Accounting for the Secular "Decline" of U.S. Manufacturing

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Abstract

The debate over the decline of U.S. manufacturing has focused upon the sharp fall in relative employment and the potential roles of differential productivity growth and international trade. Extending this analysis to cover prices and output, we show that a closed-economy two sector model with faster manufacturing productivity growth cannot go very far in accounting for the data unless we assume that consumers are unwilling to substitute between manufactures and services. Under the extreme assumption of zero substitutability, the model explains about two-thirds of the decline in the share of manufacturing employment since the mid-1950s. Allowing for manufactured imports does lead to a small but noticeable improvement in the model's ability to explain employment (in the 1990s and beyond) but provides no evidence to reject the hypothesis that the elasticity of substitution between the two goods is zero.

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1. Introduction

Employment in the manufacturing sector in the United States has grown noticeably more slowly than employment in services over most of the post-war period; in fact, despite a steadily growing labor force, the *level* of employment in the manufacturing sector today is noticeably lower than it was in the late 1960s (see Figure 1). This is often interpreted as evidence of the decline of manufacturing in the United States, with rising imports from abroad (Japan in the 1980s and China more recently) often cited as the source of this decline.

As a rejoinder to this argument, many have pointed to the potentially important role that productivity could play in the reallocation of labor from the manufacturing to the services sector.[1] That is, with faster productivity growth in the manufacturing sector, the economy can move resources into the services sector and allow consumption of both manufactured goods and services to increase. This argument is also consistent with the observed sustained decline in the relative price of manufactured goods during the post-war period.

In addition, advocates of this "productivity" hypothesis point to another piece of evidence that appears inconsistent with a significant role for international trade, which is that industrial sector output has grown at about the same average rate as the output of the services sector over this period.[2] If international trade were the principal driving force behind the reallocation of labor, one would expect to see a secular change in the composition of domestic output as well.

However, the fact that domestic output in the manufacturing sector has not grown more rapidly than output in the services sector in the face of consistently faster productivity growth in the former raises questions of its own. Why don't firms try to profit from the greater productivity in manufacturing by moving more resources (including labor) into

[1] Baumol(1967) makes the earliest such argument that we know of; see also Baumol, Blackman and Wolff (1989).

[2] See Bernanke(2003).

that sector? Why don't households react to the productivity-induced decline in the price of manufactured goods by raising their consumption of these goods relative to the increasingly more expensive output of the service sector?

This paper addresses these issues with the help of a simple two-sector model. The economy produces two kinds of goods: manufactures and services. To focus on the role of productivity, the production technology is identical for the two sectors, except that they experience different rates of exogenous technological progress. To examine the importance of the demand side of these markets, households are assumed to derive utility from both types of goods, where the degree of substitutability between manufactures and services can be varied by parameterizing a *CES* utility function.

The willingness of households to substitute between the types of goods turns out to play a significant role in determining the behavior of relative prices and quantities. The lower is the elasticity of substitution between the two goods, the greater is the rate at which the relative price of manufactures declines for a given difference in the rate of productivity growth. Even so, faster productivity growth in the manufacturing sector leads to a decline in the relative price of manufactures for *any* finite elasticity of substitution. However, a secular sectoral shift of employment out of manufacturing and into services is not guaranteed; for this shift to occur, it is necessary that the two goods are not very close substitutes. Moreover, in a closed economy, the condition that output in the two sectors grow at the same rate in the face of differential productivity growth rates across sectors imposes an extreme requirement on preferences. It is necessary that the elasticity of substitution between manufactures and services be zero. This parameterization also induces the greatest relative price response to a given difference in productivity growth rates.

We examine data on output, prices and employment over the 1955Q1 to 2004Q2 period to see how it compares to predictions from this closed economy model. The behavior of relative prices and employment is roughly consistent with the predictions from the model, though the decline in manufacturing employment is greater than the model would imply. To our surprise, the average growth rate of manufacturing output turns out to be close to that of service sector output over most of the sample period.[3] The only way this stylized fact can be reconciled with faster average productivity growth in manufacturing in this model is by imposing a zero elasticity of substitution, an assumption we are uncomfortable with.

Allowing for imports of manufactured goods provides a way out, since an increased demand for manufactures can be met by higher imports without a significant change in domestic production. Accordingly, we expand our model to incorporate the possibility of production abroad. Domestic manufacturing workers are assumed to earn a wage premium relative to foreign manufacturing workers. The assumption that this premium is growing over time (empirically, as the U.S. increases trade with low wage economies) leads to the prediction that domestic production of manufactures decreases while rising imports satisfy the higher demand associated with falling goods' prices.

Shocks that lead to an increase in the share of manufactured imports cause a reduction in the relative price of manufactures and a reduction in domestic manufacturing output and employment regardless of the elasticity of substitution. They also lead to an increase in the domestic consumption of manufactures relative to services. Empirically, we find the domestic consumption of the sum of domestically produced and imported goods relative to that of services to be more or less unresponsive to the decline in the relative price of goods over our sample period, which also suggests very limited substitutability between manufactures and services.

We find that incorporating trade data on manufactured goods does not lead to much of a change in the model's prediction of employment

[3]It is, in fact, slightly lower.

shares over most of the sample period. The exception is the last few years of the sample beginning in the early 1990s, when the addition of the foreign sector can account for most of the underprediction of the decline in U.S. manufacturing employment. However, trade with "low wage" countries does not appear to have much potential to explain the larger forecast errors that occurred in the early 1970s.

In order to find out what might have happened in the 1970s, the last section of the paper takes a closer look at the data. It is well known that productivity growth slowed down around this period, and a number of papers have argued that this represented a change in relative productivity growth rates across sectors. Our model implies that such a change should be reflected in the behavior of relative prices, employment levels and (if the elasticity of substitution is not zero) in relative quantities. We test for, and find, breaks in the growth rates of relative prices and employment, which are consistent with a break in relative productivity growth rates. We do not, however, find a break in relative output growth rates, which again implies a zero elasticity of substitution. Failure of relative output growth rates to react to a break in the growth rate of relative prices also provides evidence against arguments that would reject a zero elasticity of substitution in favor of a low income elasticity of demand for manufactures that has historically offset the higher demand that would result from lower prices.

2. A model where all production is domestic

This section sets up a model to study the effects of differing productivity growth rates across sectors. We study a two-sector model of a closed economy in which the production technologies in the manufacturing and service sectors differ only with respect to the rate of technological progress. Households may view the goods as imperfect substitutes. Adjustments to productivity differentials take the form of shifts of employment between sectors in order to equate real wage rates, and of changes in the relative price of goods versus services.

2.1 Households.

The economy consists of a large number of identical households that derive utility by consuming both services as well as the service flows from manufactured goods in accordance with a *CES* utility function:

$$U(s,m) = \left[\eta s^{-\rho} + (1-\eta)m^{-\rho}\right]^{-\frac{1}{\rho}}, \quad \eta > 0, \quad \rho \in [-1,\infty] \qquad (1)$$

where: s = consumption of services and m = service flows received from manufactured goods. The intratemporal elasticity of substitution between services and service flows from manufactures is given by:

$$\sigma = \frac{1}{1+\rho}, \quad \sigma \in [0,\infty] \qquad (2)$$

and determines the marginal rate of substitution between m and s:

$$\frac{U_s}{U_m} = \left(\frac{\eta}{1-\eta}\right)\left(\frac{m}{s}\right)^{\frac{1}{\sigma}} \qquad (3)$$

At each point in time, households maximize utility by choosing the mix of services (s) and manufactured goods (x) to purchase, as well as choosing the service flows from manufactures (m) and the allocation of labor between the production of services (n^s) and the production of manufactures (n^x).

$$\max_{\{s,m,x,n^s,n^x\}} U(s,m) \qquad (4)$$

The household's choices are subject to a budget constraint:

$$s + qx \leq w^s n^s + w^x n^x \qquad (5)$$

where q is the relative price of manufactured goods in units of services, and w^s and w^x are real wage rates for employment in the two sectors.

