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Research Memorandum GD-74

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**RESEARCH MEMORANDUM**

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**Abstract:** This paper studies procyclical productivity growth at the industry level in the U.S. and in three European countries (France, Germany and the Netherlands). Industry-specific demand-side instruments are used to examine the prevalence of non-constant returns to scale and unmeasured input utilization. For the aggregate U.S. economy, unmeasured input utilization seems to explain procyclical productivity. However, this correction still leaves one in three U.S. industries with procyclical productivity. This failure of the model can also be seen in Europe and is mostly concentrated in services industries.

JEL codes: D24, E32, O47
Keywords: Cyclical productivity; input utilization; returns to scale; instrumental variables

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## 1. Introduction

In the short run, output growth and productivity tend to move together in many countries and across a wide range of industries. In recent years this observation has gained increased prominence, as each proposed explanation for the observed procyclicality has important implications for modelling the business cycle and measuring technical change. The goal of this paper is to evaluate the role of increasing returns to scale and unmeasured input utilization in explaining procyclical productivity growth. The eventual aim is to better understand short-run changes in productivity growth and how firms adjust to (adverse) changes in demand. The analysis is carried out in a production function framework using a recent, internationally consistent dataset for three European countries and the United States.

This paper is the first to test whether the Basu-Fernald model is similarly successful in reducing output-technology correlations outside the U.S. and to what extent it is successful not only at the aggregate but also at the industry level. I confirm the main finding of Basu and Fernald (2001) for the aggregate U.S. economy, but also show that the Basu-Fernald model does not explain much beyond this. Even after correcting for possible non-constant returns to scale and unmeasured input utilization, nearly one in three U.S. industries still show significant procyclical productivity growth.

In Europe, the model performs even worse as in the Netherlands, not even aggregate productivity becomes less cyclical. The results for France and Germany are comparable to those for the United States: the cyclicality of aggregate productivity is notably reduced by correcting for non-constant returns to scale and unmeasured input utilization, but productivity is still procyclical in many industries. One possible reason for this finding is that the proxy for unmeasured input utilization, hours worked per person, is not very relevant in Europe and in services industries. Better proxies and more attention to cross-industry heterogeneity as in Hart and Malley (1999) would probably be helpful.

The second finding is of a more technical nature, but nevertheless important for the analysis in this paper. Identification of the production functions estimated in this literature tends to rely on relatively weak instruments. To correct for the simultaneity bias of ordinary least squares estimates, many authors use variables such as the change in the oil price or military government expenditure as instruments. These aggregate variables seem at best only weakly correlated with demand changes at the industry level. Following Shea (1993) and Baily, Bartelsman and Haltiwanger (2001), I construct a set of industry-specific instruments capturing downstream intermediate demand. A recently developed statistical test confirms that these are less prone to weak-instrument bias than the more commonly used instruments such as the real oil price. Therefore, using these downstream indicators allows for a greater degree of confidence in the estimates presented here than in some of the other studies in this literature.

The rest of this paper is organized as follows. First, the main stylised fact of cyclical productivity is introduced alongside the most important proposed explanations for this phenomenon from the literature. The next section presents the theoretical framework for the analysis. Section III discusses the estimation framework and the data used in this study. Results are shown in Section IV, first with regards to the production function estimates, while the second part focuses on the cyclicality of the technical change residual. Section V summarizes and discusses some of the implications of the results.

## 2. Background

One of the more robust stylised facts in the macroeconomic literature is that output and productivity move together in the short run. Table 1 illustrates this fact by showing the correlation between output growth and total factor productivity (TFP) growth in European countries and the United States. With few exceptions, the correlations are positive and highly significant. Although other filtering methods could have been used, we focus on these correlations mainly because Basu and Fernald (2001) do so.

**Table 1**

**Correlation between total factor productivity and GDP growth, Europe and the U.S., 1979-2001**

| | | | |
|---|---|---|---|
| Austria | 0.59* | Italy | 0.46* |
| Belgium | 0.53* | Netherlands | 0.42 |
| Denmark | 0.56* | Portugal | 0.51* |
| Finland | 0.75* | Spain | -0.46* |
| France | 0.56* | Sweden | 0.65* |
| Germany | 0.67* | UK | 0.54* |
| Greece | 0.71* | US | 0.89* |
| Ireland | 0.68* | | |

Notes: * denotes a correlation significantly different from zero at the 5% level

Source: Timmer, Ypma and van Ark (2003)

Four explanations for cyclical productivity are popular in the literature: 1) procyclical technology shocks, 2) increasing returns to scale, 3) unmeasured input utilization and 4) reallocations of resources across sectors. The first explanation is the most obvious: if technology shows high-frequency fluctuations, it should not come as a surprise that output will show similar fluctuations and hence, productivity will be procyclical. Under the second explanation, increasing returns to scale, a decline in inputs in a recession will lead to a more than proportionate decline in output and hence lower output per unit of input. If the third explanation holds, firms adjust not only measured inputs such as capital and labour, but also unmeasured inputs like the workweek of capital or the labour effort per hour worked. Therefore, during a growth slowdown or a recession the decline in productive inputs will be understated and observed productivity will be procyclical. The final explanation is important only for aggregates of industries. Returns to scale can vary by industry, which implies that reallocations of inputs between industries will have an impact on aggregate measured productivity growth. If a sector with above average increasing returns to scale also shows above average input cyclicality, aggregate productivity growth will be procyclical.

