The Decline of Manufacturing Employment in the United States*

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Abstract

This paper uses panel data from the several states to assess the sources of the decline in manufacturing employment from 1986 through 2001. It estimates and calibrates a structural model where each state is a small open economy with a manufacturing sector and a service sector. The common rate of Hicks-neutral technological progress in manufacturing is 2.1% per annum and that in services is 0.5% per annum. Technological progress has the strongest effect, international economics conditions have the second strongest effect, and changes in local taxes have only a minor effect on the decline of the national share of workers in manufacturing.

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1 Introduction

In the broad sweep of the economic history of the last half century, we discern three important forces. First, the share of manufacturing employment has been declining in almost all the major industrialized countries; there is even some evidence that it has begun to decline recently in some of the less developed countries. Second, technological progress in manufacturing has been more rapid than that for services, if simply because services are ineluctably linked to the time one needs to produce them. Indeed, a quality-adjusted haircut today does not take a lot less time than it did two hundred years ago. Third, the increase in world trade has been astoundingly rapid, even when compared with the unprecedented rate of growth of world output since the second war. Globalization and its discontents are now here to stay. These forces have had a strong influence on domestic manufacturing employment, and the goal of our work is to identify and quantify three sources of the decline of manufacturing employment's share in the national economy.

Manufacturing's share of employment in the United States has been falling for at least 50 years.[1] The share of manufacturing employment in 1950 was about 35% and in 2004 it was about 13%.[2] This phenomenon has been the topic of substantial debate, especially in those regions–often called the rust belt–where manufacturing has typically been the largest source of employment. At the same time, there has been an inexorable shift in the distribution of

[1] Fisher (2004) shows that almost every industrialized country has experienced a declining share of manufacturing employment in the last half century. He argues tentatively that there is a slight positive correlation between this decline and the long-term rate of economic growth among these countries.
[2] These data are from the Bureau of Labor Statistics' Establishment Survey.

manufacturing employment within the United States. The rust belt and other similar regions might be losing jobs in manufacturing owing in part to technological advance, but there are long-term demographic trends that have reallocated employment among the several states. This paper explores the extent to which various economic forces may have contributed to the decline of manufacturing employment's share in the national labor force. We use a panel of data to identify these effects. In particular, we decompose changes from three sources: the effect of technology in a two-sector model; the effect of international economic conditions; and the effect of local state taxes on manufacturing activity.

Treating each state as a small open economy, we use a version of Obstfeld and Rogoff's (1996) two-sector model. Capital flows freely between states, but labor is not mobile. Hence the real interest rate is equal in every state, but wage rates may differ across the states. Since each state has a not traded good (services) and a traded good (manufactures), there is a different real exchange rate for each state. Local taxes have long-run effects on production; we assume a very simple form of taxation in the model. The main advantage of our model is that it gives us a logically consistent framework in which to analyze an important public policy issue. Also, we can quantify the three effects fairly accurately.

We assume that there are two common national rates of Hicks-neutral technological progress. Each state's productive capacity is idiosyncratic; we assume different Cobb-Douglas production functions for manufacturing and for services in each of the fifty states. Thus in some states, manufacturing is globally capital intensive and in others it is globally labor intensive. A surprising empirical finding is that services–considered as a national aggregate–

are capital intensive. Thus a rise in the relative price of manufactures on average benefits labor, not capital, in the United States economy.

We postulate that manufactures are traded goods and that services are not traded. Hence the relative price of manufactures in each state is its own real exchange rate. This is an endogenous variable in our model, and it does not make sense, strictly speaking, to ask what effect a depreciation of the real exchange rate–a rise in the relative price of manufactures *qua* traded goods–has on the sectorial allocation of resources in each state. This is an important point that much of the literature has seemed to overlook. The effect of the international economic conditions on manufacturing employment actually depends on why the real exchange rate is changing. We follow Obstfeld and Rogoff and identify changes in the real exchange rate with a change in the real rentals rate. Taking the price of manufactures as numeraire, we identify a rise in the rentals rate as an increase in the own rate of return on capital in manufacturing. In a state where services are labor-intensive, a rise in this own rate of return is associated with a depreciation of the real exchange rate.

We also model the effect of state taxes on economic activity. There are two ways to think about taxes: the income approach and the production approach. If agents' tax liabilities depend upon their residences, an increase in local taxes affects the demand side. If tax liabilities affects a firm's decisions about where to produce, it influences the supply side. In our panel of data, state-specific taxes can potentially have a very important effect on the allocation of resources–and hence the pattern of manufacturing employment–among the several states. An important empirical contribution of our work is to quantify this effect.

The literature explaining the declining share of employment in manufacturing employment in the United States is not quite as old as the phenomenon itself. An important early article by Krugman and Lawrence (1994) claims that international economic forces have only had a minor effect on the decline of manufacturing employment. Sachs and Shatz (1994) disaggregate trade in manufactures into 131 categories and 150 trading partners; they argue that internationalization has indeed contributed to the decline of manufacturing employment, particularly of low-skilled workers. Bernard, Jensen, and Schott (2002) take a much more disaggregated approach; they use plant-level data to show that imports from low-wage countries are correlated with slower growth of output and employment. They also show that plants that have high measures of skill intensity and of capital intensity tend to mitigate this effect.

We derive no small degree of empirical and analytical bite by exploiting a panel of data. Hanson and Slaughter (2002) have used a similar technique; concentrating on four categories of labor, they employ international trade theory to analyze local labor markets in the several states. Hanson and Slaughter argue that there are common changes in production techniques across all the states; we build on their work by imposing common rates of technological progress in our model and empirical work. They also argue that state-specific changes in production techniques account for relatively little factor absorption; this fact is why we analyze balanced growth paths. They also argue that industry production techniques are similar across states, especially for neighbors. We find a much greater degree of variability among our manufacturing aggregate across the states. Our finding seems to indicate that the mix of industries that constitute manufacturing can be quite different, even among the several states in this country.

It seems important to emphasize that the manufacturing aggregate in the national data consists of a quite diverse group of economic activities. In the national data, bakeries and petrochemical refineries are manufacturing establishments, while neither laborers in construction nor miners are manufacturing workers. The practical implication of this taxonomy is that manufacturing in Wyoming is a lot different from manufacturing in Ohio. The thrust of this observation is compelling: international economic forces affect manufacturing employment quite differently in disparate parts of the country.

The rest of this paper is structured as follows. The second section sketches out the model; it is an application of the earlier work of Obstfeld and Rogoff. The third section describes the model's equilibrium; it concentrates on balanced growth paths where the real exchange rate in each state and the shares of workers in each sector are constant. The fourth section describes model's the estimation and calibration using panel data. The fifth section gives the nuts and bolts of our contribution; it shows exactly how many manufacturing jobs have been lost because of technology, economic forces often associated with international conditions, and state-specific local taxes. The sixth section gives our conclusions.

2 The Model

Our model is a simple extension of that used by Obstfeld and Rogoff. There are n states, each with its own taxation policy. Each state will be indexed by a superscript j. Manufacturing output in state j at time t is produced according to:

$$Q_1^j(t) = \exp(g_1 t) F_1^j(K_1^j(t), L_1^j(t))$$

and output of services in that has this production function:

$$Q_2^j(t) = \exp(g_2 t) F_2^j(K_2^j(t), L_2^j(t)).$$

The parameters $g_1$and g_2 are the deterministic rates of technological progress in the two sectors. Both sectors exhibit constant returns to scale, so that payments to factors exhaust the value of a sector's output. The rates of exogenous technological progress do not depend upon states because we are assuming that knowledge flows across states and also international boundaries easily.