The flow of services from manufactured goods is assumed to be given by the following function (where depreciation is taken to be 100 percent):

$$m \leq H(x), \quad H_x > 0, \quad H_{xx} \leq 0 \tag{6}$$

with the subscripts denoting first and second derivatives.

Labor allocations also must satisfy the resource constraint:

$$n^s + n^x \leq 1 \tag{7}$$

The Euler equations for the household's problem are:

$$\left(\frac{\eta}{1-\eta}\right)\left(\frac{m}{s}\right)^{\frac{1}{\sigma}} = \frac{H_x}{q} \tag{8}$$

$$w^s = w^x \tag{9}$$

2.2 Production sectors.

Labor is assumed to be the only factor of production in both the manufacturing and service sectors, which are assumed to be competitive in both product and factor markets. Except for the productivity processes, the production functions in the two sectors are identical.

The service sector firm chooses the quantity of labor to employ to maximize profits given by the value of output minus the wage bill:

$$\max_{n^s} F^s(n^s, \theta) - w^s n^s \tag{10}$$

where output is determined by the production technology:

$$F^s(n^s, \theta) = \theta (n^s)^\alpha, \quad \alpha \in (0, 1) \tag{11}$$

with θ representing the exogenous process for total factor productivity (TFP). The first-order condition equates the wage rate to the marginal product of labor.

$$w^s = \alpha\theta(n^s)^{\alpha-1} \tag{12}$$

Similarly, the manufacturing sector firm maximizes profits:

$$\max_{n^x} qF^x(n^x, \mu) - w^x n^x \tag{13}$$

where the production technology is given by:

$$F^x(n^x, \theta) = \mu(n^x)^\alpha, \quad \alpha \in (0, 1) \tag{14}$$

with μ representing the TFP process. The maximization yields the following first-order condition:

$$w^x = q\alpha\mu(n^x)^{\alpha-1} \tag{15}$$

Note from equations (9), (12), and (15), equating wage rates across sectors implies:

$$\phi \equiv \frac{n^x}{n^s} = \left(\frac{q\mu}{\theta}\right)^{\frac{1}{1-\alpha}} \tag{16}$$

where ϕ is the ratio of employment in the manufacturing sector to employment in the services sector. Equation (16) indicates that there is a relationship between how relative prices and employment levels adjust to exogenous productivity shocks. Holding employment shares fixed, for instance, leads to a greater adjustment in relative prices than if employment shares are allowed to change. We will examine this issue more closely below.

2.3 The equilibrium growth path.

In equilibrium, the amount of services and manufactured goods produced must equal the amount purchased by the households, or:

$$s = F^s(n^s, \theta) = \theta(n^s)^\alpha \tag{17}$$

$$x = F^x(n^x, \mu) = \mu(n^x)^{\alpha} \tag{18}$$

To solve the model, a linear function for H is specified such that:

$$m = \gamma x, \quad \gamma > 0 \tag{19}$$

From equations (8) and (16) through (19):

$$\phi = \gamma^{\frac{\sigma-1}{\alpha}} \left(\frac{1-\eta}{\eta}\right)^{\frac{\sigma}{\alpha}} q^{-\frac{\sigma}{\alpha}} \left(\frac{\theta}{\mu}\right)^{\frac{1}{\alpha}} \tag{20}$$

Note that if employment in both sectors grows at the same rate, equation (16) implies:

$$\hat{q} = \hat{\theta} - \hat{\mu} \tag{21}$$

where a " ˆ " over a variable denotes a growth rate. This expression indicates that, in the absence of labor mobility, differences in productivity growth rates across sectors are reflected one for one in changes in the relative price of manufactured goods to services. More concretely, if TFP in the manufacturing sector grows 1 percent faster than TFP in the services sector over a given period, then the relative price of manufactured goods will fall by one percent during that period.

Maintaining the assumption that ϕ is a constant, note that equation (20) implies:

$$\sigma\hat{q} = \hat{\theta} - \hat{\mu} \tag{22}$$

which is consistent with equation (21) if and only if the intratemporal elasticity of substitution (σ) equals one. Thus, if the utility function were Cobb-Douglas, for instance, workers would not get reallocated across sectors and the relative price would decline at a rate equal to the difference in the growth rates of the two productivity processes.

Suppose, on the other hand, that employment in the two sectors is allowed to grow at different rates, that is to say, $\hat{\phi}$ is allowed to differ from zero. Then, equations (16) and (20) imply:

$$\hat{\phi} = (1 - \sigma)\hat{q} \tag{23}$$

Equation (23) highlights the pivotal role of σ (the intratemporal elasticity of substitution in the household's utility function) in determining the relationship between the change in employment growth rates and the relative price. If σ exceeds 1, the relative price and relative employment growth rates move in opposite directions. An acceleration in the rate at which the relative price of manufactures is falling, for instance, will be accompanied by manufacturing sector employment growing faster than services sector employment. Only if σ is less than 1 will the relative price and the employment share move in the same direction.

How do these variables respond to changes in productivity growth in either of the two sectors? To answer this question, equations (16) and (20) can be used to solve for $\hat{\phi}$ and $\hat{q}$. This yields:

$$\hat{q} = -\frac{1}{(1-\alpha)\sigma + \alpha}(\hat{\mu} - \hat{\theta}) \tag{24}$$

$$\hat{\phi} = \frac{(\sigma - 1)}{(1-\alpha)\sigma + \alpha}(\hat{\mu} - \hat{\theta}) \tag{25}$$

These expressions show that relative employment growth rates and relative prices will respond in the same manner whether TFP growth in the manufacturing sector accelerates or TFP growth in the services sector decelerates. In this framework, then, the behavior of these variables only provides information about relative productivity growth rates and cannot be used to determine which of the two sectors is experiencing a change in productivity growth.[4]

[4] This difficulty echoes a debate in the literature about the productivity slowdown in the 1970s. We will return to this issue below.

To further examine the properties of the solution, first differentiate (24) and (25) with respect to the differential TFP growth rates $(\hat{\mu}-\hat{\theta})$:

$$\frac{d\hat{q}}{d(\hat{\mu}-\hat{\theta})} = -\frac{1}{(1-\alpha)\sigma+\alpha} \tag{26}$$

$$\frac{d\hat{\phi}}{d(\hat{\mu}-\hat{\theta})} = \frac{\sigma-1}{(1-\alpha)\sigma+\alpha} \tag{27}$$

Equation (26) indicates that the faster productivity grows in the manufacturing sector (or equivalently, the slower it grows in the services sector) the more rapidly the relative price of manufactured goods will fall (given that σ is nonnegative). However, whether employment in manufacturing grows faster than employment in services depends upon the value of σ. As long as σ exceeds 1, households are very willing to substitute manufactures for services, and therefore it is optimal to move workers into manufacturing to take advantage of the relative increase in productivity in that sector. However, the lower the value of σ, the less desirable it is to move workers toward manufacturing. For σ less than 1 (which implies that households are not very willing to substitute manufactures for services), it is actually optimal to move workers in the reverse direction, that is, to move workers into services in response to higher productivity growth in the manufacturing sector.

An intuitive way to think about this process is as follows. Higher productivity growth in the manufacturing sector makes the household wealthier and increases demand for both products. At the same time, it also makes the manufactured good cheaper and pushes the household towards higher consumption of this good. How much the household is willing to shift consumption towards the manufactured good depends upon the elasticity of substitution between the two goods. To see this, define the ratio of output from the manufacturing sector to output from the services sector by ψ, or:

$$\psi = \frac{x}{s} \tag{28}$$

Then, from equations (16) through (18), the difference between output growth in the two sectors is given by:

$$\hat{\psi} = \frac{\sigma}{(1-\alpha)\sigma + \alpha}(\hat{\mu} - \hat{\theta}) \tag{29}$$

The lower the elasticity of substitution, the smaller the increase in the growth rate of manufacturing output relative to services in response to a given increase in the relative growth rate of manufacturing productivity. For Cobb-Douglas utility (σ=1) relative output growth rates change by exactly the same amount as changes in relative productivity growth rates, an outcome explained by the fact that no labor actually moves across sectors in this case. At the extreme, when σ equals 0, changes in relative productivity growth rates have no impact on the relative growth rates of output, because households are completely unwilling to substitute one good for another (that is to say, the indifference curves are right angled). Therefore, firms move resources into the low productivity sector until the effect of relatively higher manufacturing productivity growth on relative outputs is neutralized.