Knowing which of these explanations hold up in practice is important for understanding business cycles. The presence of technology shocks argues in favour of models where technology drives the business cycle as in Real Business Cycle Theory (e.g. Cooley and Prescott, 1995). If on the other hand increasing returns to scale is related to imperfect competition, changes in government expenditure or even shifts in expectations can generate business cycles (see the survey by Rotemberg and Woodford, 1995). Increasing returns may not just be due to firm-level (internal) increasing returns but also due to external economies. If the activity level of a firm or industry influences productivity in another industry, linkages between firms and industries become important and need to be modelled. Unmeasured input utilization makes demand for capital and labour more elastic than actually measured, thereby increasing the effects of shocks. If reallocations are important, multiple sectors also need to be explicitly modelled.

Different explanations for cyclical productivity also have different implications for the interpretation of productivity growth as technical change. Researchers such as Gordon (2000) try to separate the ‘cyclical’ from the ‘structural’ part of productivity growth. This approach might have some merit if unmeasured input utilization were the leading cause for procyclical productivity growth. However, as Basu and Fernald (2001) argue, if increasing returns to scale and reallocations are important, cyclical productivity is a ‘structural’ phenomenon in that it reflects the ability of firms to produce output given a certain level of inputs. As a result, a more formal analysis is needed to identify technical change.

There is an extensive literature that tries to distinguish between the various explanations of procyclical productivity. Most of these papers focus on the U.S., but there is international evidence as well, most notably from Caballero and Lyons (1990), Oliveira Martins, Scarpetta and Pilat (1996) and Vecchi (2000). But although this paper is not the first to look at returns to scale and unmeasured input utilization for countries outside the U.S., the international evidence so far is confined to production function and related estimates. However, in a recent study for the U.S., Basu and Fernald (2001) use production function estimates to evaluate whether these estimates can actually decrease the correlation between output and the technology residual they estimate. From this exercise Basu and Fernald (2001) conclude that there is only a limited role for increasing returns to scale outside durable manufacturing and that unmeasured input utilization and reallocations can explain the cyclicality of aggregate U.S. productivity. In this paper the same approach is chosen to see whether their conclusions extend across industries and other countries as well. As a first step though, the production model is discussed that lies at the basis of the empirical analysis.

## 3. A model of cyclical productivity

This section discusses a model that is commonly used to study the cyclicality of productivity growth. A firm produces using the following production function:

$$(1) \qquad Y = F(zK, eHN, M, A)$$

Output, denoted by Y, is produced using capital K, workers N, average hours worked H and intermediate inputs M, given the state of production technology A. Additional choice variables for the firm are the intensity of capital use z and the effective labour effort e. In a model with costless input adjustment, these last variables are irrelevant. However, we assume that labour and capital are quasi-fixed inputs, so in the short run, firms adjust to shocks by varying average hours worked, labour effort and the intensity of capital use. Following Basu and Fernald (2001), we think of the z as being determined by the number of shifts and higher intensity of capital use is costly due to a shift premium.

Along similar lines, the firm can pay its workers more in order to ensure higher effort levels, given the number of hours worked per worker. If this extra compensation is in the form of better promotion chances or spread out over several years, it will not fully show up in the labour compensation figures of any single year. Furthermore, the level of effort can be interpreted directly as the intensity of work, but reasoning along similar lines, an employee might divide his time between immediately productive work and training or other learning activities. In that case, the firm might simply shift workers from non-productive to productive work without having to pay a higher wage immediately. The cost would lie in the fact that future labour productivity improvements will be lower as less human capital will have been accumulated.

If the firm is a price taker on the market for factor inputs and minimizes cost, inputs will be purchased up to the point where the marginal product equals factor prices. This means we can construct an input growth index (see e.g. Basu and Fernald, 1997):

$$(2) \qquad dX = s_L(de + dH + dN) + s_K(dz + dK) + s_M dM$$

where d denotes the percentage growth of the variable and  is the two-period average share input x in total cost. Note that equation (2) gives the Törnquist approximation to the continuous-time Divisia index of input growth. This way, very few restrictions are placed on the underlying production function.