The resource constraints in the $j-th$ states are:

$$L_1^j(t) + L_2^j(t) \leq L^j(t)$$

and

$$K_1^j(t) + K_2^j(t) \leq K^j(t).$$

The demand side of the economy is represented by a stand-in household that has preferences summarized by a homothetic utility function

$$U(C^j(0), C^j(1), ...) = \sum_{t=0}^{\infty} \beta^t u(C^j(t))$$

where $C^j(t) = (C_1^j(t), C_2^j(t))$, $C_1^j(t)$ is the quantity consumed of manufactures in state j, and $C_2^j(t)$ is that of services. Manufactures are considered traded goods, and we define the state-specific real exchange rate as the relative price of not traded goods $p^j(t) \equiv p_2^j(t)/p_1(t)$. We have assumed that $u(.)$ is homothetic, and this postulate implies that the distribution of income among states will not affect demand patterns in the country. We have been careful here to indicate that the price of traded goods is equalized among the several states, and thus there is only one price of traded goods $p_1(t)$.

Capital flows freely between states and across international boundaries. We will then take the rentals rate as given. We have thus assumed that each state is a small open economy, and we will identify changes in the rentals rate on capital with changes in international economic conditions. This assumption is essentially a description of the national economy in the long run. An exogenous change in the rentals rate will cause *pari passu* a change in the relative price of manufactures.

The initial asset position of each state is given by B_0^j. The list of state-specific wage rates is $w(t) = (w^1(t), ..., w^n(t))$ and the common (world) real interest rate is $r(t)$. Then the cumulative discount factor is

$$\delta(t) = \prod_{s=0}^{t} (1 + r(s))^{-1}$$

where we follow the usual convention that $r(0) \equiv 0$. Then the representative household for each state chooses

$$\{C^j(t)\}_{t=0}^{\infty} \text{ to maximize } U = \sum_{t=0}^{\infty} \beta^t u(C^j(t))$$

subject to

$$\sum_{t=0}^{\infty} \delta(t)(p_1(t)C_1^j(t) + p_2^j(t)C_2^j(t)) \leq B_0^j + \sum_{t=0}^{\infty} \delta(t)w^j(t)(1 - \tau^j(t)).$$

In each period, a firm in sector 1 in state j takes traded local prices of service $p_1^j(t)$, local wages $w^j(t)$, and the national rentals rate $r(t)$ as given and chooses $K_1^j(t)$ and $L_1^j(t)$ to maximize

$$p_1^j(t)\exp(g_1 t)F_1^j(K_1^j(t), L_1^j(t)) - r(t)K_1^j(t) - w^j(t)L_1^j(t)$$

Likewise, a firm in sector 2 in state j takes traded goods price $p_2(t)$,local wages $w^j(t)$, and the national rentals rate $r(t)$ as given and chooses $K_2^j(t)$ and $L_2^j(t)$ to maximize

$$p_2(t)\exp(g_2 t)F_2^j(K_2^j(t), L_2^j(t)) - r(t)K_2^j(t) - w^j(t)L_2^j(t)$$

Since firms everywhere in the world have constant returns to scale, solving this problem in each period implies that each firm maximizes the present value of its stream of profits.

We can now define equilibrium. Let $Q_1(t) = (Q_1^1(t), ..., Q_1^n(t))$ be the list of outputs in all the states, and let $Q_2(t)$ be analogous. Since traded goods can come in from abroad, it is convenient to write $M(t)$ as national imports of traded goods. Also we can write $p(t) = (p_1(t); p_2^1(t), ..., p_2^n(t))$, the list of goods price (with only one common traded goods prices for all the states). Also, let $w(t) = (w^1(t), ..., w^n(t))$ be the list of local wages. Then an equilibrium is a list of strictly positive prices prices $\{p(t)\}_{t=0}^{\infty}$, factor prices $\{w(t), r(t)\}_{t=0}^{\infty}$, and corresponding outputs $\{(Q_1(t), Q_2(t)\}_{t=0}^{\infty}$ such that: (i) taking prices as given consumers maximize utility given their budget constraint and initial asset positions; (ii) taking prices as given, firms maximize profits; (iii) $\sum_j C_1^j(t) = \sum_j Q_1^j(t) + M(t)$;and (iv) $C_2^j(t) = Q_2^j(t)$ for each state j.

Notice that factor prices can differ across states, but we are not modeling the migration decision of households. Likewise the cost of living indices will differ among the states because non-traded goods may be cheaper in some states than in others. Since we are aiming at a simple empirical implementation of this model, we will take labor supply decisions as exogenous. Thus the migration decision–admittedly an important part of the national economy in the long run–is not a part of our model. The goods market equilibrium states that the markets for services clears in each state, and the market for traded goods clears nationally, with the explicit possibility of imports.

3 Defining the Three Effects

The task at hand is to give analytical expressions for the three effects on sectorial employment shares that are at the crux of this paper: (1) technological advancement; (2) international economic conditions; and (3) local state taxes. These three effects are the foci of this paper.

The first is the *aggregate effect of technological progress on the share of employment in manufacturing.* We define this effect as the model-based prediction for

$$L_1(t)/L_2(t) = \frac{\sum_j L_2^j(t)}{\sum_j L_1^j(t)}. \tag{1}$$

under the assumption that $g_1 = g_2 = 0$.[3] There is an important ambiguity in this definition. The model has a demand side and a supply side, and we will calibrate it using disposable income for each state. So if there were no technological progress in either sector, then

[3] Consider again a balanced growth path for the United States economy as a whole. Then $L_1(t)/L_2(t) = \frac{\sum_j \mu_2^j(t) q_2^j(0)}{\sum_j \mu_1^j(t) q_1^j(0)} \exp[(\theta - 1)(g_1 - g_2)t]$. This if the rate of technological progress in manufacturing exceeds that in services ($g_1 - g_2 > 0$), and if the two goods are complements ($0 < \theta < 1$), then equation the asymptotic share of workers in manufacturing will be zero on a balanced growth path. Here we have assumed that any change in the national labor force is distributed among the states to keep the national economy on a balanced growth path. The first term on the right side of this equation is a time-varying weighted average of the initial productivity differences among the states. If a state's share of national employment in either sector declines, then so does the importance of its initial productivity level in that sector.

real disposable income would grow more slowly than what we see in the data. We *do not believe* that the interesting counter-factual situation to policy makers is one in which standards of living stagnate because of an absence of technological progress. We *do believe* that policy makers have the following counter-factual history in mind: What would the share of manufacturing employment be today if we were able to maintain the same standard of living without unduly rapid labor-saving technological progress in manufacturing? Thus the counter-factual that we explore is best interpreted as addressing this question: What would the current pattern of sectorial employment in the United States be if we had frozen technology in 1986 and had received enough real income–perhaps from a boom in natural resources–to maintain the standard of living between 1986 and 2001?

Second, we are interested in the how real exchange rate influences the national share of workers in manufacturing. The real exchange rate is of course an endogenous variable, so it does not make any sense to do comparative statics with respect to this relative price. Also, there is a different real exchange rate for each state, since we consider each state to be a small open economy with its own technology for producing traded goods and services. However, we can ask how an unanticipated change in the exogenously given own rate of return in manufacturing affects the national share of workers in manufacturing. We have thus identified a permanent change in the unobservable own rate of return in manufactured goods with a movement in the real exchange rate. This makes sense because these are the only two prices that are determined on the world market, and each state takes the ratio r/p_1 as exogenously given. Since we take traded goods as numeraire, an increase in the relative price of services is an appreciation of the real exchange rate. Since the price of traded goods is fixed, the logic of the Stolper-Samuelson Theorem states that a rise in the rentals rate is associated with an increase in the price of services in states where not traded goods are capital-intensive. In our data, we use our proxy for r/p_1 shows a general decline from 1986 through 2001. Thus the second effect is the *aggregate effect of international economic conditions* is the same as fixing the real interest rate in terms of traded goods. We define this effect as the model-based prediction when

$$r(t)/p_1(t) \equiv r(0)/p_1(0). \tag{2}$$

We emphasize that keeping not traded goods artificially high will actually have disparate effects on the several states, depending on whether manufacturing is locally labor-intensive. Also, the base year for our model was a time when the dollar was relatively strong; the central banks of the major industrial countries intervened in concert to weaken the dollar after the Plaza Accord of September 1985.