Figure 2 provides more detail on the response of these key variables to a change in productivity growth as a function of σ. It shows what happens in response to a 1 percent increase in manufacturing productivity growth (relative to service sector productivity) for values of σ between 0 and 5 under the assumption that $\alpha = 0.67$.[5] Note that all three variables ($\hat{\phi}$, $\hat{q}$, and $\hat{\psi}$) increase with the value of σ, though the responses themselves can be negative or positive. The growth rate of the relative price of manufactured goods always declines in response to an increase in the growth rate of manufacturing sector productivity, with the rate of decline tending to zero from below as σ goes to infinity. By contrast, the relative growth rate of manufacturing output is bounded below by zero, and the zero value is attained only when σ itself equals

[5] For smaller values of α the curves are steeper early on (that is, when the value of σ is relatively small) and flatter for relatively large values of σ; the curves tend towards straight lines as α goes to 1.

zero. Finally, the response of employment switches signs depending upon the value of σ, with manufacturing employment growing faster when σ exceeds 1 and services employment growing faster when it is less than 1.

In the next section we turn to the data to see how the behavior of relative prices, employment and output compares to the predictions from the model.

3. How much can productivity account for?

Data for output and prices are available from the *Bureau of Economic Analysis* web site. The *BEA* makes data available by major type of product and the major categories under this classification are goods, services and structures. We work with the first two categories; in addition, we also remove the government sector from the data. Data on employment are from the *Bureau of Labor Statistics* web site. Here again we exclude the government sector and use data on employment in the private service and goods sectors. Use of goods sector employment rather than manufacturing allows us to include workers in the mining industries and makes it consistent with the GDP accounts, where the output of the mining sector is grouped together with manufactures under goods. Compatibility requires that we make one adjustment to goods sector employment, which is the removal of employment in the construction sector (since structures are classified separately from goods in the output and price data). For convenience, we will continue to refer to the two sectors as manufacturing and services.

Figure 3 presents data on the relative price of manufacturing to services as well as the relative employment levels in these two sectors.The upper panel shows (the log of) relative employment levels; the decline in manufacturing sector employment relative to services sector employment is obvious here. The lower panel shows that the (log of) the relative price has fallen quite dramatically over the 1955Q1-2004Q2 period.

The behavior of the two series over our sample looks remarkably similar, and the graphs suggest that the two series could well have a common trend. Indeed, this is what our model specification suggests as well (see equations (24) and (25)). However, the data reject this implication of the theory. Specifically, we carried out an Augmented Dickey-Fuller test on the residual obtained from a regression of the log of relative employment levels on the log of relative prices (and some lags of first differences). We obtained a test statistic of -2.2 which is well below the -3.4 required to reject the null of no cointegration at the 10 percent level.[6] Thus, the levels of these series have tended to move apart over time.

How different are the growth rates from each other? For the sample at hand, the quarterly average of the growth rate of relative employment is -0.68 percent with a standard error of .06 while the quarterly average of the growth rate of the relative price is -.46 percent with a standard error of .05. In our model, the relationship between these growth rates is given by equation (23), which states that the ratio of the growth rate of relative employment levels to the growth rate of prices equals $1 - \sigma$. Since σ is bounded below by zero, the drop in relative prices over this period obviously cannot "account" for the entire drop in (relative) manufacturing employment. At most, the fall in relative prices can account for 68 percent of the fall in employment, and this happens when σ equals 0. If σ were equal to 0.2 only 54 percent of the fall in employment could be accounted for by prices, and if σ were equal to 0.5 only 34 percent could be accounted for.

One way to determine which value of σ is consistent with the data is to look at the behavior of relative output growth rates. (See Figure 2.) It turns out that the average difference between the growth rates of real output in the two sectors is -.04 percent per quarter, which means that service sector output has grown slightly faster than manufacturing output over this period. This could suggest the influence of other factors

[6] The reverse cointegrating regression leads to the same result. See Maddala and Kim (1998) for a discussion of the tests as well as tables on critical values.

which have caused relative manufacturing output to contract a little bit. However, the standard error of the difference in the mean growth rates is 0.14, which is more than large enough to argue that one cannot distinguish this number from zero, that is, that the average output growth rate in both sectors is the same. Equation (29) shows that real output in both sectors will grow at the same rate while productivity is growing at different rates only if σ is zero.

While the data appear to be consistent with a zero elasticity of substitution between goods and services, we are not entirely comfortable with this finding. It is not particularly hard to come up with examples where goods and services are substitutes: buying a washing machine is obviously a substitute for going to the laundromat.

In any case, even under the extreme assumption that σ equals zero, the decline in manufacturing employment over our sample exceeds what one would predict on the basis of the decline in relative prices. And the cointegration test fails as well. These findings suggest a role for other factors, such as rising goods imports. An imports-based explanation is potentially important for another reason as well, which is that it may allow us to explain the observed behavior of output growth rates without resorting to a zero elasticity of substitution. Specifically, it would allow consumers to react to the falling price of manufactures by increasing consumption of these goods, without any need for this greater demand to show up in higher domestic production of goods. The higher demand would show up, instead as an increase in imports.

4. A model where manufactures can be imported

The model in Section 2 is augmented in this section by allowing for the possibility that imports of manufactured goods can displace domestic production. The focus is exclusively on whether the benefits of importing from "low wage" trading partners could have played a significant role in the relative decline in U.S. manufacturing employment. As such, no explanation is sought for relative employment shifts across sectors as a result of the lack of mobility of technology across economies. Regardless of whether manufactures are produced in the United States or abroad, the production technologies are assumed to be identical up to a constant of proportionality for a given level of employment (which is a scale parameter that may be unity). However, manufacturing wages are allowed to differ across economies. There are many reasons why this may occur, such as differing opportunity costs of employment outside of the manufacturing sector, government tariffs, capital controls, etc. The reason for the wage differential is not taken up in this paper. The question is whether its effect is likely to be quantitatively significant in accounting for the observed sectoral shift of U.S. employment.

For simplicity, both the domestic production of manufactured goods, denoted x^d, as well as the foreign production of domestically consumed manufactures, denoted x^f, are assumed to be carried out by a single firm with the production technology:

$$F^x(n^x, n^f, \mu) = \mu[(n^x)^\alpha + b(n^f)^\alpha], \quad b > 0, \quad \alpha \in (0,1) \tag{30}$$

such that:

$$x^d = (n^x)^\alpha \text{ and } x^f = b(n^f)^\alpha \tag{31}$$

where n^x and n^f denote domestic and foreign employment in the manufacturing sector.

Profit maximization in the manufacturing sector can be jointly represented by choosing domestic and foreign employment, or:

$$\max_{n^x, n^f} qF^x(n^x, n^f, \mu) - wn^x - w^f n^f \tag{32}$$

First-order conditions yield:

$$w = q\alpha\mu(n^x)^{\alpha-1} \tag{33}$$

$$w^f = q\alpha\mu b(n^f)^{\alpha-1} \tag{34}$$

To capture wage differentials across economies, it is assumed that the domestic wage rate, w, is proportional to the foreign wage rate, w^f:

$$w = \lambda w^f, \quad \lambda > 0 \tag{35}$$

Therefore, higher labor productivity in the manufacturing sector in the United States would coincide with a value of $\lambda > 1$. The foreign wage rate here is best thought of as a trade-weighted wage rate. When the domestic economy first starts importing goods from a foreign economy whose wages are lower than those of other trading partners, the trade-weighted wage rate declines; with an unchanged domestic wage rate, the markup (λ) goes up.