The standard calculation of total factor productivity growth as the Solow residual subtracts the growth of inputs from the growth of output, but this will only give a valid measure of technical change under constant returns to scale. In general, if we assume neutral technical change, the relationship is as follows:

$$(3) \qquad dY = \gamma dX + dA$$

where  denotes the returns to scale. The problem with estimating equation (3) is that neither effort levels nor the intensity of capital use is usually observed and we can only measure a biased version of equation (2):

$$dX^{*} = s_L\left(dH + dN\right) + s_K dK + s_M dM = dX - s_L de - s_K dz \tag{4}$$

The usual solution to this problem is to find a proxy for input utilization. For the manufacturing sector, a number of researchers have used capacity utilization measures (i.e. Shapiro, 1996). Other studies have proposed energy use or materials use as a proxy for capital utilization (e.g. Burnside et al., 1996). However, such measures are silent on labour utilization or not available outside manufacturing so alternatives are needed. Abbott, Griliches and Hausman (1998) proposed using changes in average hours worked as a proxy for both labour and capital utilization. This was later formalised in the model of Basu and Kimball (1997), whose rationale for this proxy is that if optimising firms adjust inputs along one margin, namely average hours worked, they will also adjust along unobserved margins. As long as labour effort increases if average hours worked are increased, growth in average hours worked will be a valid proxy for labour utilization. Similarly, if the only way to increase capital utilization in the short run is to increase the number of shifts and hence, average hours worked, the growth in average hours worked will also be a good proxy for capital utilization. Equation (3) can then be written entirely in terms of observable variables:

$$dY = \gamma dX^{*} + \gamma \xi dH + dA \tag{5}$$

Although data on average hours worked are available for all sectors of the economy, the interpretation of this variable as a proxy for unmeasured input utilization seems to be most relevant for manufacturing industries. Most non-manufacturing industries do not work in shifts and many workers are not paid by the hour, leading to less reliable measures of hours worked. Another proxy, which is also available economy-wide, is intermediate inputs use. The reasoning for this proxy, as originally advanced by Basu (1996), is that if capital and labour utilization goes up, this is partly reflected in higher use of intermediates such as energy or raw materials. However, intermediate inputs make up on average nearly half of all input cost, so one would expect parameter to adequately pick up any utilization effects as well. Adding changes in intermediate use per hour worked as done by Vecchi (2000) may be problematic since intermediate use is then included as part of input growth and as a separate explanatory variable.

No explicit role is given to external effects in equation (5), although some researchers such as Caballero and Lyons (1990, 1992) and Vecchi (2000) argue their importance. There are two reasons for this. First, adding aggregate output growth to equation (5) may indeed pick up the effect of growth in other industries, but as Sbordone (1997) argues, is may just as well be a proxy for demand-induced utilization changes. Second, while it is interesting to know whether increasing returns to scale are internal or external to the firm or industry, in the present paper the main focus is on whether returns to scale can explain procyclical productivity growth. Equation (5) gives the general estimation framework to analyse the cyclicality of productivity growth. A number of econometric issues need to be dealt with first, however.

## 4. Methods and data

### *Econometric methodology*

We estimate two specifications, one including only the returns to scale parameter g, and a specification which includes both returns to scale and the correction for unmeasured input utilization in the form of parameter x:

$$\text{(6a)} \qquad dY_{i,j,t} = \mu_{i,j} + \gamma_j^1 dX_{i,j,t}^* + \varepsilon_{i,j,t}^1$$

$$\text{(6b)} \qquad dY_{i,j,t} = \mu_{i,j} + \gamma_j^2 dX_{i,j,t}^* + \xi_j dH_{i,j,t} + \varepsilon_{i,j,t}^2$$

Output growth of industry i in country j at time t is the dependent variable in both regressions. In (6a), measured input growth is the only explanatory variable while in (6b) the growth in average hours worked is included to proxy for unmeasured input utilization changes. Input growth is a weighted average a growth in labour, capital and intermediate inputs (equation (4)). In both specifications a country/industry fixed effect, , is included as well. One of the main goals of this exercise is to see to what extent European countries show different results from the U.S., so the parameters are allowed to vary by country. Technical change is partly accounted for in the fixed effect and partly ends up in the residuals . The results from Basu and Fernald (2001) suggest that (6a) should give returns to scale estimates significantly greater than 1, while in (6b), significant increasing returns should disappear and instead give significantly positive estimates of . Note that in equation (5), parameter was interacted with . As in practice, is close to one, taking this nonlinearity into account has little effect on the results.

One of the objectives of this paper is to come up with comparable estimates to Basu and Fernald (2001), but in specification (6b), growth in average hours worked is included both as part of input growth and as a separate explanatory variable. This is likely to bias the elasticity estimates, so a modified version of (6b) is also estimated where input growth is calculated excluding growth in average hours worked.

An important problem with estimating equations (6a) and (6b) is that optimising firms set their levels of inputs and outputs simultaneously in response to productivity shocks. Therefore we need variables unrelated to industry productivity shocks to identify and . Most of the literature has relied on relatively weak instruments to estimate variants of equations (6a) and (6b) and some have even decided to rely on OLS estimates to avoid small-sample bias in IV estimates (e.g. Diewert and Fox, 2004). The most commonly used instruments are those first used in Hall (1988), as proposed by Valerie Ramey: the world price of oil, real military spending and the political party of the president. As Basu and Fernald (1997, p. 258) note, the first stage F-statistic of equation (6a) using the Hall-Ramey instruments is around three. According to the statistical test of Stock and Yogo (2004, Table 1) the resulting weak instrument bias will be larger than 30 percent of the simultaneity bias inherent in ordinary least squares (OLS). In other words, the estimates are seriously biased towards OLS. In this paper we rely on downstream indicators of industry demand, based on the work by Shea (1993) and Baily, Bartelsman and Haltiwanger (2001).