The third effect is the *aggregate effect of state taxes on manufacturing employment*. We use a local tax index as a proxy for more general economic policies affect local employment in manufacturing. There are two ways of thinking about local taxation: the income approach and the production approach. In the income approach, agents' tax liabilities depend upon their residences; thus an increase in local taxes affects the demand side. In the production approach, local taxation affects firms' decisions about where to produce.

For simplicity's sake, we will analyze the effect of freezing local taxes at their levels at the beginning of the sample. Our simple definitions follows the income approach. Because we define human wealth as the present value of an infinite stream of wage income net of taxes, we are exploring the counter-factual in which total local wealth is given by:

$$B_0^j + \sum_{t=0}^{\infty} \delta(t) w^j(t)(1 - \tau^j(0)). \tag{3}$$

This income effect influences the local demand for trade and not traded goods. It will change the derived demand for local labor used to produce services. Since the local labor supplies are taken as given in the data, the full employment conditions determine the allocation of labor between manufacturing and services. Then the aggregate national effect is the sum of the fifty individual effects.

4 Tractable Functional Forms

Simple explicit the functional forms will be used in the empirical work. They make the model tractable and help in the exposition of the economic forces that have contributed to the secular decline in manufacturing employment in this country.

Production for traded goods in each state is described by:

$$F_1^j(K_1^j(t), L_1^j(t)) = [A_1^j(t)][K_1^j(t)]^{\alpha^j}[L_1^j(t)]^{1-\alpha^j}$$

and that for not traded goods is given by

$$F_2^j(K_2^j(t), L_2^j(t)) = [A_2^j(t)][K_2^j(t)]^{\beta^j}[L_1^j(t)]^{1-\beta^j}.$$

The big advantage of this specification is that no factor intensity reversal can occur in any state. Also, we are flexible enough so that traded goods can be capital-intensive in some states and labor-intensive in others. We impose further that $A_i^j(t) = A_i^j(0)\exp(g_i t)$ for both sectors. Hence the rates of technological progress in both sectors are common for all the states.

This simple formulation of the supply side for each state links factor prices and output prices in a simple way. Let $k_i^j(t)$ be the capital-labor ratio in sector i of state j at time t and let $\omega^j(t) = w^j(t)/r(t)$ be the analogous wage-rentals ratio. Since the capital-labor ratios in each state satisfy

$$k_1^j(t) = \frac{\alpha^j}{1-\alpha^j}\omega^j(t)$$

and

$$k_2^j(t) = \frac{\beta^j}{1-\beta^j}\omega^j(t).$$

These formulae imply that an exogenous increase in the price of traded goods–a real depreciation–benefits workers only if a state's manufacturing sector is labor-intensive.[4]

In the empirical work, we assume that the utility aggregator is described by a simple CES utility function

$$u(C) = \left[\frac{1}{1-1/\sigma}\right]\left[\left(\gamma^{1/\theta}C_1^{(\theta-1)/\theta} + (1-\gamma)^{1/\theta}C_2^{(\theta-1)/\theta}\right)^{\theta/\ (1-\theta)}\right]^{(1-1/\sigma)},$$

where $\theta > 0$ is the elasticity of substitution between traded goods and services, $0 < \gamma < 1$ is the parameter that captures the share of income spent on manufactures, and $\sigma > 0$ is the inter-temporal elasticity of substitution.

[4] One can derive an analytical solution for the local real exchange rate on a balanced growth path for a closed economy. Using the assumption that the wage-rentals ratio is constant on such a path and the fact that the real exchange is defined by $p^j(t) = p_2^j(t)/p_1(t)$, we can derive $p^j(t) = p^j(0)\exp[(g_1 - g_2)t][\omega^j(t)]^{\alpha^j-\beta^j}$, where the constant $p^j(0) \equiv [A_1^j(0)](\alpha^j)^{\alpha^j}(1-\alpha^j)^{1-\alpha^j}/[A_2^j(0)](\beta^j)^{\beta^j}(1-\beta^j)^{1-\beta^j}$.

5 Estimation and Calibration

This section consists of three subsections. First, we describe the data. Second, we describe our estimation using panel data and the demand-side parameters we are forced to calibrate. Third, we account for the decline in manufacturing employment using the three forces we have just adumbrated.

5.1 Data

The data on employment are from the Current Employment Survey, done by the Bureau of Labor Statistics (BLS). These data ares based on the Standard Industrial Classification (SIC), which was discontinued after 2002. We use the SIC instead of its successor the North American Industrial Classification System (NAICS) because the former has a longer consistent time series. Manufacturing employment consists of the number of workers employed in the durable and non-durable manufacturing sectors. For our study, we exclude the government sector from services employment. Thus employment in services consists of the following sectors: transport and public utilities, finance and real estate, trade, and other services.

The data for gross state product (GSP) come from the Bureau of Economic Analysis' (BEA) Survey of Current Business. It defines GSP as the value added in production by the labor and property located in a state. Hence, it is the sum of the gross state product originating in all local industries. An industry's GSP is equivalent to its gross output (sales or receipts and other operating income, commodity taxes, and inventory change) net of its intermediate inputs (consumption of goods and services purchased domestically or imported).

For each industry, GSP is composed of three components: compensation of employees, taxes on production and imports, and gross operating surplus.

Compensation of employees also comes from the BEA and is defined as wage and salary disbursements and supplements to wages and salaries received by U.S. residents, including wages and salaries received from the rest of the world. The BEA also provides indirect business taxes, defined as tax liabilities, such as general sales and property taxes, that are chargeable to business expense in the calculation of profit-type income and of certain other non-tax liabilities to government agencies (except government enterprises) that are treated like taxes.

Property-type income is also from the BEA. It is defined as proprietors' income and other capital charges. Proprietors' income includes income of unincorporated establishments, rental income of persons, proprietors' inventory valuation adjustment, and non-corporate capital consumption allowance (CCA). The capital charges include corporate profits before taxes, net interest, corporate inventory valuation adjustment, corporate capital consumption allowance (CCA), business transfer payments, and subsidies.

Where necessary, nominal variables are deflated by the Consumer Price Index for all urban consumers (CPI-U). The Producer Price Index (PPI) data is also available from the BLS. It measures the average change over time in the selling prices received by domestic producers for their output. The prices included in the PPI are from the first commercial transaction for many products and some services. The GDP price deflator is defined as the ratio of the current-dollar value of gross domestic product (GDP) to its corresponding chained-dollar value.

5.2 Estimation and Calibration

The first step is to calculate the shares of capital and labor in each sector in each state. We used data on gross state product from 1986 through 2001 inclusive for each state[5] For each year and each state, we divided property income by the sum of property income and compensation to employees, and then averaged over the 16 years in the sample. It is an important fact about the data that capital's shares in manufacturing are quite variable across the states, but capital's shares in services are much more stable. This fact is illustrated dramatically in Figure 1 where the blue crosses show capital's share in manufacturing and the red squares show capital's share in services in each of the fifty states.

This fact was the most compelling reason to adopt a specification of the model in which states had different production functions. The states where manufacturing was the most capital intensive were (in decreasing order of $\alpha^j - \beta^j$) are New Mexico, Louisiana, and Kentucky, all states where processing primary commodities is important. The states where manufacturing was the least capital intensive were (in increasing order of $\alpha^j - \beta^j$) Delaware, Connecticut, and Rhode Island, places where the financial services industry is important. The key point here is that this kind of comparison among localities depends upon a complete specification of the supply side of a general equilibrium model with two sectors. Also, we are assuming that these are global factor intensity comparisons; there are no factor intensity reversals within the class of Cobb-Douglas production functions.

[5] The "states" do not include the District of Columbia.

