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Abstract

There has been considerable debate about the causes of the "decline" of U.S. manufacturing over the post-war period. We show that the behavior of employment, prices and output in manufacturing relative to services over this period can be explained by a two-sector growth model in which productivity shocks are the only driving forces. The data also suggest that households are unwilling to substitute goods for services (the estimated elasticity of substitution is statistically indistinguishable from zero), so the economy adjusts to differential productivity growth entirely by re-allocating labor across sectors.

keywords: productivity growth, manufacturing employment

*Any opinions expressed in this paper are those of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

1. Introduction

Over most of the post-war period, employment in the manufacturing sector in the United States has grown noticeably more slowly than employment in services, while the relative price of manufactures has declined. Faster productivity growth in the manufacturing sector is often cited as an explanation.[1] Moving resources to services may be the optimal response to higher productivity growth in manufacturing because it could allow increased consumption of both goods. However, others have emphasized the role of rising imports[2]; indeed, in popular discussions, the decline in manufacturing employment is often seen as evidence of the decline of U.S. manufacturing. In rebuttal, it has often been noted that a significant role for imports is hard to reconcile with output data which show little, if any, secular decrease in manufacturing output relative to real GDP.[3]

However, an approximately constant ratio of manufacturing output to GDP does not necessarily imply that increased imports have had little effect on the U.S. economy. For example, the constant share of manufacturing output to GDP could be the result of two roughly offsetting changes: an increase in demand (of any size) for manufactures in response to productivity-induced declines in the relative price and an increase in imports to satisfy this demand.

How much the demand for manufactures will go up in response to falling prices depends upon household preferences. Consequently, in Section II below, we specify a two-sector model (manufactures and services) in which close attention is paid to how the parameters of the household utility function affect the response of the economy to various disturbances. Specifically, we assume that household utility is given by a *CES* utility function, so that the economy's response to productivity

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

[2]See Ravenga (1992), and Sachs and Shatz (1994)for analyses of the effects of increased imports on U.S. manufacturing employment and wages.

[3]See, for example, Bernanke (2003).

shocks depends upon how willing the consumer is to substitute between manufactures and services. On the supply side, in order to focus on the role of productivity, we assume the same constant-returns-to-scale production technology in the two sectors, but allow them to experience different rates of exogenous technological progress.

Our objective is to try and determine how much a productivity-driven model can explain. As we show below, the production side of our model imposes restrictions on the relationship between the growth rates of relative prices, output and employment in the two sectors. These restrictions are not rejected in our data sample which spans the 1950Q1-2006Q1 period. Two other findings are worth noting. First, we find that the average growth rate of manufactured goods output is statistically indistinguishable from that of the output of services. Second, the decline in the price of investment goods relative to the price of services is of the same size as the decline in manufacturing employment relative to services employment. In our model these findings are equivalent, in the sense that one implies the other. In addition, since relative prices depend only upon relative productivity in the two sectors, the latter finding also suggests that relative productivity shocks have been the dominant factor behind the decline in manufacturing employment over this period.

We also show that the utility function imposes restrictions upon how the ratio of goods to services consumption should grow relative to the growth rate of prices. It turns out that while the consumption of manufactures has grown at the same rate as the consumption of services over the 1950Q1-2006Q1 sample, the price of manufactures relative to services has fallen quite sharply over this period. In the model this implies that the elasticity of substitution is zero, that is, consumers appear to be completely unwilling to substitute manufactures for services.

Equal growth rates of consumption over a roughly 50-year span in the face of a pronounced trend in relative prices do not, by themselves, prove the case for a zero elasticity of substitution between manufactures and services. To take one example, a relatively high income elasticity of demand for services could offset the effect of technologically induced declines in the relative price of manufactures and make it appear as though consumers were unwilling to substitute between the two goods. The sample period under study turns out to contain a natural experiment that provides a way to distinguish alternative hypotheses. It turns out that there is a statistically significant acceleration in the rate of productivity growth in the manufacturing sector relative to productivity growth in the services sector during the late 1960s.

According to our model, this permanent change in relative productivity growth rates should show up in changes in the growth rates of relative prices, employment, etc. We find evidence of breaks in the relative employment series and in the series measuring the price of investment goods relative to services whether we condition on the productivity break date or not. We also find that the change in the growth rate of the relative price variable is (statistically) of the same magnitude as the change in the growth rate of relative employment, which again is what the productivity-driven model predicts. We find no evidence of any break in relative consumption growth rates but do find some evidence of a break in the relative price of consumer goods relative to services when we condition upon the productivity break, which again suggests a substitution elasticity of zero.

The remainder of the paper is organized as follows. Section 2 lays out the theoretical model and derives the restrictions placed by the model on the behavior of output, employment and prices in the two sectors. Section 3 presents the data as well as the results of the empirical tests based upon the model while Section 4 concludes.