Shea (1993) proposed to use input-output tables to identify industries with close demand links but relatively modest reverse links. Take for example the metal industry and the car industry: output changes in the car industry will likely induce higher demand in the metal industry, so growth in the car industry is certainly relevant. In this case, however, it is not clear whether output changes in the car industry are also exogenous to productivity shocks in the metal industry because a notable part of intermediate inputs of the car industry come from the metal industry. Baily, Bartelsman and Haltiwanger (2001) constructed a weighted average of growth in downstream industries using all industries that buy output from a certain industry and for which these purchases represent less than five percent of intermediate inputs. In constructing the downstream instruments for this paper the same procedure was followed.

It is useful at this point to compare how the various instrument sets fare when confronted with the data (described in more detail in Section III). As shown by Stock and Yogo (2004), the F-statistic from the first-stage regression of the explanatory variable and the instruments is a useful test statistic to gauge the strength of the instruments. The first and third columns of Table 2 show the average F-statistic across industries based on the first-stage regressions that try to explain (measured) input growth by the current value and one lag of the downstream indicator for each industry in each country. The second and fourth columns show the same results from regressions with the standard Hall-Ramey instruments as explanatory variables. These instruments are the current value and one lag of the change in the oil price relative to the GDP deflator and the growth of real government spending. As the table shows, in each country the downstream indicators generate a considerably better fit than the more widely used Hall-Ramey instruments. In quite a number of the 24 industries in this study the simultaneity bias inherent in OLS estimation can be reduced by 90 percent or more by using the downstream indicators, while the Hall-Ramey instruments lead to estimates that are much more biased towards the OLS estimates.

**Table 2**

**Comparing the fit of first-stage regressions of instrument sets on growth of inputs, downstream indicator vs. Hall-Ramey instruments**

| | *Average first-stage F-statistic* | | *Number of industries with IV bias less than 10% of OLS bias* | |
|---|---|---|---|---|
| | Downstream indicator | Hall-Ramey | Downstream indicator | Hall-Ramey |
| France | 13.5 | 3.7 | 15 | 0 |
| Germany | 11.3 | 3.7 | 11 | 1 |
| Netherlands | 13.6 | 4.3 | 12 | 1 |
| U.S. | 13.6 | 6.2 | 9 | 4 |

First and third column: Regression of current and one lag of downstream indicator on the growth of inputs. Second and fourth column: Regression of current and one lag of oil price change and growth of real government spending on growth of inputs. Third and fourth column: Number of industries where the first-stage F-statistic exceeds the critical value of 9.08 (third column) and 10.83 (fourth column), using Table 1 of Stock and Yogo (2004).

As Table 2 shows, downstream indicators seem to be much stronger demand-side instruments, probably because they are industry-specific. Although there are differences across countries, the downstream indicators are more relevant for all countries than the Hall-Ramey instruments. A related question is whether the instruments are sufficiently exogenous. This is harder to establish statistically, but correlations between OLS residuals and the various instruments suggests that the downstream indicators do not perform much worse than the Hall-Ramey instruments. The average correlation with the downstream indicators is 0.17 versus nearly 0 for the Hall-Ramey instruments. Although this difference might seem substantial, only 13 industries (out of 96 industries) showed significant correlations using the downstream indicators versus 7 industries for the Hall-Ramey set. Based on these results, we will rely on the downstream indicators to estimate equations (6a) and (6b).

### *Data*

A quite extensive dataset is needed to estimate the model discussed in Section 2. Data is collected on gross output, intermediate inputs, capital services and labour input for 24 market industries in France, Germany, Netherlands and United States. The period covered is 1979 to 2001.

For data on capital by asset type and hours worked by skill type, this paper relies on previous work (see Inklaar, O'Mahony and Timmer, 2003). For each country, investment data is available for 6 asset types, namely computers, communication equipment, software, non-IT machinery, transport equipment and non-residential structures. For France, Netherlands and the U.S., these investment data are available as detailed investment matrices from the national statistical offices. In the case of Germany, investment figures from the National Accounts are supplemented with results from investment surveys by the Ifo Institut (see Appendix A of Inklaar et al., 2003). From those data, capital stocks are estimated using the perpetual inventory method and asset depreciation rates from the U.S. Bureau of Economic Analysis (see Fraumeni, 1997). Given the large differences across countries in how statistical offices account for quality change of ICT products, we use U.S. price indices to deflate ICT investment and the output of ICT-producing industries, after adjusting for differences in the general inflation level. To aggregate across asset types we estimate rental prices as follows:

$$(7) \qquad R_{i,j,t} = r_t + \delta_i - \dot{p}^I_{i,j,t}$$

The rental price of asset i for industry j at time t is equal to an external rate of return r, assumed equal to the government bond yield (from the IMF's International Financial Statistics), the asset depreciation rate and the investment price change of the asset.