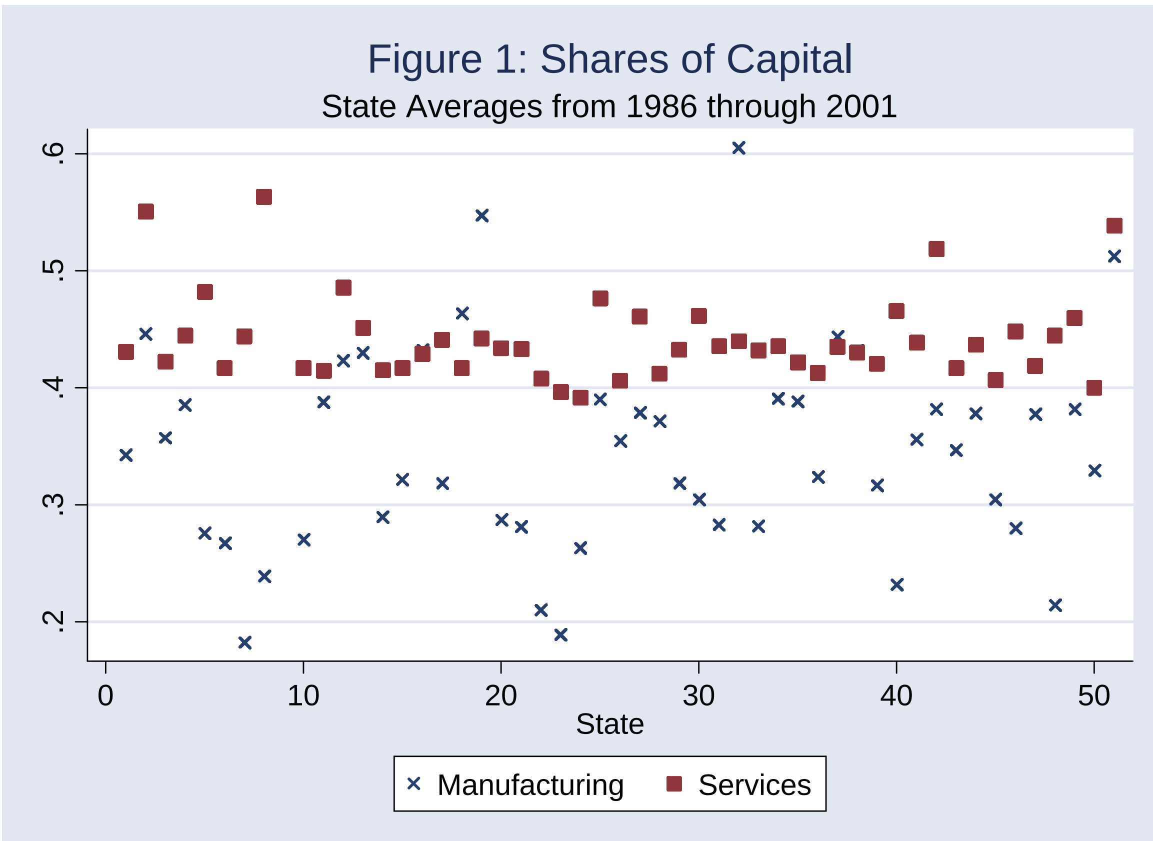
Figure 1: Shares of Capital
State Averages from 1986 through 2001
.2
.3
.4
.5
.6
0
10
20
30
40
50
State
Manufacturing
Services

Figure 1:

The next step is to use these shares to estimate the aggregate production functions for each sector in each state. We used time series on real gross state product in manufacturing and in services (not including government) and the number of workers in manufacturing and in services in each state in each year. These series determined output per worker in each sector. As Solow (1957) emphasized, the hardest part of this kind of exercise is to get a good measure of the flow of capital services. We define capital per worker in each sector as real property income per worker. The nominal value of property income is deflated by the national GDP deflator, to give us a series that captures the real payment for services of capital in each state and sector annually.[6] Let

$$\begin{aligned} z_1^j(t) &= \ln(q_1^j(t)) - \alpha^j \ln(k_1^j(t)) \\ z_2^j(t) &= \ln(q_2^j(t)) - \beta^j \ln(k_2^j(t)). \end{aligned}$$

Where $z_i^j(t)$ is the Solow residual at time t in sector i in state j, and, as defined above, $q_i^j(t)$ is output per worker and $k_i^j(t)$ is real property income per worker. Then, using data from 1985 through 2001 inclusive, we estimated the following regression using panel data separately for each sector $i = 1, 2$

$$z_i^j(t) = \gamma_i^j + \varphi_i t + u_t^j$$

where the fixed effect γ_i^j determines the level effect A_i^j and the error term u_t^j my be interpreted

[6] Value added in each sector can be broken up into compensation to employees, income to property, and indirect taxes.

as a state-specific growth shock. The estimates (and their asymptotic standard errors) are

$$\hat{\varphi}_1 = \underset{(.0007)}{.0215}$$

$$\hat{\varphi}_2 = \underset{(.0002)}{.0048}$$

Here the diacritical circumflex denotes an estimated value. We have very accurate estimates of the rates of common exogenous technological progress in each sector, and manufacturing is experiencing much more rapid technological progress than is services. Fix the real exchange rate and the capital stock in each state. Then manufacturing output per worker in each state is expanding by 2.2% per annum, while services output per worker is expanding only at 0.5% per annum.

The estimate initial levels of output per worker in each sector and state are $q_1^j(0) = \exp(\hat{\gamma}_1^j)[k_1^j(0)]^{\alpha^j}$ and $q_2^j(0) = \exp(\hat{\gamma}_2^j)[k_2^j(0)]^{\beta^j}$, where $\hat{\gamma}_i^j$ are the estimates of the fixed effects and the initial local capital-labor ratios and levels of output per worker are in the data.

We pin down local employment in each sector in four steps. First, we use the demand side of the model to determine the quantities demanded of traded and not traded goods in each locality.[7] Second, we use the supply side of the model to determine output per worker in each sector. Third, we set local demand and local supply for services equal to one another; this determines the predicted number of local workers employed in the not traded

[7] We pin down the initial distribution of assets by assuming that each state owns an annuity that pays value of the initial property income at the initial national interest rate. In essence, we are assuming that "net foreign assets"–including ownership of capital in Ohio by people in Texas–is zero in 1986. Then we keep track of the model's prediction for the evolution of each state's assets, and this level of wealth influences the demand for all goods. We do not need to keep track of net foreign assets because we tie down the model by focussing on the local demand and supply for not traded goods. Thus local output of manufactures can be consumed anywhere, and a state can have a loss of net foreign assets to another state or to the rest of the world.

sector. Fourth, we use the actual number of workers in each state and the full employment conditions to predict how many workers are employed in the traded goods manufacturing sector.

Because we are only using data on the supply of output in services and manufacturing, we can not identify the elasticity of substitution between traded goods and non-traded goods, a preference parameter. Hooper, Johnson, and Marquez (2000) show that θ is roughly 0.7. Also, using data from 1990-2004 from the *Economic Report of the President*, we calculate that the average share of traded goods in personal consumption expenditures, γ in our model, is approximately 0.3.[8] We need to specify two more demand-side parameters. Following Ogaki and Reinhart (1998), we specify that the inter-temporal elasticity of substitution $\sigma = 0.4$. This parameter will influence how saving decisions adjust to changes in the national real interest rate. We also assume that the annual subjective discount factor $\beta = 0.97$.

We allow for one normalization in calibrating the model. Because the proxies for traded goods prices (the national producer price index) and not traded goods prices (the regional consumer price indices) have arbitrary initial values, we ran a simple regression to fit the model's predictions for labor in services to the actual data. This gave us an initial scale factor of 57.5; hence, we multiplied all of the models predictions for local employment in the services sector by that scalar.