2. A Two-Sector Model with Differential Productivity Growth

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 can take the form of changes in the relative price of goods versus services, changes in relative outputs as well as shifts of employment between sectors.

2.1. **Households.**

The economy consists of a large number of identical households that derive utility by consuming services, s, and manufactured goods, m^c, in accordance with a *CES* utility function:

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

The intratemporal elasticity of substitution between services and manufactures is given by:

$$\sigma = \frac{1}{1+\rho}, \quad \sigma \geq 0 \tag{2}$$

and determines the intratemporal marginal rate of substitution between m^c and s:

$$\frac{U_s}{U_{m^c}} = \left(\frac{\eta}{1-\eta}\right)\left(\frac{m^c}{s}\right)^{\frac{1}{\sigma}} \tag{3}$$

The representative household maximizes lifetime utility by choosing the mix of services and manufactured goods to purchase, the allocation of labor between the production of services (n^s) and the production of manufactures (n^m), and gross investment (i) in capital (k) that is rented to the producing firms:

$$\max_{\{s,m^c,i,n^s,n^m\}} \int_0^\infty e^{-\nu t} U(s, m^c), \quad \nu \in (0,1) \tag{4}$$

The household's choices take the initial capital stock, k_0, as given and are subject to a budget constraint:

$$s + q(i + pm^c) \leq w^s n^s + w^m n^m + qrk \tag{5}$$

where q is the relative price of investment goods in units of services, r is the real rate of return on capital, pq is the relative price of household manufactured goods to services, and w^s and w^m are real wage rates for employment in the two sectors.

Net investment in capital is given by:

$$\frac{dk}{dt} = i - \delta k, \quad \delta \in (0,1) \tag{6}$$

where δ is the depreciation rate.

Labor allocations also must satisfy the resource constraint:

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

The set of optimality conditions that solve the household's problem is:

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

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

$$\frac{1}{U_s}\frac{dU_s}{dt} = \nu - r + \delta - \frac{1}{q}\frac{dq}{dt} \tag{10}$$

$$\frac{1}{U_{m^c}}\frac{dU_{m^c}}{dt} = \nu - r + \delta + \frac{1}{p}\frac{dp}{dt} \tag{11}$$

Equation (8) represents the efficiency condition that determines the household's intratemporal consumption bundle, and equation (9) is the condition that induces an optimal allocation of labor. Equations (10) and (11) indicate how relative prices affect the trends in the marginal utilities of services and manufactures. As discussed below, a secular decline in the relative price of investment goods, that would occur in the event of faster productivity growth in the manufacturing sector than in the services sector, increases the marginal utility of services, while a secular decline in the relative price of household manufactures, that may come about through a combination of economic growth and a lack of substitutability between manufactures and services in consumption, would reduce the growth in the marginal utility of manufactures. These relationships impose restrictions from household preferences that relate the relative growth rates of household manufactured goods and services to changes in their relative price. Specifically,

$$\hat{\varphi} \equiv \hat{m}^c - \hat{s} = -\sigma(\hat{p} + \hat{q}) \tag{12}$$

where a "ˆ" over a variable denotes a growth rate and φ is defined to equal the ratio of the consumption of manufactures to services.

2.2. **Production sectors.** The production technologies in the manufacturing and service sectors are represented by CRS production functions.[4] Except for the productivity processes, the production functions in the two sectors are identical. With both sectors assumed to be competitive in the factor and product markets, their optimal factor

[4]We have deliberately chosen to combine manufactured consumption goods and investment goods into a single production sector. This is consistent with our primary interest, which is the shift of employment from all manufacturing jobs to the services sector. An important reason for not studying the two manufacturing sub-sectors separately is that no clear distinction can be made in the data between workers employed in the production of consumption goods versus investment goods. A clear, simple example is a laptop computer that could be either type of good. In the model, we adjust the equilibrium condition, equation (22) below, in a manner similar to Greenwood and Hercowitz (1998), where the relative price between the two types of manufactures captures the difference in sectoral productivities from their respective production processes at this level of aggregation.

employment decisions can be characterized as decisions taken by individual profit-maximizing firms.