Data on labour input by educational attainment are from national labour force surveys. Due to differences in educational system we do not have the same number of categories in each country, varying between 3 categories in the case of Germany and 7 in the case of the Netherlands. Information on the wages of each labour type was used to aggregate across different skill categories. Finally, average hours worked by industry are from the GGDC (2003) 60-industry database.

The data from Inklaar et al. (2003) are supplemented with information on gross output at current and constant prices from the National Accounts of the various countries. Especially for the 1980s, prices for gross output are frequently not given in the National Accounts. In those cases we either use producer price indexes or we estimate prices based on implicit value added deflators. Intermediate inputs are implicitly estimated based on gross output and value added at constant prices. Apart from the growth of each input, the share of labour, capital and intermediate inputs are also needed to compute an aggregate input index. The main issue lies in estimating self-employed labour income as this is included as part of capital income. As in Inklaar et al. (2003), data for the U.S. from Jorgenson, Ho and Stiroh (2002) are used to estimate that at the aggregate level, self-employed wages are on average 70 percent of employee wages. This ratio is applied to each industry and country.

To construct the downstream indicator for each country, information is needed on deliveries by industry x to industry y. For this we use benchmark input-output tables for each of our countries. Although the sales shares of industries are likely to change over time, experiments using annual input-output tables for the Netherlands show that the impact on the indicators is limited. Therefore, only a single input-output table is used for 1995 (France and the Netherlands), 1997 (United States) and 2000 (Germany). The downstream indicators are calculated at the industry detail of the 60-industry database and then aggregated to the level of the 24 market industries in this paper. Finally, the indicators are limited to intermediate demand. Although there are no conceptual problems with including final demand as well, we have not done this.

## 5. Results

*Production function estimates*

In this subsection, the estimation results from equations (6a) and (6b) are presented. In all cases, two-stage least squares is used to estimate the parameters with the current value and one lag of the industry-specific downstream indicators as instruments. To improve efficiency, first-stage coefficients are allowed to vary by industry. The standard errors of the parameters have been corrected for autocorrelation and heteroscedasticity using the procedure of Newey and West (1987).

Table 3 shows the results from estimating equation (6a). The table shows that there is limited evidence of significant increasing returns. Returns to scale are significantly different from one in France, Germany and the U.S., and this can mostly be traced to (durable) manufacturing. The results are shown for groups of industries, as the time series dimension (21 observations) is too short for reliable inference at the industry level. Indeed, for some individual industries very large, very small and even negative returns to scale are found (see Appendix Table A3). Both agriculture and mining seem to have a noticeable impact on point estimates in the Netherlands and the U.S., as is most clear when comparing the estimates for non-manufacturing, which includes agriculture and mining, to the estimates for services, which does not include these industries. Although there is no statistical difference between the estimates, the differences become more poignant later on.

**Table 3, Returns to scale in France, Germany, Netherlands and United States**

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| Market economy | 1.14* | 1.16* | 1.01 | 1.11* |
| | (0.06) | (0.04) | (0.05) | (0.05) |
| Market economy excluding agriculture & mining | 1.14* | 1.15* | 1.04 | 1.16* |
| | (0.06) | (0.04) | (0.04) | (0.03) |
| Durable manufacturing | 1.25* | 1.17* | 1.10 | 1.26* |
| | (0.05) | (0.06) | (0.06) | (0.05) |
| Non-durable manufacturing | 1.34* | 1.15* | 1.02 | 1.07 |
| | (0.11) | (0.05) | (0.09) | (0.06) |
| Non-manufacturing | 0.96 | 1.15 | 0.88 | 0.82 |
| | (0.09) | (0.08) | (0.11) | (0.13) |
| Services | 0.94 | 1.13 | 0.96 | 0.99 |
| | (0.09) | (0.08) | (0.07) | (0.07) |

Notes: Table shows parameter estimates from a regression with output growth as the dependent variable and growth of inputs as independent variable. Estimation is done for a panel of industries, with industry fixed effects included (not shown) using two-stage least squares with the current value and one lag of the downstream indicator for each industry as instruments. Parameters in the first stage regression are allowed to vary across industries. Standard errors, consistent for heteroscedasticity and autocorrelation, are shown in parentheses. * denotes parameters significantly different from one at the 5% level. See Table A3 for definitions of industry groupings.

The next step is to include growth in average hours worked to correct growth of inputs for unmeasured input utilization as in equation (6b). Table 4 presents the results from that regression. The number of industry groups showing increasing returns to scale has decreased, thereby confirming the results from previous studies. Partly this is due to lower parameter estimates, especially for the total market economy in the U.S., but larger standard errors are also important. For example, if in the case of France, the standard error on g for the market economy and the market economy excluding agriculture & mining had been the same as in Table 3, returns to scale would still have been significantly increasing. A similar phenomenon can be seen for the U.S. market economy excluding agriculture & mining. Indeed, adding the utilization proxy has barely affected the German coefficients or standard errors.