With a portion of domestic production of manufactures exported, total domestic purchases of manufactured goods can be represented by:

$$x = (1-e)x^d + x^f, \quad e \in (0,1) \tag{36}$$

where ex^d represents the amount of domestically produced manufactured goods that are exported. We do not model the determinants of e.

Allowing for "offshore" production results in the following expressions for the growth rates of (relative) employment($\hat{q}$) and prices ($\hat{\phi}$):

$$\hat{q} = -\frac{1}{\alpha+\sigma(1-\alpha)}(\hat{\mu}-\hat{\theta}) - \frac{(1-\alpha)}{\alpha+\sigma(1-\alpha)}\hat{\Lambda} \tag{37}$$

$$\hat{\phi} = \frac{(\sigma-1)}{\alpha+\sigma(1-\alpha)}(\hat{\mu}-\hat{\theta}) - \frac{1}{\alpha+\sigma(1-\alpha)}\hat{\Lambda} \tag{38}$$

where $\Lambda \equiv 1 - e + b^{\frac{1}{1-\alpha}}\lambda^{\frac{\alpha}{1-\alpha}}$.

Note that $\hat{\Lambda}$ could change in response to factors affecting U.S. exports, or changes in the relative efficiency of manufacturing abroad or changes in the wage markup. For simplicity, we will refer to $\hat{\Lambda}$ as the foreign sector shock, with a positive shock leading to increased imports. Equations (37) and (38) indicate that the international trade of manufactured goods affects (secular movements in) either relative prices or employment only if $\hat{\Lambda} \neq 0$. Further, foreign sector shocks push relative prices and employment shares in the same direction. These effects are larger the smaller is the intratemporal elasticity of substitution between services and manufactures and reach a maximum when this elasticity is zero.

The foreign sector shock does have a greater effect on relative employment than on relative prices, which is consistent with the observed behavior of these variables over our sample. In the augmented model, the relationship between relative employment growth and the rate of growth of relative prices is given by

$$\hat{\phi} = (1-\sigma)\hat{q} - \hat{\Lambda} \tag{39}$$

(which is the counterpart of equation (23) in the closed economy model). Thus, $\hat{\phi}$ can fall by more than $\hat{q}$ as long as $\hat{\Lambda}$ is positive.

Further, note that the growth rate of domestic manufacturing output relative to service output is now given by

$$\hat{\psi} = \frac{\sigma}{\alpha + \sigma(1-\alpha)}(\hat{\mu} - \hat{\theta}) - \frac{\alpha}{\alpha + \sigma(1-\alpha)}\hat{\Lambda} \tag{40}$$

while the growth rate of the consumption of manufactures relative to services is given by

$$\hat{\psi^c} = \frac{\sigma}{\alpha + \sigma(1-\alpha)}(\hat{\mu} - \hat{\theta}) + \frac{\sigma(1-\alpha)}{\alpha + \sigma(1-\alpha)}\hat{\Lambda} \tag{41}$$

Note that foreign sector shocks affect the relative growth rate of domestic manufactures regardless of the value of σ but will not effect the relative consumption of manufactures if σ is zero.

Figure 4 shows how the effect of foreign sector shocks varies with the elasticity of substitution. As long as σ is finite, positive foreign sector shocks have an adverse effect on employment, output and prices in the manufacturing sector, with employment hit the hardest. These effects get larger the lower the value of σ. The relative consumption of manufactures always goes up in response to increased availability, but the effect gets smaller as σ falls. As before, there is no change in relative consumption when σ is zero. The intuition behind these results is straightforward: the less the consumer is willing to change the relative quantities of the two goods she consumes in response to a given increase in imports, the greater the amount by which the other variables must adjust.

We can also illustrate how foreign sector shocks can provide a means of reconciling a zero or relatively small growth rate of (relative) domestic manufacturing production with a nonzero elasticity of substitution. Specifically, equation (40) shows that positive foreign sector shocks could, in theory, offset the positive effects of faster manufacturing productivity growth on manufacturing output. (Note, from equation (41), that both forces would tend to increase the consumption of manufactures.)

To see how important this might have been in practice, it is necessary to get a measure of these shocks over our sample. While it is not easy to get a direct measure of $\hat{\Lambda}$, a little algebra shows that in our model $\hat{\Lambda}$ equals the growth rate of the ratio of total manufactures $(x^d + x^f)$ to domestic output of manufactures (x^d). It turns out that the mean growth rate of this variable is just .06 per cent per quarter (with a standard error of .04).

If we treat this mean growth rate as being zero, the implication is that foreign sector shocks simply cannot have played a significant role in the evolution of relative prices, output and employment over this period as a whole. Assume for the sake of argument that this value is different from zero. Even in that case these data provide little information to argue against our earlier finding that the elasticity of substitution equals zero. Specifically, with $\sigma = 0$ equation (39) above becomes

$$\hat{\psi} = -\hat{\Lambda}.$$

Over our 1955-2004 sample period, the right hand side of this expression is -.06 while the left hand side is -.04. Given the standard errors associated with these estimates, there is nothing here to contradict the assumption that $\sigma = 0$.

And the data pertaining to equation (41) do not suggest that σ is very different from zero either. Over the 1955Q1-2004Q2 period $\hat{\psi}^c$ equals .03 per cent per quarter with a standard error of .14. If we accept that $\hat{\psi}^c$ cannot be distinguished from zero, (41) implies either that $\sigma = 0$ or that the manufacturing productivity has been *declining* relative to productivity in services, albeit at a relatively low rate. Even if one were to argue that $\hat{\psi}^c$ should not be treated as zero, the resulting value of σ is small. For instance, if manufacturing productivity is assumed to have grown 1 percent faster than services productivity, the implied value of σ is 0.02; even if the difference between the two productivity growth rates is only 0.25 percent, the computed σ is still smaller than 0.08. Thus, our conclusion is that explicitly allowing for trade in manufactures with "low wage" countries provides little, if any, evidence to argue against the earlier results suggesting that the elasticity of substitution between goods and services is either zero or very close to it.

The other question is whether the incorporation of foreign sector shocks improves our ability to explain the decline in relative manufacturing employment over this period. Assuming that $\sigma = 0$, the right hand side of equation (38) equals -.52 while the left hand side is -.68, which means that one can explain a little more than 76 percent of the decline in employment over this period, which compares to 68 percent in the closed economy case.

Foreign sector shocks could, of course, still be playing a relatively large role in explaining relative employment declines in particular episodes. To see whether this might be the case, Figure 5 shows the actual and predicted changes in the ratio of manufacturing employment to 'total' employment over our sample (where total employment is defined as the sum of manufacturing and services employment). It turns out that in the data the share of manufacturing employment fell from 39.9 percent in 1955Q1 to 14.5 percent in 2004Q2. The line labelled 'forc_price' shows that based on the change in relative prices alone (and a zero σ) we would have predicted a manufacturing share of 21.1 percent in 2004Q2, while the line labelled 'forc_both' shows that including the effect of foreign sector shocks would have led us to predict a share of 19.1 percent. Note that there is little difference between the two forecasts over most of the sample. It is only during the 1990s that the two begin to show a sustained divergence, with the forecast based on equation (41) (which explicitly incorporates foreign sector shocks) lying closer to the actual value.

The bottom panel shows the cumulative error from these forecasts. These errors remain close to zero almost till the end of the 1960s but have been falling since then. The really large errors appear to be clustered around the early 1970s, and allowing for foreign sector shocks does not lead to a significant reduction in errors during this period. Note also that at the end of the sample the errors based on equation (41) are actually a bit smaller than they were in the 1970s while those based on equation (40) are a bit larger.