The service sector firm chooses the amount of capital, k^s, to rent from the household, and the quantity of labor to employ in order to maximize profits (or output minus factor payments):

$$\max_{k^s, n^s} \quad \theta F^s(k^s, n^s) - qrk^s - w^s n^s \tag{13}$$

where the production technology is given by: $F^s(k^s, n^s) = k^{s\alpha} n^{s1-\alpha}$, $\alpha \in (0,1)$, and θ is the total factor productivity term that is assumed to grow at an exogenous rate, $\hat{\theta} > 0$. The first-order conditions for this problem yield:

$$qr = \alpha\theta\Big(\frac{k^s}{n^s}\Big)^{\alpha-1} \tag{14}$$

$$w^s = (1-\alpha)\theta\Big(\frac{k^s}{n^s}\Big)^{\alpha} \tag{15}$$

The manufacturing sector has a symmetric set of optimal factor employment decisions resulting from the profit-maximization condition:

$$\max_{k^m, n^m} \quad q\mu F^m(k^m, n^m) - qrk^m - w^m n^m \tag{16}$$

where k^m is the capital rented from the household and the production technology is given by: $F^m(k^m, n^m) = k^{m\alpha} n^{m1-\alpha}$, and μ is the total factor productivity term that grows exogenously at rate $\hat{\mu} > 0$.[5] The first-order conditions are:

$$r = \alpha\mu\Big(\frac{k^m}{n^m}\Big)^{\alpha-1} \tag{17}$$

$$w^m = q(1-\alpha)\mu\Big(\frac{k^m}{n^m}\Big)^{\alpha} \tag{18}$$

[5]The predictions of this model that are taken to the data are independent of whether the factor shares for capital and labor differ between sectors.

With an economy-wide capital market, and equating wage rates across sectors, (9), (14)-(15), and (17)-(18) yield:

$$\frac{k^s}{n^s} = \frac{k^m}{n^m} \tag{19}$$

implying that the capital-labor ratios are identical in both sectors, and:

$$q = \frac{\theta}{\mu} \text{ or } \hat{q} = \hat{\theta} - \hat{\mu} \tag{20}$$

indicating that the relative price of manufactured goods is determined by the ratio of the two productivity terms, such that the relative price declines when productivity is growing more rapidly in the manufacturing sector than in the service sector.[6]

2.3. **Properties of the equilibrium growth path.** In equilibrium, the amount of services and manufactured goods produced must equal the amount purchased by the households, and the stock of capital owned by households equal the amount employed in production:

$$s = \theta F^s(k^s, n^s) \tag{21}$$

$$pm^c + i = \mu F^m(k^m, n^m) \tag{22}$$

$$k = k^s + k^m \tag{23}$$

Note that p is the investment-goods price of consumption goods and reflects the difference in productivities associated with the production of investment versus consumption goods.[7]

[6]In this framework, the behavior of the relative price 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. This issue is related to a debate in the literature about the productivity slowdown in the 1970s, and we will return to it below.

[7]Had we chosen to write down a three-sector model by disaggregating the manufacturing sector, we would have obtained expressions identical to equations (25) and (26), which are among the key model predictions that we take to the data.

From equations (20) through (22):

$$\phi = \frac{\psi}{q} \tag{24}$$

where $\phi \equiv (pm^c + i)/s$ and $\psi \equiv n^m/n^s$, that is, ϕ is defined as the ratio of output in the manufacturing sector to output in the services sector and ψ is defined as the ratio of employment in the manufacturing sector to employment in the services sector.

Equation (24) imposes theoretical restrictions from the production side of the economy on the relative growth rates of the key variables in our model. Specifically, we get

$$\hat{\phi} = \hat{\psi} - \hat{q} \tag{25}$$

which states that the growth rate of relative output equals the growth rate of relative employment minus the growth rate of the relative price. From (20), since the growth rate of the relative price equals the relative growth rate of productivity in the two sectors, equation (25) implies that differences in productivity growth in the two sectors will lead to changes in labor allocation across sectors depending upon how the output of manufactures changes relative to the output of services. Household preferences obviously have a major role to play here, since they determine how much the household will change consumption in response to productivity-induced changes in relative prices.

When preference restrictions from (12) are included, equation (25) becomes:

$$\hat{\psi} = \widehat{pm^c + i} - \hat{m}^c - \sigma\hat{p} + \big(1 - \sigma\big)\hat{q} \tag{26}$$

Therefore, preferences play a role in the shifts of employment between manufacturing and services by influencing the weights attached to the two different relative prices: $\hat{q}$ and $\hat{p}$. In the special case of Leontief preferences, where $\sigma = 0$, households are unwilling to substitute between household manufactures and services, and equation (26) becomes

$$\hat{\psi} = \widehat{pm^c + i} - \hat{m}^c + \hat{q}.$$

In this case, the relative price of manufactured consumption goods does not matter and the relative price of investment goods to services, (or $\hat{q}$), has a larger impact on employment shifts across sectors. As σ increases, which is to say that households become more willing to substitute between services and manufactured consumption goods, changes in the relative price of household manufactures to services have a larger impact on the shifts of employment across sectors. In the special case of Cobb-Douglas preferences, for example, where the elasticity of substitution is $\sigma = 1$, equation (26) becomes:

$$\hat{\psi} = \widehat{pm^c + i} - \hat{m}^c - \hat{p}$$

Note that, in contrast to the case where $\sigma = 0$, here $\hat{p}$ has replaced $\hat{q}$ in determining the secular employment shift between manufacturing and services when the two sectors are experiencing different rates of productivity growth.