### Table 4
### Returns to scale and a correction for unmeasured input utilization, France, Germany, Netherlands and the U.S.

| | *Returns to scale* | | | | *Utilization correction* | | | |
|---|---|---|---|---|---|---|---|---|
| | France | Germany | Netherlands | US | France | Germany | Netherlands | US |
| Market economy | 1.12 | 1.16* | 1.00 | 0.96 | -0.61 | -0.06 | -0.13 | 0.92* |
| | (0.07) | (0.04) | (0.05) | (0.09) | (0.47) | (0.18) | (0.13) | (0.36) |
| Market economy excluding agriculture & mining | 1.12 | 1.16* | 1.02 | 1.08 | -0.52 | -0.07 | -0.29* | 0.44 |
| | (0.06) | (0.04) | (0.04) | (0.06) | (0.46) | (0.19) | (0.09) | (0.22) |
| Durable manufacturing | 1.16* | 1.11* | 1.01 | 1.17* | -1.11* | 0.42 | -0.49* | 0.49 |
| | (0.08) | (0.05) | (0.08) | (0.08) | (0.53) | (0.23) | (0.21) | (0.35) |
| Non-durable manufacturing | 1.32* | 1.14* | 1.01 | 0.88 | 0.46 | -0.03 | -0.06 | 0.77 |
| | (0.10) | (0.05) | (0.08) | (0.15) | (0.45) | (0.25) | (0.15) | (0.47) |
| Non-manufacturing | 0.93 | 1.18* | 0.86 | 0.73 | -1.00 | -0.53 | 0.27 | 1.27 |
| | (0.10) | (0.06) | (0.11) | (0.16) | (0.67) | (0.29) | (0.29) | (0.76) |
| Services | 0.89 | 1.2* | 0.98 | 1.02 | -0.97 | -0.86* | -0.22 | -0.26 |
| | (0.09) | (0.06) | (0.08) | (0.08) | (0.66) | (0.34) | (0.17) | (0.37) |

Notes: Table shows parameter estimates from a regression with output growth as the dependent variable and growth of inputs and growth of average hours worked as independent variable. Parameters are estimated for a panel of industries, with industry fixed effects included (not shown). Parameters are estimated using two-stage least squares with the current value and one lag of the downstream indicator for each industry as instruments. Parameters in the first stage regression are allowed to vary across industries. Standard errors, consistent for heteroscedasticity and auto correlation, are shown in parentheses. * denotes parameters significantly different from one (returns to scale) or zero (utilization correction) at the 5% level. See Table A3 for definitions of industry groupings.

Looking at the estimates for x, the utilization proxy, Table 4 shows some interesting results. For the entire U.S. market economy, the coefficient on growth of average hours worked is significant and positive, but excluding agriculture and mining renders the estimate insignificant. Although the coefficients in especially manufacturing are reasonably large, the standard errors are too large for meaningful conclusions.

This stands in marked contrast to Basu et al. (2002), who do find strongly significant parameters for each of the industry groupings from Table 4. One possible reason for this is that their dataset (based on the work of Jorgenson and Stiroh, 2000) contains more industries (33 vs. 24) and more years (31 vs. 21) and as a result their estimates are likely to be more precise. Another possibility is that growth in average hours worked is more appropriate as a utilization proxy in manufacturing than in services. If we look at the (unconditional) correlation between growth of output and growth of average hours worked for the U.S., the correlation is on average 0.45 for the 13 manufacturing industries, but only 0.21 for the 11 non-manufacturing industries in our data for the United States. The Jorgenson-Stiroh dataset only includes eight non-manufacturing industries and three of these cover utilities and construction, where work practices are probably more comparable with manufacturing industries than with, say, finance or business services. At the very least the results in Table 4 suggest that the findings of Basu et al. (2002) are not very robust, even when looking solely at the U.S. parameters.

This conclusion is reinforced when taking into account the estimates for France, Germany and the Netherlands. In the countries, the estimates of x are even predominantly negative and significantly so in durable manufacturing (France and the Netherlands) and services (Germany).

However, as discussed in Section III, including growth in average hours worked both in aggregate inputs and as a separate explanatory variable may bias the estimate of x. Table 5 therefore shows similar results as Table 4, except that growth in average hours worked is no longer included in aggregate input growth (dH is removed from equation (4)).

**Table 5**
**Returns to scale and a correction for unmeasured input utilization, excluding average hours worked from aggregate input growth**

| | *Returns to scale* | | | | *Utilization correction* | | | |
|---|---|---|---|---|---|---|---|---|
| | France | Germany | Netherlands | US | France | Germany | Netherlands | US |
| Market economy | 1.12 | 1.16* | 1.02 | 0.97 | -0.31 | 0.31 | 0.10 | 1.17* |
| | (0.07) | (0.04) | (0.05) | (0.09) | (0.47) | (0.18) | (0.12) | (0.34) |
| Market economy excluding agriculture & mining | 1.12 | 1.16* | 1.04 | 1.09 | -0.21 | 0.29 | -0.02 | 0.72* |
| | (0.06) | (0.04) | (0.04) | (0.06) | (0.47) | (0.18) | (0.08) | (0.21) |
| Durable manufacturing | 1.17* | 1.11* | 1.03 | 1.18* | -0.81 | 0.77* | -0.20 | 0.84* |
| | (0.07) | (0.05) | (0.08) | (0.08) | (0.53) | (0.23) | (0.22) | (0.33) |
| Non-durable manufacturing | 1.32* | 1.14* | 1.03 | 0.91 | 0.71 | 0.24 | 0.05 | 0.93* |
| | (0.10) | (0.06) | (0.08) | (0.15) | (0.45) | (0.27) | (0.13) | (0.44) |
| Non-manufacturing | 0.93 | 1.18* | 0.88 | 0.74 | -0.71 | -0.08 | 0.50 | 1.49* |
| | (0.10) | (0.06) | (0.11) | (0.16) | (0.68) | (0.28) | (0.26) | (0.72) |
| Services | 0.89 | 1.20* | 0.99 | 1.02 | -0.68 | -0.42 | 0.17 | 0.13 |
| | (0.09) | (0.06) | (0.08) | (0.08) | (0.67) | (0.32) | (0.16) | (0.35) |