5. A Closer Look at the Data

This section takes a closer look at how relative prices, employment and output have behaved over time. One reason is to try to determine whether something unusual happened around the beginning of the 1970s. Figure 6 shows the four quarter growth rates of the relative price and employment series (we plot four quarter changes to smooth out fluctuations). Growth rates of both series seem to be lower towards the latter part of the sample than the first.[7]

Casual inspection of the graphs suggests that the slowdown could well have occurred around the early 1970s. Recall that this is also roughly the time that aggregate productivity growth slowed down. Indeed, some have argued that the aggregate productivity slowdown was the result of slower productivity growth in the services sector; see, for instance, Griliches (1992, 1994) and Bosworth and Triplett (2003). Others, such as Greenwood, Hercowitz and Krusell (1997, 2000) and Greenwood and Yorukoglu (1997) have pointed to an acceleration in the pace of decline in the relative price of capital goods (which are more closely associated with manufactures) as evidence of faster productivity growth in that sector. For the purposes of this paper it does not matter who is correct; what matters is that both sides are saying that the difference in productivity growth between the two sectors increased over this period. As long as one of the two hypotheses is correct, our model tells us that we should be able to find the productivity growth rate changes reflected in changes in the behavior of relative prices, employment and output.

We use tests devised by Bai and Perron (1998) to look for breaks in these series.[8] These tests allow for multiple breaks and can be used to detect breaks in the series when neither the dates nor the number of breaks are known. We allow a maximum of 3 breaks over our sample in all of the tests that follow. The limit of 3 breaks is never binding in the sequential tests below.

We present the results from three different tests in Table 1, based on recommendations in Bai and Perron (2000). According to Bai and Perron (BP), the sequential procedure works best overall, but often can be improved upon by a combination of the UDmax and the Sup(i+1|i) test. For that reason, we present results from all three tests.

[7]Unit root tests indicate that we can reject the null of a unit root in either of these series quite easily.

[8]We are grateful to Pierre Perron for providing us with a copy of his program to perform the calculations below.

The hypothesis that manufacturing sector employment has grown at the same rate relative to service sector employment over this period is rejected at the 5 percent level on the basis of the Udmax test and at the 10 percent level when the sequential procedure is used. The 95% confidence interval is quite wide, extending from 1960Q1 to 1983Q1. The coefficient estimates (not shown here) imply that after the break the rate of decline in manufacturing employment relative to services employment accelerated by 0.5 percentage points per quarter.

There is unambiguous evidence of a break in the relative price series as well. The break is estimated to have occurred in 1979Q2 with the 95% confidence interval extending from 1977Q1 to 1995Q1. According to the estimates, the rate of decline of the relative price of manufactured goods has also accelerated by close to 0.5 percentage points over this period.

Although the confidence intervals associated with the breaks that are found in the two series do overlap (which allows for the possibility of a common shock), the estimated break date for the relative price series is somewhat latter than appears consistent with the productivity slowdown. However, Figure 6 shows two positive spikes in the relative price series during the 1970s (whose timing coincides with the two major oil price shocks of this decade) and it is possible that these spikes are affecting the estimated break date. To examine what influence these oil price spikes may be having on the estimated break date we computed a price series for the goods sector that excluded oil and constructed an index that measured the price of non-oil goods relative to services. There is unambiguous evidence of a break in this series as well but the date of the break is located at 1974Q1 and the 95 percent confidence interval extends from 1970Q3 to 1979Q4. Thus, the oil price shocks do appear to be affecting the estimated break date of the relative price series and could be obscuring the fact that both the price and employment series were affected by a single shock.

We decided to conduct a straightforward test of this hypothesis by looking for evidence of a break in the difference between the growth rates of relative prices and employment. If the two series have breaks at different dates, then we should find evidence of two breaks in the series we are testing. As shown in column 3 of Table 1, the test statistics strongly reject the hypothesis that the two series break at different dates.

These results seem to confirm what Figure 5 suggests, which is that there has not been a change in the relationship between the the growth rates of relative prices and employment over the sample, even though both growth rates are lower in the second half of the sample than in the first. The errors in the early 1970s, then, represent a change in the *levels* of the series relative to each other. This suggestion may be useful in attempting to explain the relative decline in manufacturing during this period.

Taken together, the test results in the first 3 columns of the Table provide evidence about more than just a common break in the relative price and employment series. Consider, first, what this evidence tells us about the possible source of the break. From equations (37) and (38), the foreign sector shock changes the employment growth rate by three times as much as it changes relative prices (given our assumption that the labor share equals 2/3). Thus, the difference between the $\hat{q}$ and $\hat{\phi}$ will not remain unchanged if $\hat{\Lambda}$ changes. Note that the same argument can be made about $(\hat{\mu} - \hat{\theta})$ (the productivity differential term) – unless σ is zero. In other words, a change in relative productivity growth rates will lead to a change in the growth rate of prices relative to employment unless the elasticity of substitution between manufactures and services is zero.

Another place to find some evidence on this issue is to look at the behavior of the (relative) domestic output variable around this time. This variable is plotted in Figure 7. The chart does not provide much evidence of a change in the growth rate. Nor does the BP test; as shown in the last column of Table 1, we are unable to reject the null that there has been no change in the rate of growth of manufacturing sector output relative to service sector output over this period. Taken together with the other evidence in Table 1, this finding also implies that the elasticity of substitution is zero. From either equation (29) or (40), the lack of a break in the growth rate of relative output can be reconciled with a break in relative productivity growth only if the elasticity of substitution is zero.

More generally, the pattern of a change in relative prices and employment with no change in output seems consistent with a break on the production side in the presence of a zero elasticity of substitution than with a break on the demand side. A shift in preferences (a break in income elasticities, perhaps, even with the elasticity of substitution held at zero) would lead to changes in output, prices and employment.

Finally, the failure of output growth rates to respond to a change in the trend growth rate of prices provides information regarding another hypothesis as well, which is the role that differential income elasticities may have played in explaining the observed growth of manufacturing and services over this period. It has been argued that services have a higher income elasticity than manufactures do (see Rowthorn and Ramaswamy,1999). A relatively low income elasticity could then be the reason why the demand for manufactures has not gone up any faster than the demand for services over this period, despite the substantial fall in the relative price of manufactures. Thus, what looks like a zero elasticity of substitution could just be the result of these two factors fortuitously offsetting each other. However, the fact that the growth rate of manufacturing relative to services did not change even after a (likely productivity-induced) break in the trend growth rate of prices shows that the elasticity of substitution is essentially zero – unless one wants to invoke an even more fortuitous offsetting break in some other variable at about the same time.

This argument is not meant to claim that the income elasticity of demand for services does not exceed the income elasticity of demand for manufactures at any point in time or at any income level, but only that differential income elasticities do not appear to have a large role to play in explaining the evolution of manufacturing relative to services in the postwar U.S. data.

6. Conclusions

Since 1955, there has been a secular decline in the manufacturing sector's share of employment in U.S. economy. There has also been a secular decline in the relative price of manufactured goods, while the share of total output in the U.S. economy attributable to manufacturing has held fairly steady. We have shown that these "facts" are largely consistent with faster productivity growth in the manufacturing sector and a zero elasticity of substitution between manufactures and services.

Using the restrictions from a two-sector closed economy model, price data suggest that differential productivity growth across sectors can account for approximately two-thirds of the observed relative decline in U.S. manufacturing employment between 1955Q1 and 2004Q2. The two periods when this explanation falls short are in the early 1970s and the most recent period, beginning in the early 1990s. The latter period may be associated with increased imports from "low wage" trading partners, and may account for as much as eight percent of the overall relative decline in manufacturing recorded over the entire sample period. The larger prediction errors that occurred in the early 1970s appear to be unrelated to trade with "low wage" countries, and remain an unexplained puzzle.

Interestingly, a very low elasticity of substitution between manufactures and services turns out to be essential for explaining the observed behavior of output, prices and employment in the two sectors. The data on relative output, in particular, argue that this elasticity is effectively zero. Looking at sample averages, this is evident in the fact that output in the two sectors has grown at about the same rate even though the relative price of manufactures has fallen so much. The break tests provide perhaps even stronger proof: there is no hint of a change in the growth rates of relative quantities even though the growth rates of both relative prices and employment show clear evidence of change, evidence that is consistent with a break in relative productivity growth rates.