3. Testing the model

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 NIPA accounts, where the output of the mining sector is grouped together with manufactures under goods. Compatibility requires that we make two other adjustments. First, goods sector employment is adjusted to remove employment in the construction sector (since structures are classified separately from goods in the output and price data). Second, housing services are removed from the output and price data, which ensures compatibility with the employment data and the goods output data. For convenience, we will continue to refer to the two sectors as manufacturing and services.

Figures 1 and 2 present data for the 1950Q1-2006Q1 period for some key variables as identified by our discussion in the previous section. The first panel in Figure 1 shows the growth rate of the output of manufactured goods relative to services, where the output measure has been defined according to the model above; specifically, we plot $\hat{\phi}$. The second panel shows the growth rate of manufactured consumption goods relative to the growth rate of services, or $\hat{\varphi}$ in the model. The last panel plots the growth rate of manufacturing employment relative to services (that is, $\hat{\psi}$). Figure 2 presents data on prices. The top panel plots the growth rate of the price of investment goods relative to services ($\hat{q}$) while the bottom panel plots the growth rate of the price of consumption goods relative to services ($\hat{q} + \hat{p}$).

We now examine whether these data are consistent with the restrictions imposed by the model above. Consider, first, equation (25) which requires that the growth rate of output equal the difference between the growth rates of employment and prices in the two sectors. For our sample, the average growth rate of ϕ (relative output) equals 0.11 percent,[8] with a standard error of 0.15 percent, while the average growth rate of ψ (relative employment) equals -0.61 (SE =0.06)and that of q (relative price) equals -0.67 (SE=.05). As a comparison of these numbers would suggest, the restriction that the average value of $\hat{\phi} - (\hat{\psi} - \hat{q})$ equals zero cannot be rejected at even the 65% significance level. In addition,

[8]Growth rates are differences of logs multiplied by 100.

one also cannot reject the hypothesis that the average growth rate of relative output is zero at any conventional level of significance (which is what inspection of the top panel of Figure 1 also suggests.) The implication is that $\hat{\psi} - \hat{q}$ is zero as well; it turns out that this hypothesis cannot be rejected at anything close to a conventional significance level either.

In the context of our model, these findings have a powerful implication about the causes of the shift in employment from manufacturing to services over our sample period. Since the growth rate of relative employment in the two sectors equals the growth rate of relative prices and the growth rate of relative prices depends only upon the relative growth rate of productivity in the two sectors, the implication is that the difference in employment growth rates over this period can be attributed entirely to differences in productivity growth rates.

Consider, next, the condition imposed by the utility function:

$$\hat{\phi} = -\sigma(\hat{p} + \hat{q})$$

which is equation (12) above. As the middle panel of Figure 1 suggests, one cannot reject the hypothesis that the average growth rate of manufactured goods consumption is the same as the average growth rate of services consumption at conventional significance levels; the average growth rate of ϕ is -0.16 while the standard error is 0.14. On the other hand, the term in parentheses on the right hand side of the equation above is different from zero even at the 0.01 percent level of significance. (That term represents the growth rate of the price of manufactured consumption goods relative to the price of services and is plotted in the lower panel of Figure 2; it fell at an average rate of 0.48 percent per quarter.) Thus, the left hand side of the equation is zero while the term in parentheses on the right hand side is different from zero, which implies that σ must be zero. In other words, the fact that the consumption of manufactures has grown at the same rate as the consumption of services over this period even though the relative price of manufactures has been falling implies that consumers are completely unwilling to substitute between the two.

An alternative estimate of σ–one which embeds restrictions from both the production and consumption sides of the model–can be obtained from equation (26). Specifically, equation (26) implies

$$\sigma = \frac{(\widehat{pm^c + i} - \hat{m}^c) - (\hat{\psi} - \hat{q})}{\hat{p} + \hat{q}}.$$

This leads to an estimate of $\sigma = 0.36$ over the 1950Q1-2006Q1 period, but the associated standard error of 1.45 is substantially larger and implies a t-statistic of 0.25. Thus, the hypothesis that the elasticity of substitution is zero cannot be rejected. And even if one were inclined to ignore the standard error, the point estimate suggests that households are not very willing to substitute between goods and services.