Notes: Table shows parameter estimates from a regression with output growth as the dependent variable and growth of inputs and growth of average hours worked as independent variable. The growth of inputs is modified to exclude growth in average hours worked. Parameters are estimated for a panel of industries, with industry fixed effects included (not shown). Parameters are estimated using two-stage least squares with the current value and one lag of the downstream indicator for each industry as instruments. Parameters in the first stage regression are allowed to vary across industries. Standard errors, consistent for heteroscedasticity and auto correlation, are shown in parentheses. * denotes parameters significantly different from one (returns to scale) or zero (utilization correction) at the 5% level. See Table A3 for definitions of industry groupings.

This adjustment changes the results from Table 4 in a number of ways. First of all, the estimates of returns to scale are almost unaffected: point estimates change only slightly and the number of instances of significantly increasing returns to scale is unchanged. The estimates of x have changed more noticeably though. In Table 5 none of the estimates is significantly negative, which is reassuring. In the case of the U.S., the utilization correction is now significantly positive for all industry groupings except non-manufacturing and services (which is a subset of the former). This makes the results more similar to those reported by Basu et al. (2002). In Germany, there is evidence of a significant utilization effect in manufacturing. Still, outside the U.S. the evidence of utilization effects is quite patchy.

### *Cyclicality of technical change*

Basu and Fernald (2001) estimate a similar model to Basu et al. (2002) and use the results to look at the cyclicality of technical change. As is the case with traditional growth accounting, technical change is a residual. If the regressions from the previous subsection are used to account for non-constant returns to scale and correct for unmeasured input utilization, the residuals from this regression reflect technical change. Basu and Fernald (2001) show that the traditional Solow residual (assuming constant returns to scale and well-measured inputs) is positively correlated with output growth while the residuals from their regression are not.

Although most of the estimates show returns to scale that are statistically indistinguishable from constant and few significant utilization effects, the point estimates can be used to see whether these can decrease the observed procyclicality. To compare the results in this paper to those in Basu and

Fernald (2001), it is useful to start the analysis at the level of the aggregate economies. As Basu et al. (2002) discuss, aggregate technical change is calculated by aggregating industry-level residuals. However, since these residuals are based on a gross output production function, an adjustment needs to be made to deal with the double counting of output. Following Rotemberg and Woodford (1995), a value added-based technical change measure can be calculated as:

$$dA_i^V = \frac{dA_i}{1 - \gamma s_{M\,i}} \tag{8}$$

In this equation,  is the residual from either (6a) or (6b). This residual is adjusted using the returns to scale estimate  and the share of materials in gross output  of the industry in question. The value added-based technical change residuals can then be aggregated across industries using the industry’s share in GDP and correlated with GDP growth.

Table 6 presents the results from this exercise. The top panel shows the correlation between aggregate technical change and GDP growth for the market economy and the middle panel shows the same correlation for all market industries excluding agriculture and mining. Only looking at aggregate results obscures some of the industry-level heterogeneity and therefore, the bottom panel of Table 6 shows the number of market industries for which the correlation between technical change and output growth is significantly different from zero at the five percent level. Technical change at the industry level is calculated using the market economy parameters and hence, the maximum number of industries that can have a significant correlation is 24. Removing agriculture and mining and using the parameters for that part of the economy has little impact on the qualitative results.

**Table 6**

**Correlation between output growth and technical change, France, Germany, Netherlands and the U.S.**

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| *Market economy* | | | | |
| Constant returns to scale | 0.72* | 0.82* | 0.51* | 0.85* |
| Variable returns to scale | 0.45* | -0.02 | 0.52* | 0.20 |
| Variable returns to scale & utilization correction | 0.30 | 0.27 | 0.55* | 0.42 |
| | | | | |
| *Market economy excluding agriculture & mining* | | | | |
| Constant returns to scale | 0.71* | 0.83* | 0.30 | 0.79* |
| Variable returns to scale | 0.46* | 0.24 | 0.23 | 0.19 |
| Variable returns to scale & utilization correction | 0.36 | 0.05 | 0.26 | 0.37 |
| | | | | |
| *Number of market industries with correlation significantly different from zero (5% level)* | | | | |
| Constant returns to scale | 18 | 20 | 14 | 12 |
| Variable returns to scale | 11 | 6 | 13 | 6 |
| Variable returns to scale & utilization correction | 9 | 6 | 14 | 7 |

Note: correlations between output growth and technical change residuals. Constant returns to scale leads to the standard Solow residual. Variable returns to scale uses the residuals from the regressions in Table 3, Variable returns to scale & utilization correction uses the residuals from the regressions in Table 4. * denotes a correlation significantly different from zero at the 5% level.

