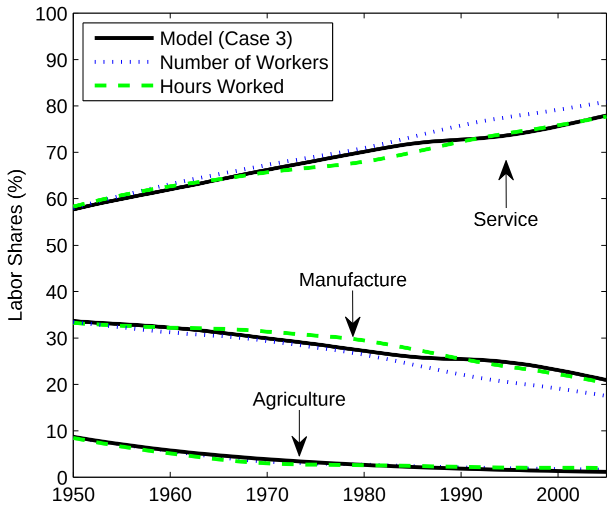

Figure 7: Case 3 Model vs U.S. Data

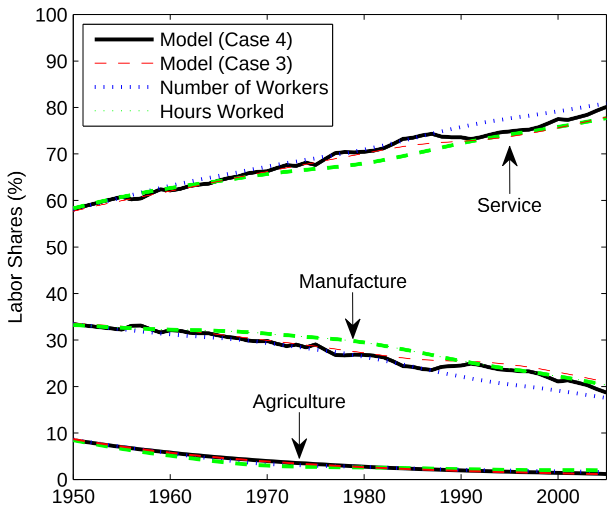

Figure 8: Case 4 Model vs U.S. Data

The introduction of trade balance significantly improves the performance of the model to replicate the labor allocations since 1980s. The case 3 model is able to reach almost exactly the employment share in service and manufacture sector in 2005 in term of hours worked from the data, while the case 4 model is more aggressive that converges to the labor share in term of shares of employment.

The structural model, therefore, is able to connect a large portion of labor movements to the trade deficit. And it provides some support for the argument that trade imbalances have a substantial effect on the labor markets.

Another benefit from working with such a model is that I can estimated a whole bunch of macroeconomics variables from the simulations. Therefore, lots of evaluations of various scenarios could be done with the help of the model. Nevertheless, I should be really cautious about making any conclusions based on these results. As the identification problem in econometrics, there is no way to identify the causality during the whole process. 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 same unknown shock. There are still lots 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 Concluding Remarks

This paper uses a three-sector model to replicate the structural transformation experience of the United States from 1950 to 2005. The benchmark model can only predict the labor movements before early 1980s. Even after controlling the change of capital income share and the slowdown of total factor productivity improvement, the closed economy version of the model couldn't trace the sharp decline of the manufacture sector since 1980s.

I make a simple modification on the model to incorporate the impact from trade balance to the domestic labor market. International trade provides a channel by which sectoral output can exceed sectoral expenditure or vice verse. Then, it is essentially asking the counterfactual question, what the optimal response of the domestic economy will be if a share of GDP is net imported into the economy (as trade deficit). The results from this exercise are intuitive that fewer labor will be employed in manufacture sector. The quantitative predictions of the model match the labor employment in the data quite well.

These findings are consistent with Sachs and Shatz (1994) that the trade balances have significant impact in the labor market and shift labor out of the tradable sector, manufacture, to non-tradable sector, such as service. However, it is far from making a clear conclusion since there is still a positive probability that both the structural change and the trade imbalances are caused by the change of technology.

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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 (PWT) 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[6] where the economy is disaggregated into 10 sectors. I aggregated 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 employment and in term of hours worked are available for the whole sample period.

I obtained investment, nominal GDP series from the NIPA tables. I use the H-P filter to focus on low frequency trends. The unit labor cost data is available from 1970 to 2008 on the OECD statistics. The data on trade balance is from the IMF, International Finance Statistics from 1970 to 2005. The trade balances from 1956 to 1969 are from Branson (1971). The productivity growth rates in agriculture come from the United States Department of Agriculture (USDA)[7]. And the detailed import/export information comes from the U.S. Census Bureau [8].

B Proofs

Proof. for Proposition 1,

The labor employment shares across sectors are given by

[6]Data is available at http://www.ggdc.net.
[7]http://www.ers.usda.gov/ Data/AgProductivity/
[8]Data is available at http://www.census.gov/

$$
\begin{aligned}
L_{A,t} &= \frac{K_{S,t} - K_t + k_{D,t}\left(L - \frac{K_{S,t}}{m_S k_{D,t}}\right)}{k_{D,t}(1-m_A)} \\
L_{D,t} &= \frac{K_t - K_{S,t} - m_A k_{D,t}\left(L - \frac{K_{S,t}}{m_S k_{D,t}}\right)}{k_{D,t}(1-m_A)} \qquad (16) \\
L_{S,t} &= L - L_{A,t} - L_{S,t}
\end{aligned}
$$

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