Comparing averages over a 50-year span does not reveal everything, of course. For instance, while the equality of output growth rates in the two sectors in the face of a continuing decline in the relative price of manufactures over this time period is consistent with a zero elasticity of substitution, it does not rule out other explanations. In particular, since services are generally believed to have a higher income elasticity of demand than manufactures, the effect of rising incomes could offset the effect of falling relative prices on the demand for manufactures relative to services and make it appear as if the elasticity of substitution was zero (see, for example, Rowthorn and Ramaswamy,1999). While a model with differential income elasticities is beyond the scope of this paper, we now present the results of some tests that provide more direct evidence about the elasticity of substitution as well as some other aspects of our model. These tests are based on the hypothesis that there was a change in the relative growth rates of productivity in the two sectors during our sample period.[9] We identify empirically

[9] A number of authors have argued that the aggregate productivity slowdown around the early 1970s reflected a change in relative productivity growth rates in the two sectors. For instance, Griliches (1992, 1994) and Bosworth and Triplett (2003) argue that the aggregate slowdown was the result of slower productivity growth in the services sector. Others, such as Greenwood, Hercowitz and Krusell (1997, 2000) and Greenwood and Yorukoglu (1997) have pointed to an

when the change in relative productivity growth rates took place, and then ask what effect this has on the variables in our model.

Direct measures of quarterly TFP growth in the two sectors are extremely difficult to construct and consequently hard to find. At an annual frequency there are the industry level measures of aggregate technology change constructed by Basu, Fernald and Kimball (2004).[10] These measures control for variations in the utilization of capital and labor as well as non-constant returns to scale and imperfect competition. We aggregate the industry level measures to get the corresponding measures for the manufacturing and services sectors and subtract the latter from the former to get a series that corresponds to $(\hat{\mu}-\hat{\theta})$ above, that is, a series which measures the difference in TFP growth between the two sectors.

We use tests devised by Bai and Perron (1998) to look for breaks in this series over the 1955-1996 period, as the Basu-Fernald-Kimball data only extend through 1996. 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.

The results from three different tests are presented below, based on recommendations in Bai and Perron (2003). 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 SupF(i+1|i) tests. For that reason, we present results from all three tests.

The hypothesis that the relative rate of productivity growth did not change (i.e., that manufacturing productivity grew at the same rate as services sector productivity) over the 1955-1996 period is rejected

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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.

[10]We thank John Fernald for providing us with these data.

at the 1 percent level by the UDmax test. At the same time, the supF(2|1) test returns a value of 2.9, which is substantially below the 10 percent critical level of 7, which means that we fail to reject the null of one break in the series against the alternative of two breaks. The point estimate of the date of the single break is 1967. The sequential procedure also finds just one break, with the rate of TFP growth in manufacturing accelerating relative to that in services in 1967. The 95 percent confidence interval associated with this break extends from 1961 to 1972.

Thus, there is strong evidence that the rate of (relative) productivity growth changed in the late 1960s. According to the model and the empirical results above, this break should show up in relative prices, quantities, etc. For instance, equation (20) implies that a change in relative productivity growth rates should show up in a break in the growth rate of the relative price.

We test this hypothesis by splitting our sample at the date identified by the break test on relative productivity growth and examining whether there is a change in the growth rates of prices, employment, etc. at this date. The results are presented in Table 1. The first row shows that the relative price of investment goods fell at a substantially faster pace in the second sub-sample than in the first, and that this difference was statistically significant. This is exactly what equation (20) would predict: a statistically significant increase in the rate of productivity growth in manufacturing relative to productivity growth in services should show up in a statistically significant increase in the rate at which the price of investment goods falls relative to the price of services.

The next row of the table shows that there is a break in the growth rate of relative employment as well, with services employment growing significantly faster in the second sub-sample. But, as shown in row 3, the same thing is not true for relative output growth, that is, one cannot reject the null hypothesis of no change in the average growth rate across the two sub-samples. At first glance the results in the first three rows of Table 1 may appear to be inconsistent with equation (25), since a permanent change in the growth rate of the variables on the right hand side of the equation should be accompanied by a permanent change in the growth rate of the variable on the left hand side. The fourth row of Table 1 provides a resolution: it shows that there was no change in the growth rate of employment relative to prices (that is, in $\hat{\psi}-\hat{q}$) from the first period to the second, which is to say that one cannot reject the hypothesis that the growth rates of the two series changed by the same amount across the two periods. Note that this finding also suggests a substantial role for productivity shocks in explaining the behavior of relative employment, prices and output over this period.[11]

Next, we consider the implications of equation (12), which expresses the relative growth of goods to services consumption as a function of relative prices. The second last row of Table 1 shows that one cannot reject the null hypothesis that the growth rate of the consumption of goods relative to services was not affected by the change in relative productivity growth. Finally, the last row provides some evidence suggesting that the price of consumer goods (relative to the price of services) fell faster after the change in the growth rate of productivity. That is, one can reject the null of no change in the growth rate of this relative price at the 10 percent level.