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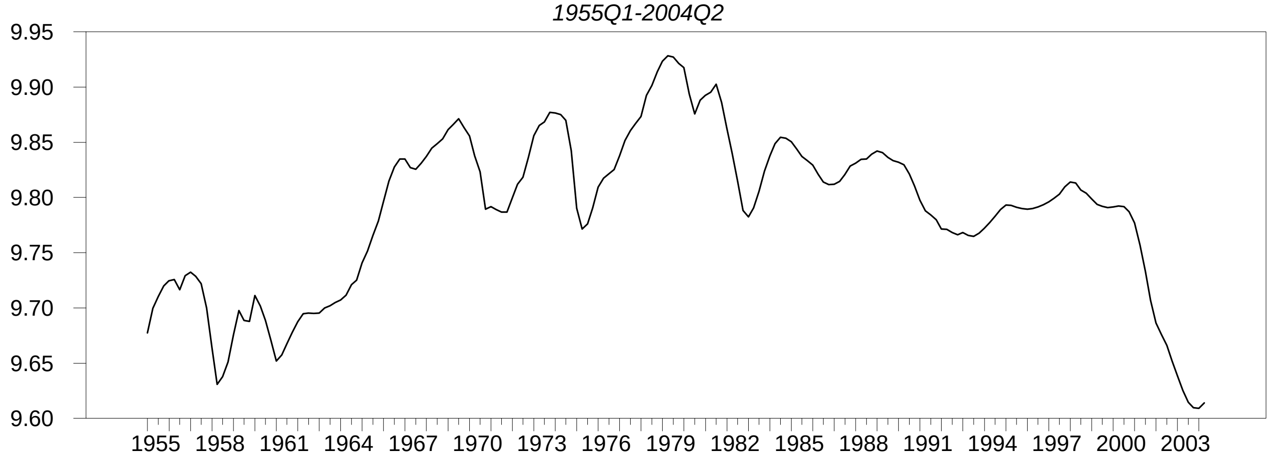
Table 1: Testing for Breaks in Relative Growth Rates

Series tested:	Employment	Prices	Emp-pri	Output
Test:				
Udmax	10.5[5]	38.8[1]	1.3	3.5
Sup (2|1)	7.2	3.7	0.7	0.5
Break dates-from Sup tests	1969Q1	1979Q2	none	none
Break Dates-from Sequential Procedure	1969Q1[10]	1979Q2[1]	none	none
95% Confidence Intervals for break dates	60Q1-83Q1	77Q1-95Q1		

A. [10] denotes significant at 10 %,[5] denotes significant at 5 %,

Figure 1. Log of Employment in Manufacturing Sector

1955Q1-2004Q2



Log of Employment in Services Sector

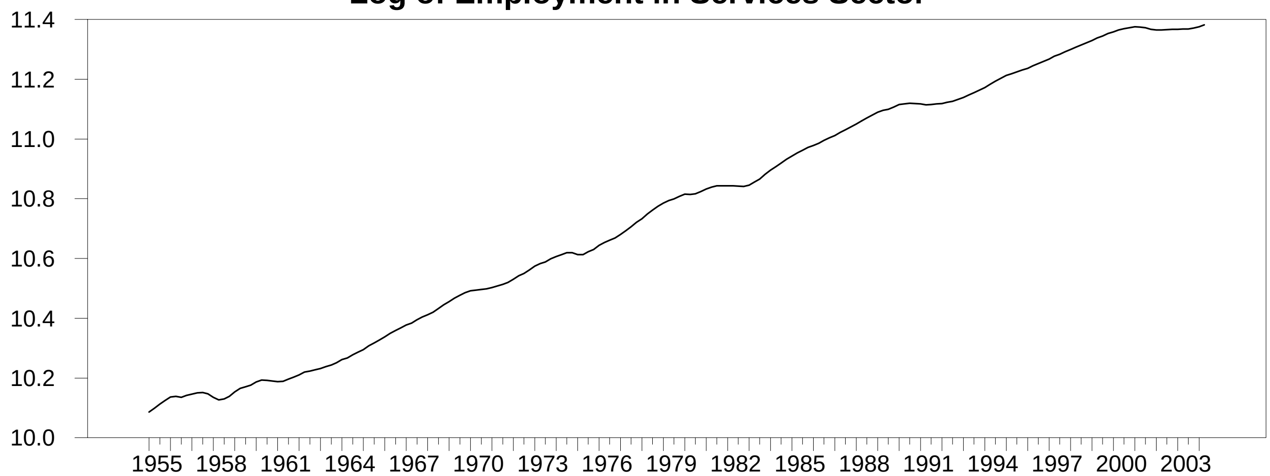


Figure 2.
Effects of a Change in Relative Productivity Growth

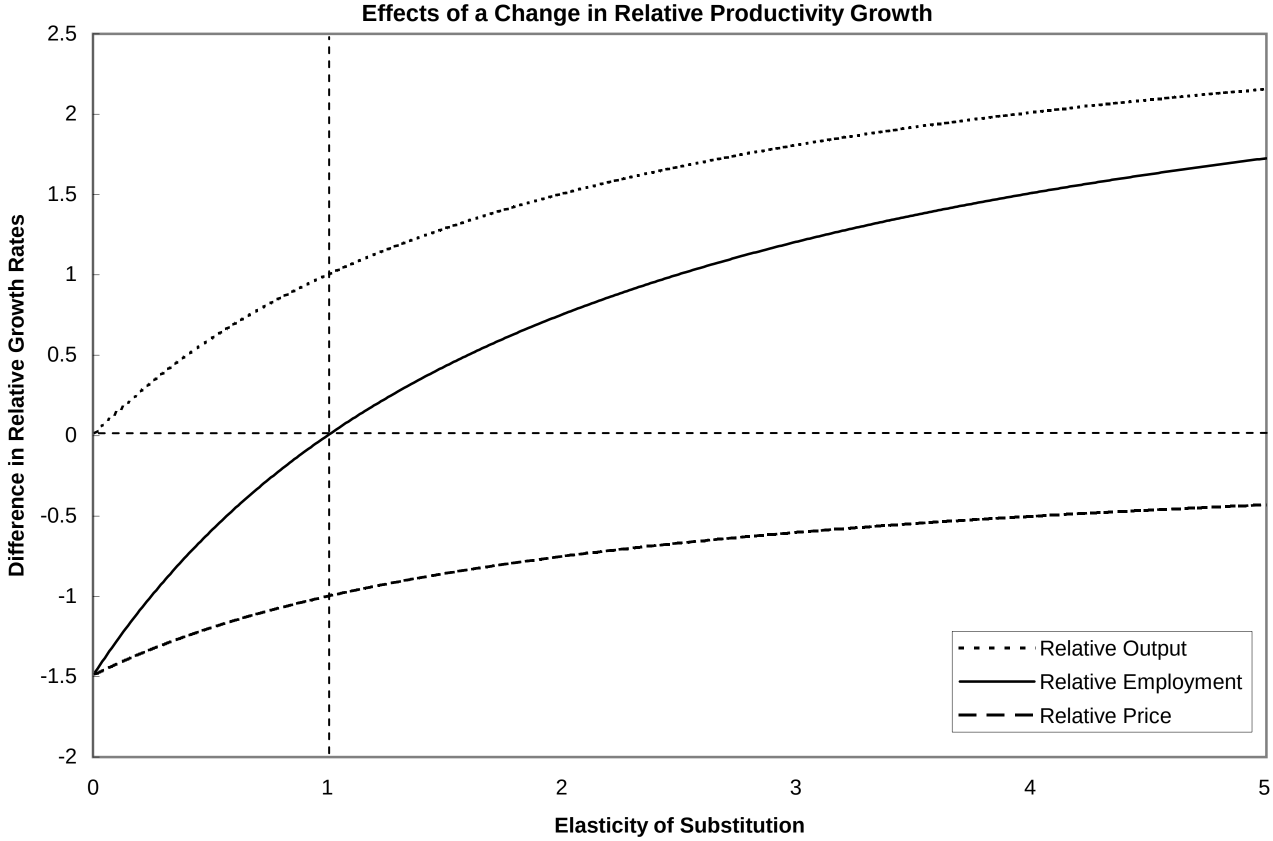
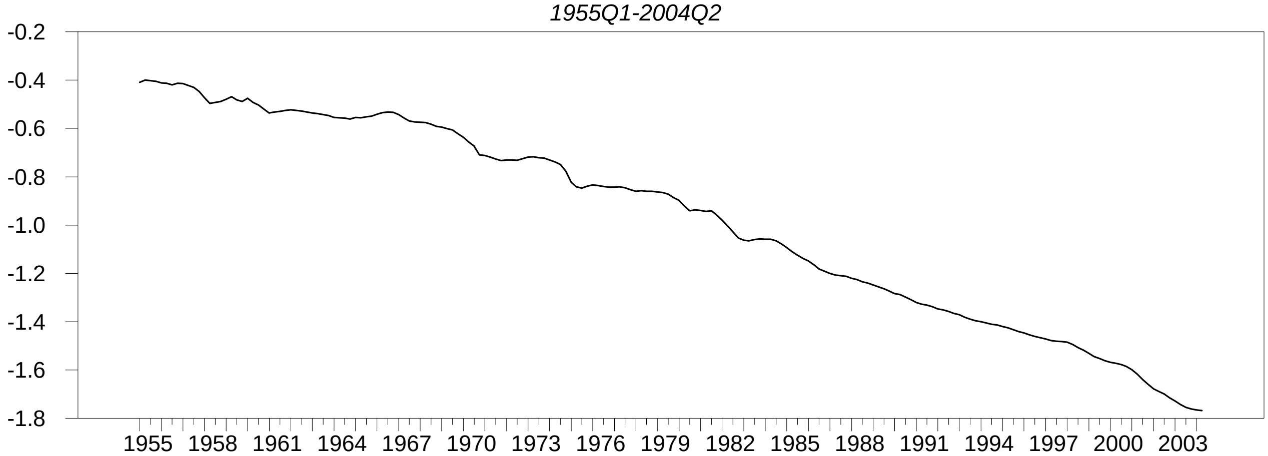