Figure 2 gives the model's predictions for local manufacturing employment, and Figure 3 gives the analog for local employment in services. Each figure plots $800 = 50 \times 16$ state-

[8] A back-of-the-envelope calculation shows that the national ratio of manufacturing workers to service workers will decline at 0.5% per annum on a balanced growth path.

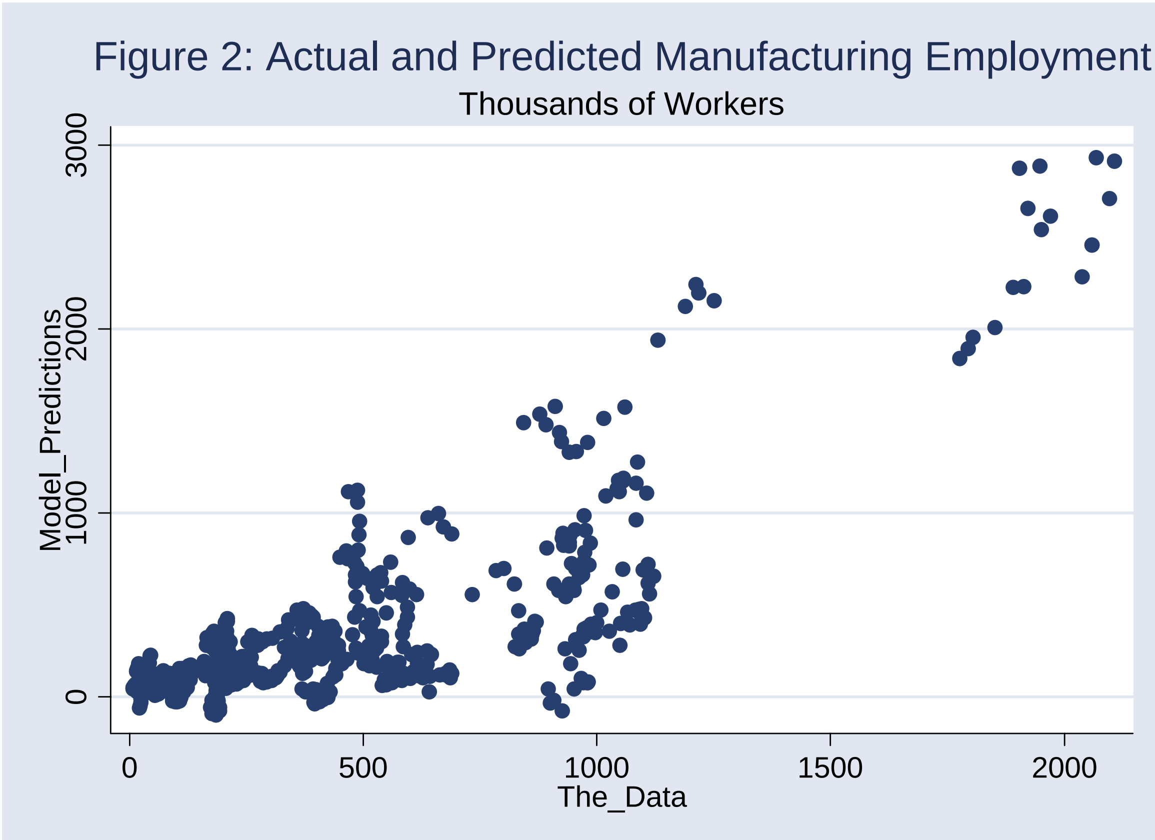

Figure 2:

year predictions against the actual data. The model does well for the services sector, and it performs adequately for the manufacturing sector. It is worth re-iterating that we are taking as given the actual numbers of workers in each state for each year. Again, we are not modeling the migration decisions between states. That is why we should expect that the calibrated model will predict employment patterns fairly well, especially for the services sector. Finally, we show the calibrated model's predictions for *national* employment in manufacturing and in services numbers in the years in our sample. The model tracks the national aggregates fairly well. The actual number of manufacturing workers in our data

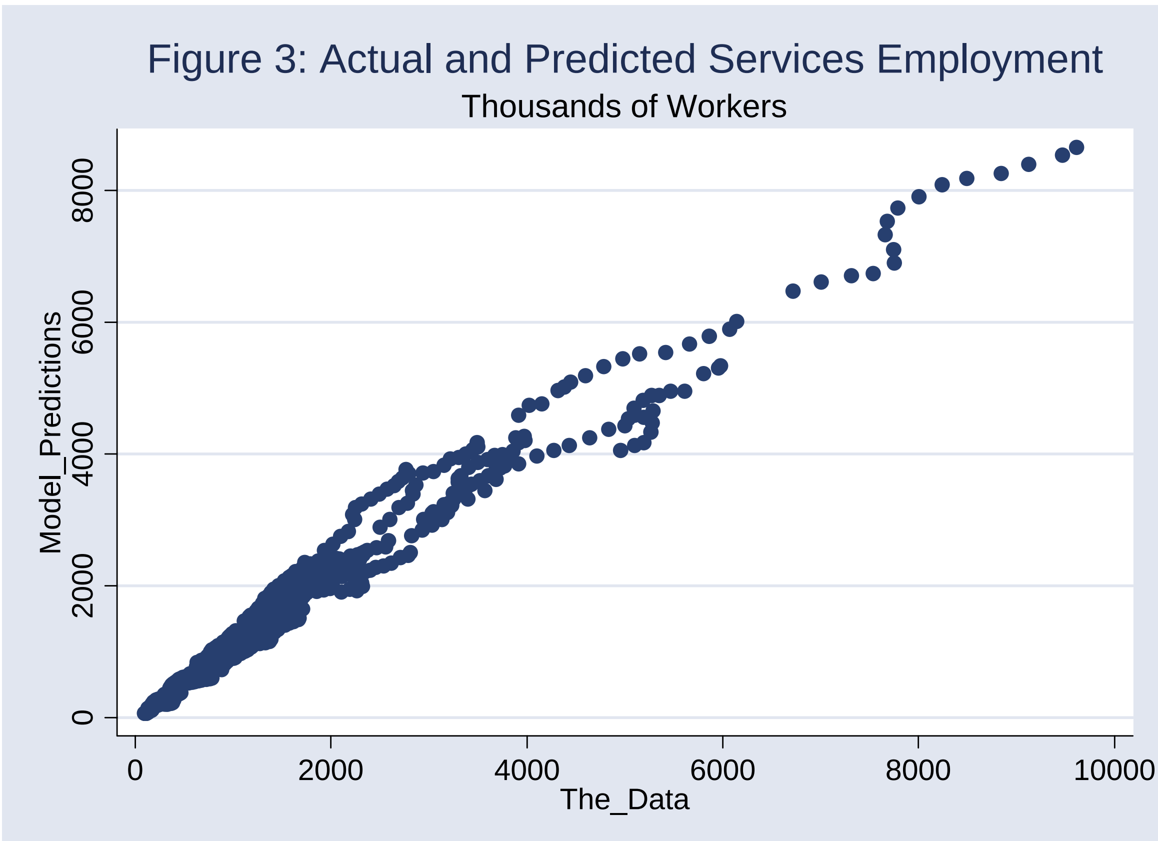
Figure 3: Actual and Predicted Services Employment
Thousands of Workers
Model_Predictions
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
The_Data

Figure 3:

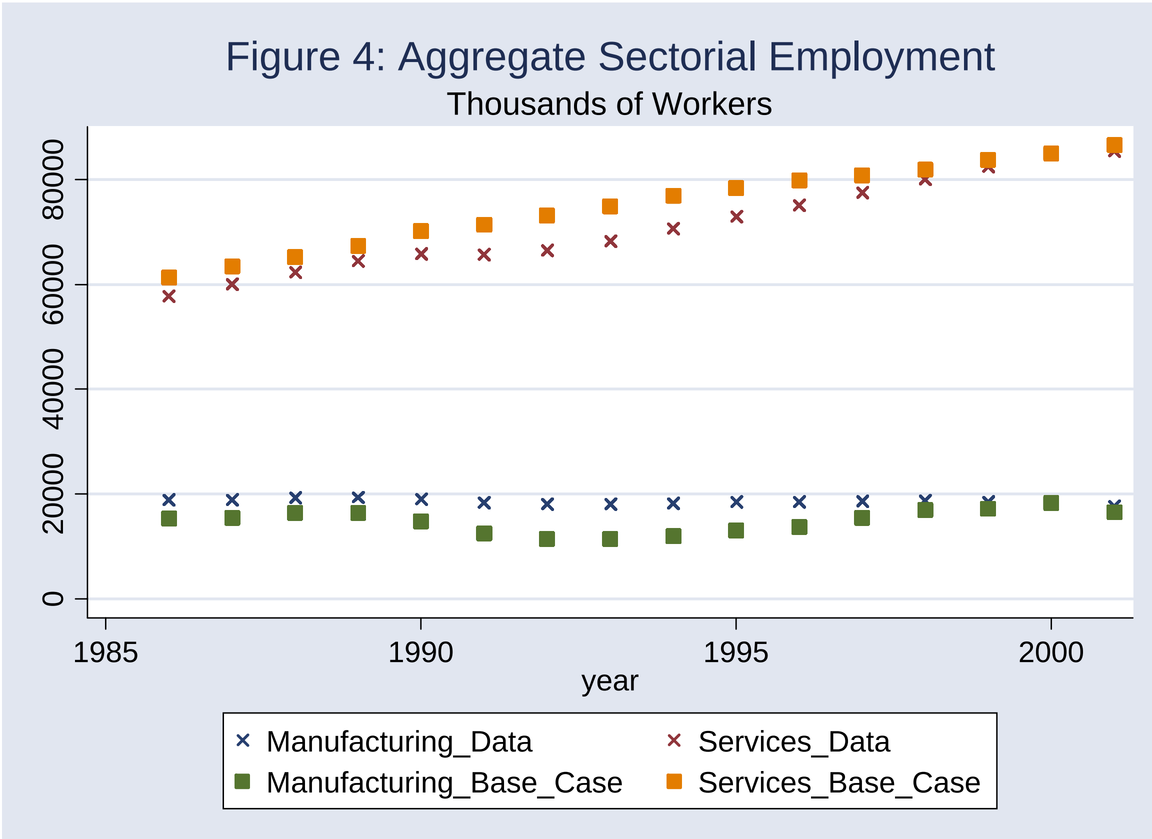

Figure 4:

was 18.9 million in 1986 and in 17.7 million in 2001. The model predicts that there were 15.4 million in 1986 and 16.6 million in 2001

5.3 Accounting for the Change in Manufacturing Employment

It is now possible to derive the change in the number of workers in the manufacturing sector in response to the three factors laid out above, namely technological change, relative prices, and taxes.

The first thing to note is that, in our data, the total number of workers in the manufacturing and service sectors has increased from 77 millions in 1986 to 103 millions in 2001.

The share of workers in manufacturing to total employment in our model was 24.7% in 1986; by 2001, this share had decline to 17.2%. So if there had been no technological change, no change in taxes, and no change in international economic conditions owing to movement in real interest rates, then the number of manufacturing workers in 2001 should have been roughly $25.4 = 103 \times 0.247$ millions. In fact, there were about 17.7 millions. This is a difference of 7.7 million workers in the manufacturing sector. We would like to account for these "lost workers" by the three effects in our calibrated model

Figure 5 gives the model's aggregate predictions when we turn off technological progress, and set $\varphi_1 = \varphi_2 = 0$. We keep the path of the price of traded goods unchanged, as befits a model of several small open economies. Then the model actually predicts an *enormous* change in the initial level of manufacturing workers, and it also predicts an increase in aggregate manufacturing employment from 51.2 million in 1986 to 67.9 million in 2001. The initial level of manufacturing employment represents a wealth effect. When we switch off technological advancement, we freeze real income permanently at its level in 2001. This impoverishes the entire American population, and it reduces consumption of both goods in all periods drastically. Since consumption of not traded goods in 1986 decreases, employment in that sector is much lower. Then the residual work force is employed in manufacturing. The number of workers in manufacturing increases from 1986 through 2001 because there is an exogenous increase in the work force without any technological progress in manufacturing. So one way to increase drastically the share of manufacturing employment in the United States is to hamstring the American consumer and then turn the county into a mercantilist

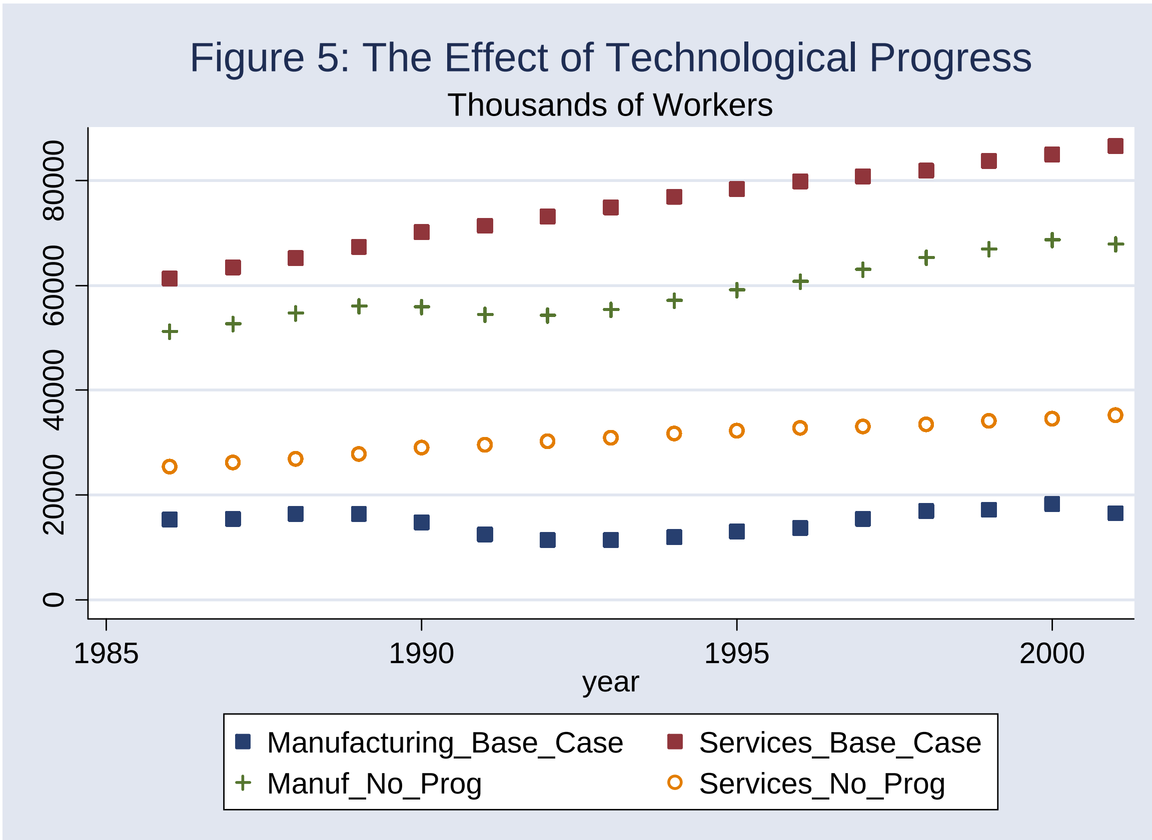

Figure 5:

bastion of exporters of low-tech manufactured goods! This is surely not the prospect that policy makers have in mind when they fret about the decline of manufacturing employment, but it does show how it the model's demand side and supply side work together in making counter-factual predictions.