This evidence of a break in the relative price series provides support for the argument that σ, the elasticity of substitution between goods and services, is zero. Importantly, this evidence cannot be explained away by appealing to the low income elasticity hypothesis. While it is possible to argue that a low income elasticity of demand can explain why the consumption of services and manufactures grew at the same

[11] The finding that the break in the relative price series is not accompanied by a break in relative output growth rates also provides evidence against arguments that the productivity slowdown of the 1970s could be the result of difficulties in measuring real output in the service sector. This argument is based on mismeasured deflators which lead to mismeasured output and would imply simultaneous breaks in both the price and output series. The simultaneous break in the employment series evident in the data is also hard to reconcile with this hypothesis. We thank John Fernald for pointing this out.

rate even as the relative price of manufactures fell sharply, one cannot make a similar argument to explain why the growth rate of relative consumption failed to respond to a sustained change in the growth rate of relative productivity.

Finally, it is interesting to ask what evidence of breaks we would find in the data if we did not condition our tests on the productivity series and whether this evidence would still be consistent with the break in the growth rate of relative productivity. We present the results from the Bai-Perron tests in Table 2.

The first row of Table 2 shows that the null of no break in the relative price series can be rejected at the 5 percent level, though the date of the break is quite late relative to the productivity break. We return to the issue of the timing of the break below. The second row shows unambiguous evidence of a break in the employment series, and this time the break is dated very close to the break in the productivity series. The third row presents the results for the relative output variable, and once again it is not possible to reject the null hypothesis of no change at conventional significance levels.

As in Table 1, the results in the fourth row help reconcile the results in the first three rows with equation (25): there is no evidence of any break whatsoever in the difference between the growth rate of prices and employment. Here it is worth pointing out that if the two series had breaks at different dates one would expect to find evidence of two breaks in this series.

The last two rows of Table 2 provide the results relevant to equation (12). As before, there is no evidence of a break in the growth rate of manufactured consumption goods relative to services. However, this time we cannot reject the null of no break in the relative price of the manufactured consumption good at even the 10 percent level (though the SupF$(2 \mid 1)$ statistic does raise some questions).

Overall, the results in Table 2 appear to be consistent with those in Table 1. There is no evidence of any break in either the relative output or relative consumption series, but there is evidence of a break in the employment series and in the relative price of investment goods to services. There is also no evidence of any break in the difference between the growth of relative employment and relative price, which implies that the break in the two series took place at the same date and is also consistent with the lack of a break in the relative output series. The one exception is the relative price series $\hat{p} + \hat{q}$, where there is some evidence of a break in Table 1, but none in Table 2.

4. Conclusions

This paper has studied the behavior of employment, prices and output in manufacturing relative to services using a two-sector growth model with constant returns in each sector and production technologies that differ only in the (exogenous) productivity processes affecting each sector. In the data, it turns out that the relative price of investment goods has fallen at about the same rate as relative employment in manufacturing over the 1950Q1-2006Q1 period. Although factors such as international trade may have played a role, in the framework of our model this empirical finding implies that the change in manufacturing employment (relative to services) can be explained by differences in productivity growth rates alone.

How much employment changes in response to differences in productivity growth rates across the two sectors also depends upon the elasticity of substitution between goods and services. The less the household is willing to substitute between the two, the greater the re-allocation of employment that must take place in response to a difference in productivity growth rates. Here the evidence is that the elasticity of substitution is zero or close to it. These preferences tend to maximize the impact of relative productivity shocks on employment.

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Table 1: Testing for Breaks Conditional on a Productivity Break

Variable	Average growth rate		t-statistic for equality of growth rates
	50Q1-66Q4	67Q1-06Q1	
Relative Price 1 ($\hat{q}$)	-.28%	-.84%	6.17^{1}
Relative Employment ($\hat{\psi}$)	-.15	-.81	6.01^{1}
Relative Output ($\hat{\phi}$)	-.12	.21	-1.2
Emp. - Price ($\hat{\psi} - \hat{q}$)	-.14	-.03	-0.73
Relative Consumption ($\hat{\varphi}$)	-.08	-.19	0.44
Relative price 2 ($\hat{q} + \hat{p}$)	-.40	-.52	1.66^{10}