Figure 3. Log of Relative Employment

1955Q1-2004Q2



Log of Relative Price

1955Q1-2004Q2

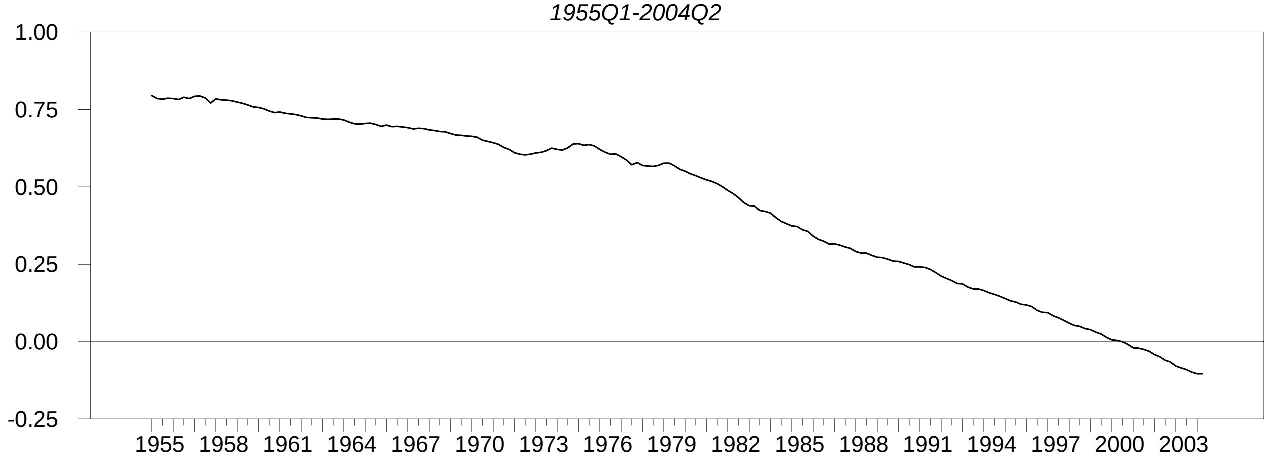


Figure 4.
Effects of Foreign Sector Shocks

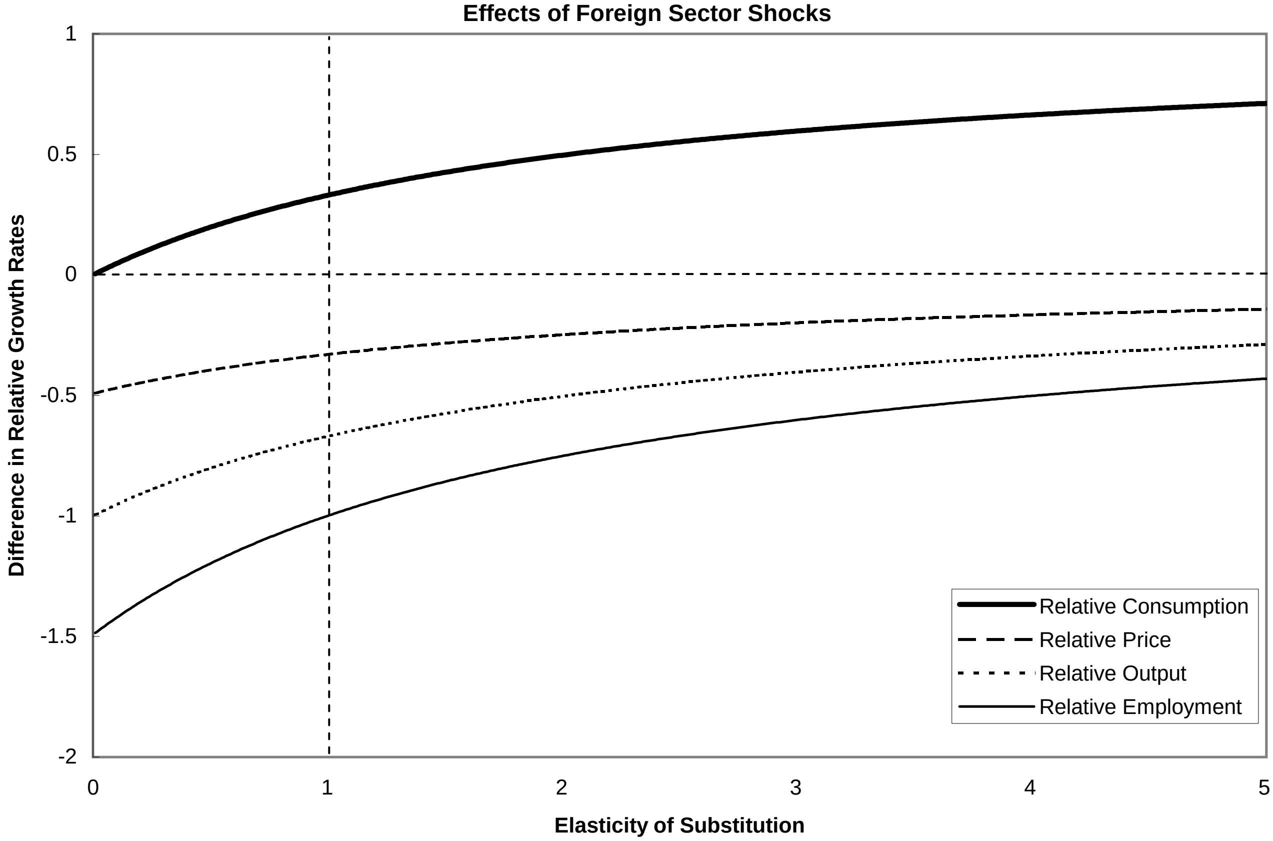
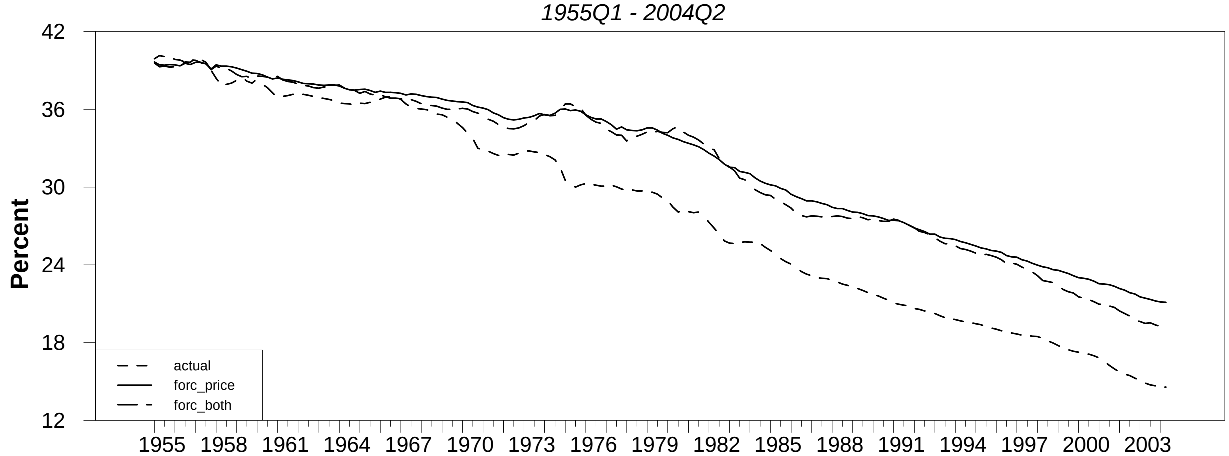