What would happen if we froze international economic conditions as they were in 1985? Again, it is worth reiterating what we mean by international economic conditions in this model. Each state takes the real interest rate as given; since traded goods are numeraire, this is equivalent to fixing the own rate of return on manufactures at its level in 1985. Figure

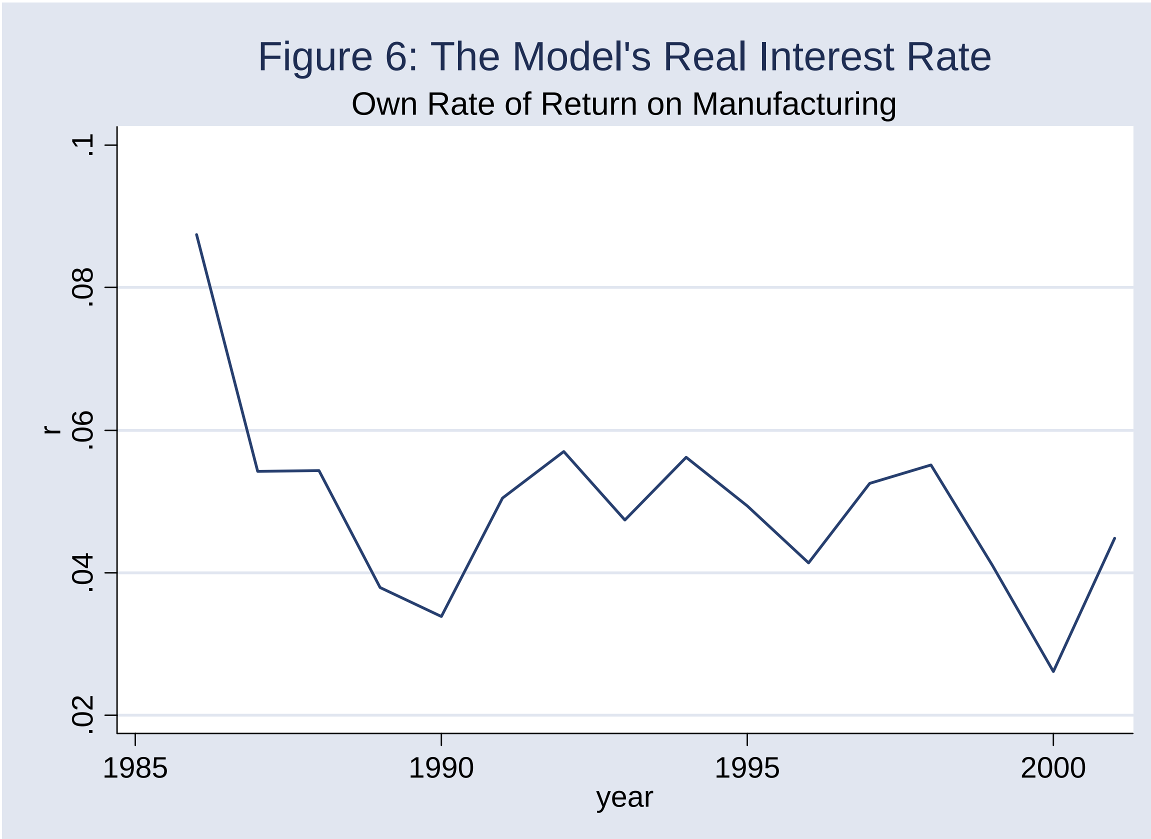

Figure 6:

6 shows that the model's measure of the real interest rate was quite high in the initial period. This corresponds to the fact that nominal interest rates have declined more rapidly between 1985 and 2001 than our proxy for expected inflation in the price of traded goods.[9] The high real interest rate in the initial period corresponds to the peak of the dollar in the 1980's; the Plaza Accord, at which the major industrial countries decided to intervene in concert to weaken the dollar, took place in September 1985.

Figure 7 shows that freezing the model's real interest rate has a very strong effect. It increases the initial level of manufacturing employment quite substantially, although the share

[9] We use the nominal interest rate minus the actual rate of inflation on commodities.

of employment in services continues to rise in the model economy. Here is the mechanism in the model that gives rise to this effect. Freezing real interest rates at their initial levels means that the present value of wealth is lower than in the base case. Financial wealth remains unchanged, but the present value of human wealth is significantly reduced. Then the demand for not traded goods is lower in each year. Hence the number of workers needed to produce local services is significantly diminished. Then the full employment conditions imply that a larger number of workers is employed in manufacturing in each state. Since technological manufacturing is still faster than that in services, the share of manufacturing employment is predicted to decline, even though the initial level effect in employment in manufacturing is enormous.

In essence, freezing "international economic conditions" at their level in 1985 forces the national economy to run a large trade surplus by the combination of a wealth effect that decreases the demand for traded goods and an employment effect that increases their supply. We would like to return to our *leitmotif:* we do not think impoverishing the American consumer to generate a trade surplus and temporarily maintain employment in manufacturing is what policy makers have in mind when they seek protectionist measures to stem the loss of manufacturing jobs.

Figure 8 shows that freezing local taxes at their initial levels has virtually no aggregate effect in this model. The variation is local taxes across time is just too small to have much of a wealth effect, and taxes rise in some states while they decline in others. We have not modeled the supply-side effects of taxes that Fisher (2004) highlighted in his reduced-form

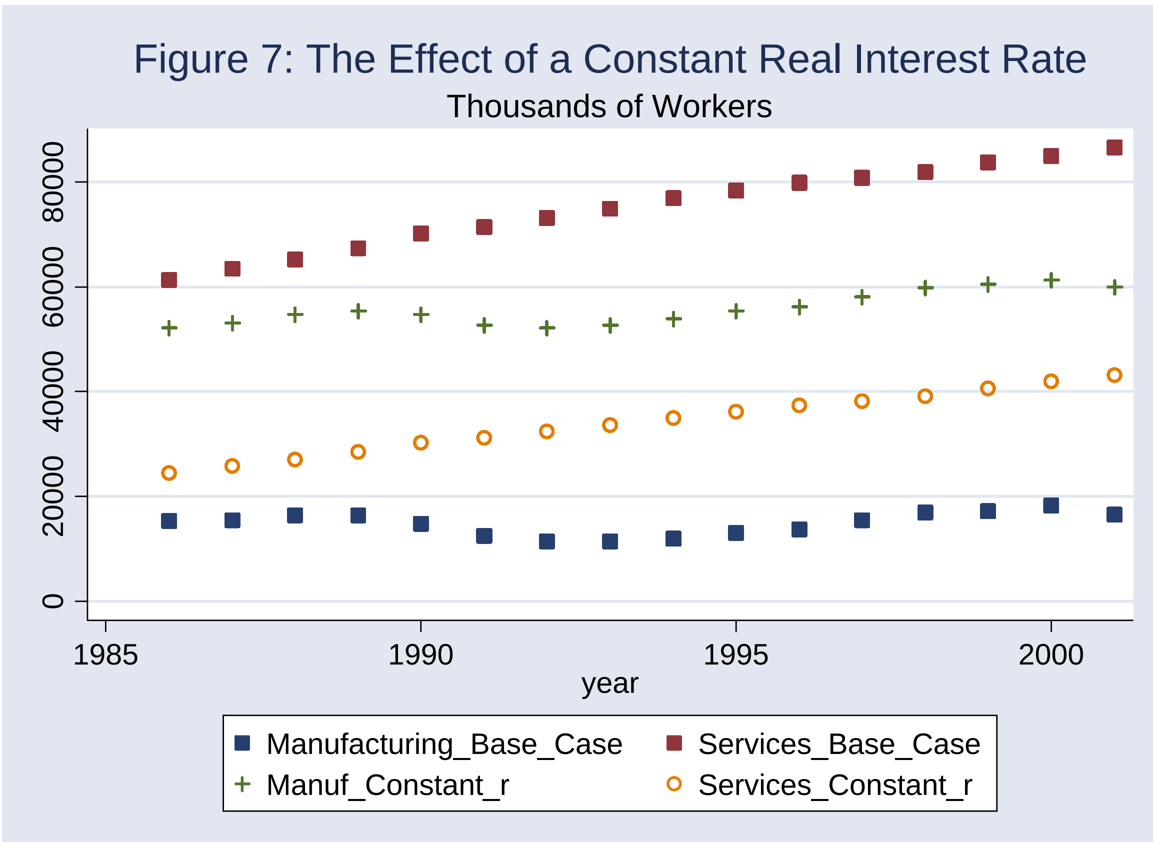
Figure 7: The Effect of a Constant Real Interest Rate
Thousands of Workers
0
20000
40000
60000
80000
1985
1990
1995
2000
year
Manufacturing_Base_Case
Services_Base_Case
Manuf_Constant_r
Services_Constant_r