Note: ^{1} denotes significant at 1 %,^{10} denotes significant at 10 %,

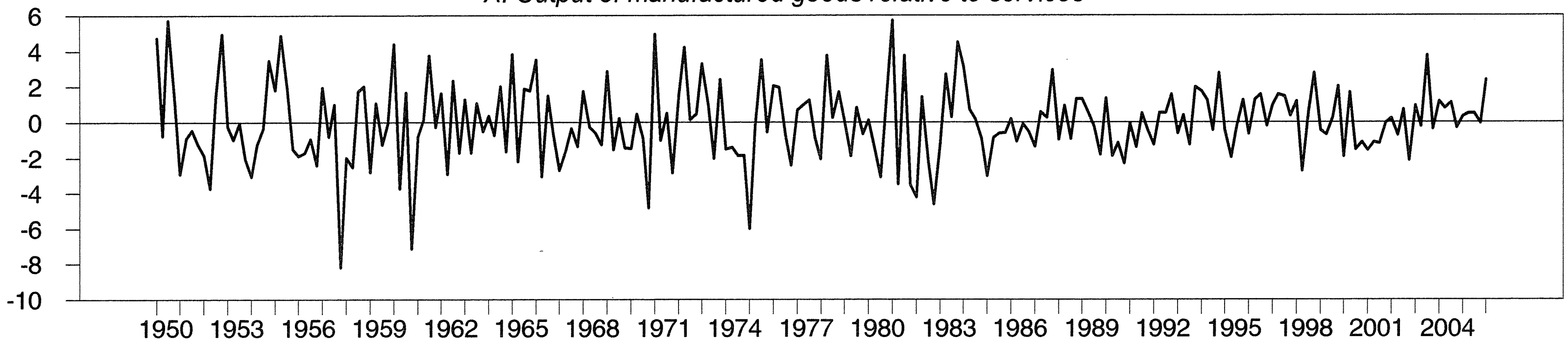
Table 2: Unconditional Tests for Breaks in Relative Growth Rates

Variable	Test: UDmax	Test: SupF(1|0)	Test: SupF(2|1)	Break date from: SupF	Break date from: Sequential	95% Confidence Interval
Relative price 1 ($\hat{q}$)	11.9^{5}	11.9^{5}	5.6	1979Q1	$1979Q1^{5}$	73Q1-96Q4
Employment ($\hat{\psi}$)	14.5^{1}	14.5^{1}	2.6	1968Q1	$1968Q1^{1}$	63Q3-78Q1
Relative output ($\hat{\phi}$)	6.9	6.9	1.0	none	none	—
Emp. - price ($\hat{\psi} - \hat{q}$)	1.7	1.2	1.8	none	none	—
Relative consumption ($\hat{\varphi}$)	3.5	1.7	4.0	none	none	—
Relative price 2 ($\hat{q} + \hat{p}$)	5.6	2.2	12.1^{5}	none	none	—

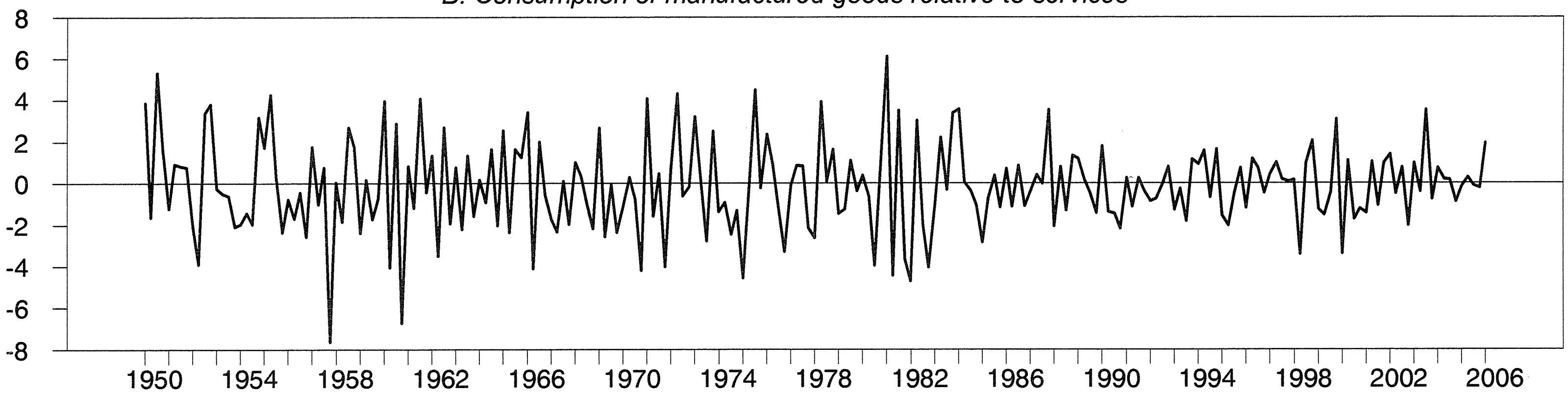
Note: ^{1} denotes significant at 1 %,^{5} denotes significant at 5 %,