Figure 5: Share of Manufacturing Employment

1955Q1 - 2004Q2



Cumulative Error in Predicting the Share of Manufacturing Employment

1955Q1-2004Q2

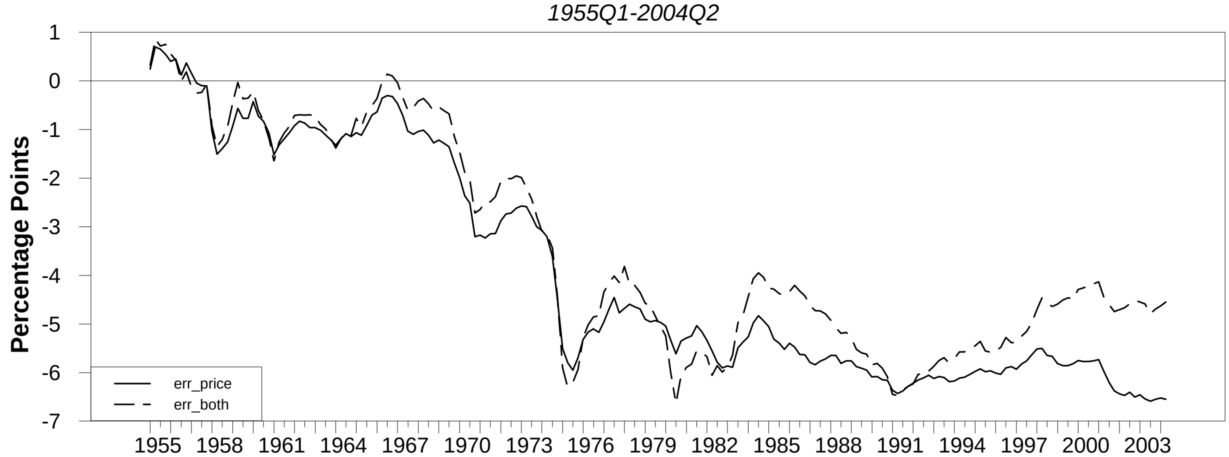
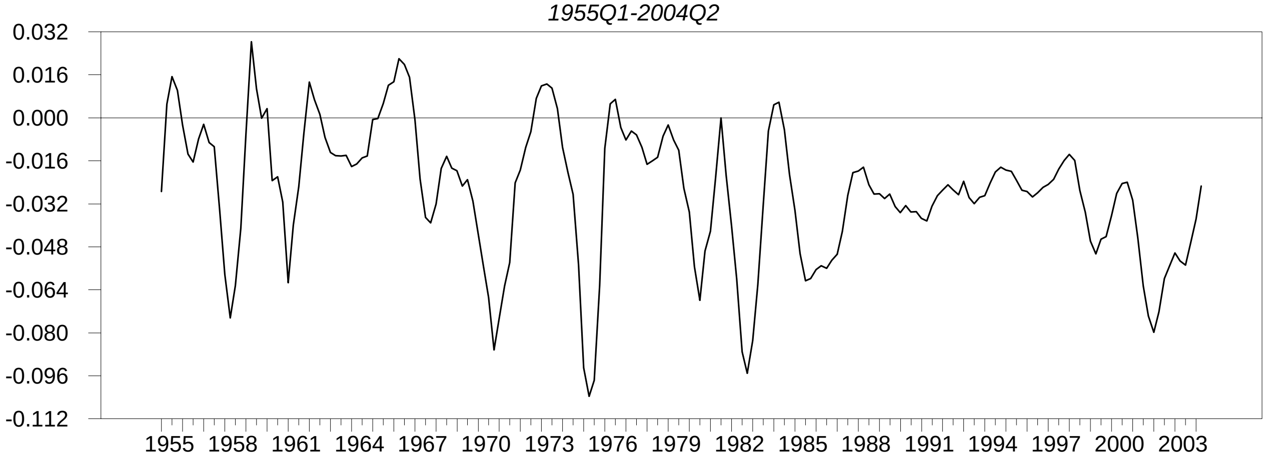


Figure 6. Four Quarter Growth Rate of Relative Employment

1955Q1-2004Q2



Four Quarter Growth Rate of Relative Price

1955Q1-2004Q2

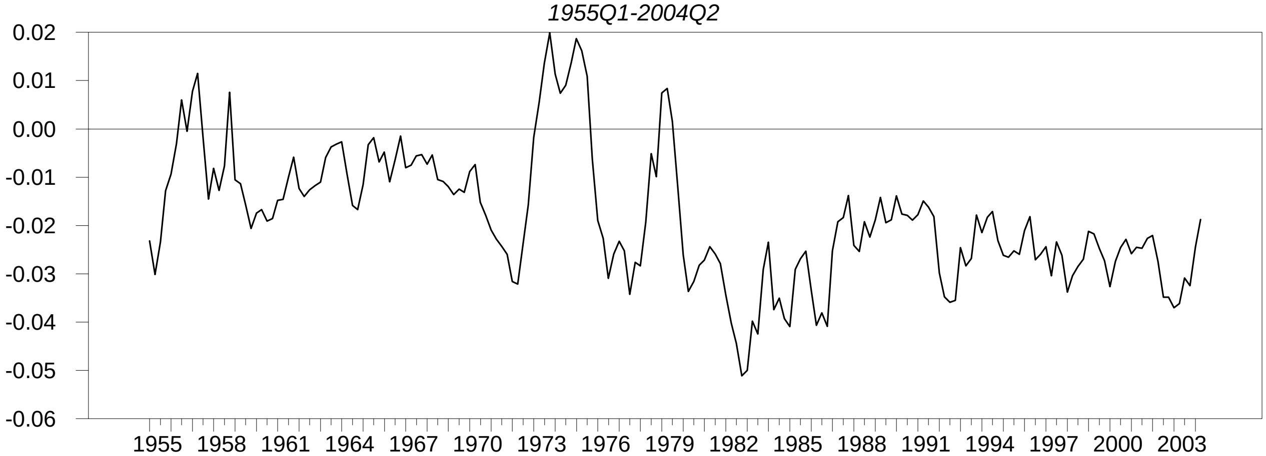


Figure 7. Four Quarter Growth Rate of Relative Output

1955Q1-2004Q2