Figure 7:

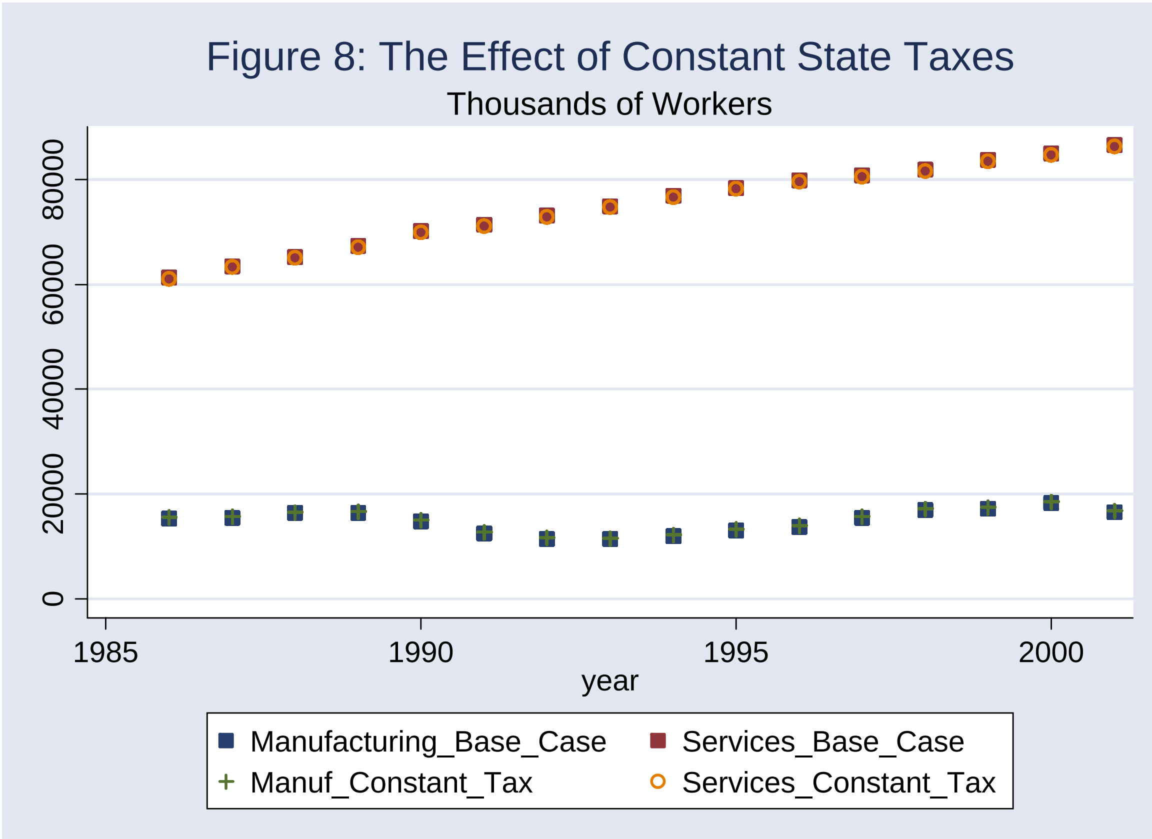

Figure 8:

econometric analysis of these data. There has been substantial change in the ranking of which states have high local taxes in these years, but the model imposes the discipline of a perfect foresight equilibrium on the quantitative analysis. So secular changes in local taxes are already factored into the model's base case, and freezing them at their initial levels has very little effect at all. In the model, the present value of human wealth is calculated by an approximation of an infinite stream of disposable income, and there is virtually no aggregate (national) effect to freezing local taxes at their initial levels

It is fair to say that the model ranks the effects in this order. The effect of technological progress on manufacturing employments is strongest; freezing technology combines a wealth effect and a supply side effect. The second strongest effect is holding fixed the initial international economic conditions; it increases the initial level of manufacturing employment, but in the secular trend is clearly towards a decreasing share of workers in manufacturing even if there is a large initial national trade surplus. The effect of local taxes on national employment in manufacturing is least important, although it may have a significant local effect for a few states where taxes have changed sharply in these years

6 Conclusion

Our work has imposed analytical discipline on an important public policy issue. We have examined the decline of manufacturing of manufacturing employment in the United States in the last two decades, and our main conclusions are fairly intuitive. There were 103 million workers in manufacturing and services in the United States in 2001; if the historical relationships from 1986 had held, then there ought to have been 25.4 million manufacturing workers. Instead there were 7.7 million fewer workers.

Using a simple two-sector model with a well specified demand side, we showed that relatively rapid technological progress in manufacturing has had a very strong effect on the decline of employment in manufacturing. Technological advancement raises expected future output; hence it increases current wealth. Thus the demand for local services increases. Since we take the supply of workers in each state as exogenous, the local share of workers in services declines. Hence the national share of workers does too. If there is no technological progress, this initial increase in the share of workers in manufacturing is permanent, even as the size of the national work force increases.

It is important to emphasize again that the real exchange rate is an endogenous variable in any well specified economic model. Thus it is conceptually inadequate to run a regression of the real exchange rate on employment in a traded goods sector and then to claim that one has explained changes in employment by this summary measure of international competitiveness. We have identified the real return on investment in manufacturing as an exogenous variable that influences each state's own real exchange rate. It also has a strong wealth effect in this model, since it determines the present value of the stream of disposable income. Freezing the real exchange rate at its initial level fixes real interest rates at a high level. This effect reduces consumption and induces an external surplus for the national economy.

Our measure of taxation is based upon the locality where households reside. There are no distorting effects of taxation in this model, and the wealth effects of freezing taxes at their initial levels are very small. Hence the effects on aggregate employment in manufacturing are almost negligible.

An important weakness of our model is that we have not assumed that workers within the United States will migrate to the states with the highest real wages. We have taken historical supplies of labor in each state as given. This assumption is essential for a simple empirical implementation of the sectorial allocation of labor within each state, but it is an important limitation of our analysis.

Another important weakness is that we have not modeled capital accumulation. Our defense is that we have allowed the real return on capital to be identical across all the states, and treating each state as a small open economy is an attractive element of our analysis. Also, our estimates about the rates of growth of the output in the two-sectors were reassuringly close to Maddison's (1982) estimates about the long-run rate of growth of the lead country (the United States) in the second half of the twentieth century. Since the service sector in the typical state is actually capital intensive, we think that capital accumulation might exacerbate the loss of manufacturing workers because of the usual Rybczynski effect.

The source of future prosperity in the United States economy is technological advancement in the services sector. It is a natural part of the economic history of every country since the industrial revolution to go through three phases. In the first, the predominant source of employment is the agricultural sector; the United States left that phase in the last century. The second phase is when a large share of employment occurs in manufacturing, and our country has left that stage in the last fifty years. The third stage is happening now and is also the wave of the future; the primary source of employment in this country and abroad will be the service sector in the next century. It is important to conclude with the observation that service jobs are not just about flipping hamburgers; indeed almost every member of the American Economic Association is a service worker, and college teachers of economics are one of the highest paid categories for which the Bureau of Labor Statistics actually computes salaries.

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