Fig. 1: Relative Growth Rates I

A. Output of manufactured goods relative to services



B. Consumption of manufactured goods relative to services



C. Employment in manufacturing industries relative to services

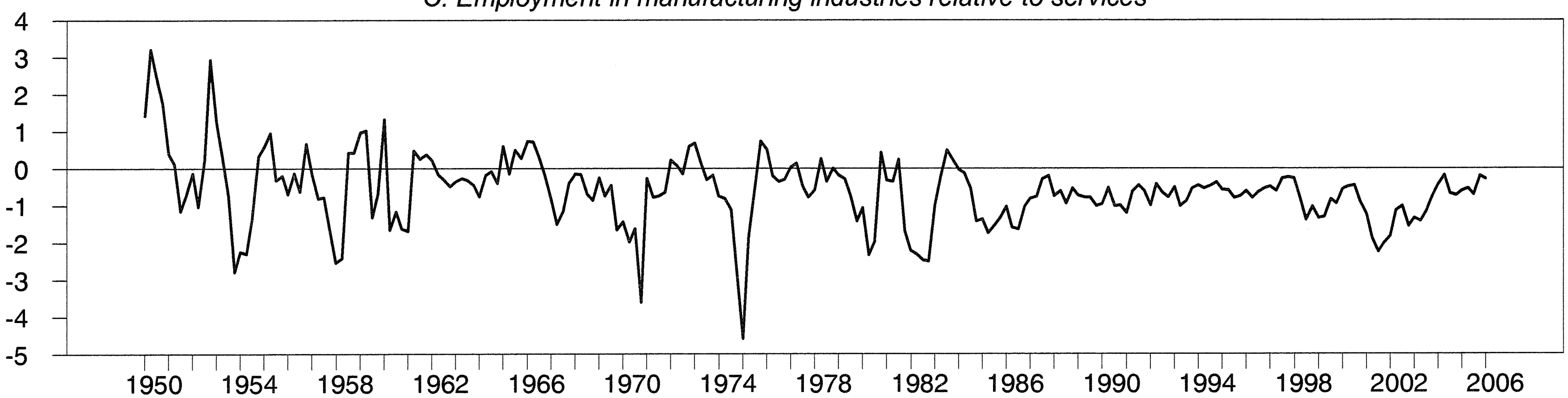
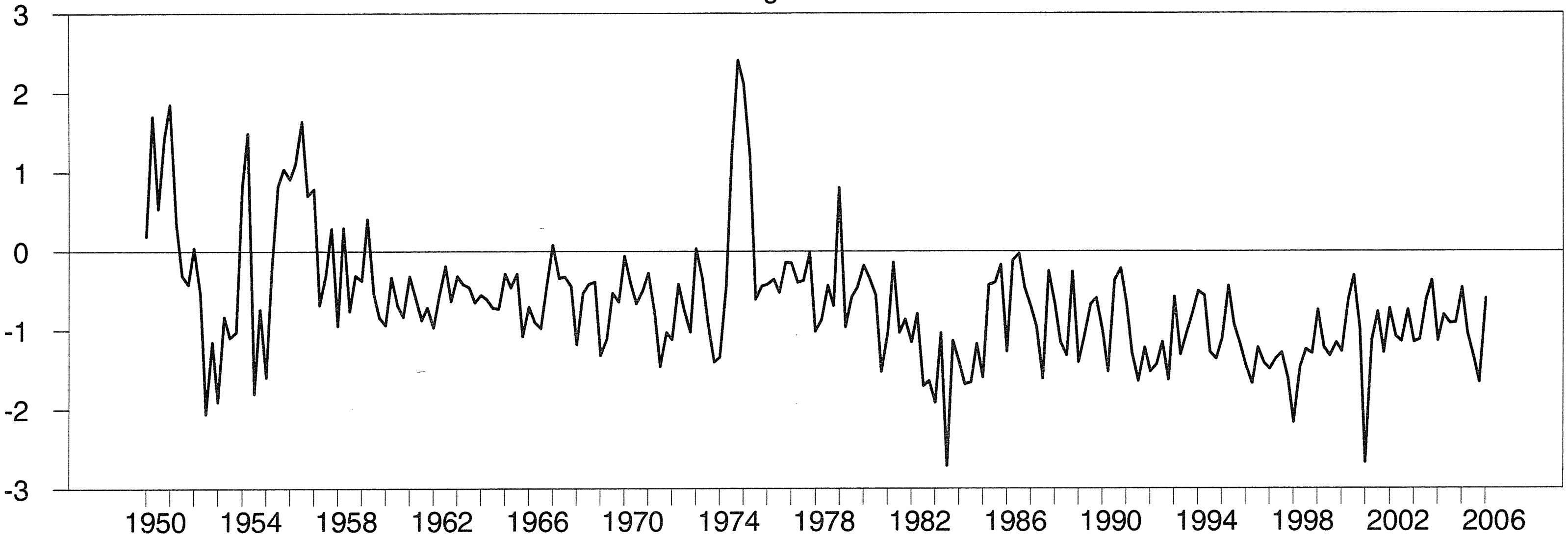


Fig. 2: Relative Growth Rates II

A. Price of investment goods relative to services



B. Price of consumption goods relative to services