As the table shows, the standard Solow residual is indeed strongly procyclical at the level of the market economy. In the case of the Netherlands though, this aggregate procyclicality disappears if agriculture and mining are excluded. In the case of France, Germany and the U.S., adjusting for non-constant returns to scale using the parameters from Table 3 reduces the correlation and in the case of Germany and the U.S. renders it insignificant. As the returns to scale parameters for the Netherlands in Table 3 are smaller, it is not very surprising to see a much smaller effect on the correlations.

Including a utilization proxy has mixed effects on the observed correlations. For these calculations, the parameters from Table 4 are used, but using the parameters of Table 5 gives virtually identical results. In France, the correlation becomes insignificant, although the parameter in Table 4 is negative. On the other hand, in the case of the Netherlands hardly anything changes. The correlations for the U.S. become somewhat larger and for the entire market economy the correlation almost becomes significant. In the market economy excluding agriculture and mining, adding the utilization proxy has a similar effect to allowing for variable returns to scale: in both cases the technical change residual is uncorrelated with output growth. Basu and Fernald (2001) get similar results and use this observation to conclude that unmeasured input utilization is the more important factor in explaining procyclical productivity growth.

However, the bottom panel shows that this finding is quite limited in scope. Assuming constant returns to scale and well-measured inputs, half of the U.S. industries have procyclical productivity growth. By correcting for non-constant returns to scale and variable input utilization the number of industries with significantly positive correlations drops from twelve to seven. Although this is a notable decrease, this still leaves the procyclicality in many industries unaccounted for. Hart and Malley (1999) have also documented heterogeneity in the cyclicality of productivity across industries. These results suggest that different degrees of returns to scale or utilization effects are not a sufficient explanation for this heterogeneity.

A possible reason for this finding is that we constrain the coefficients of equation (6b) to be equal for all 24 industries. In Table 7 we calculate correlations between output growth and technical change for the other industry groups from Table 4. In all cases, the residuals are from the full model, including both variable returns to scale and hours worked as a proxy for input utilization.

### Table 7
### Correlation between output growth and technical change for industry groups under variable returns to scale and corrected for unmeasured utilization

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| *Correlation between output growth and technical change* | | | | |
| Market economy | 0.30 | 0.27 | 0.55* | 0.42 |
| Market economy excluding agriculture & mining | 0.36 | 0.05 | 0.26 | 0.37 |
| Durable manufacturing | 0.37 | 0.26 | 0.54* | 0.12 |
| Non-durable manufacturing | 0.30 | 0.21 | 0.81* | 0.8* |
| Non-manufacturing | 0.57* | 0.66* | 0.77* | 0.6* |
| Services | 0.59* | 0.57* | 0.58* | 0.67* |
| *Number of market industries with correlation significantly different from zero (5% level)* | | | | |
| Market economy | 9/24 | 6/24 | 14/24 | 7/24 |
| Market economy excluding agriculture & mining | 10/22 | 4/22 | 11/22 | 4/22 |
| Durable manufacturing | 0/6 | 1/6 | 3/6 | 1/6 |
| Non-durable manufacturing | 1/7 | 0/7 | 2/7 | 3/7 |
| Non-manufacturing | 7/11 | 5/11 | 10/11 | 7/11 |
| Services | 6/9 | 3/9 | 7/9 | 4/9 |

Note: Top panel: correlations between output growth and technical change residuals from the regressions in Table 4. * denotes a correlation significantly different from zero at the 5% level. Bottom panel: number of industries with significantly non-zero correlations/number of industries in group. See Table A3 for definitions of industry groupings.

As the top panel of the table shows, positive and significant correlations are still very prevalent, especially outside manufacturing. As before, the lack of a sufficiently large number of observations might play a role, but it is striking that the results outside manufacturing are similar across countries. The bottom panel of Table 7 shows first, the number of industries where the correlation is significantly different from zero, and the second figure gives the number of industries in the industry group. In line with Table 5, for most groupings a considerable fraction of industries has a significant nonzero correlation. In all, this raises serious questions about the ability of the Basu and Fernald (2001) model to explain the observed cyclicality of productivity growth, especially when looking at individual industries and European countries.

## 6. Conclusions

It is important to understand why productivity growth is procyclical, both for understanding the business cycle and for measuring technical change. This paper extends the current literature by not only analyzing the U.S. but also France, Germany and the Netherlands using an up-to-date and internationally consistent dataset covering not only manufacturing but also services industries. The analysis follows along similar lines as Basu and Fernald (2001): production functions are estimated to allow for non-constant returns to scale and unmeasured input utilization. While this study is not the first to cover countries outside the U.S., none of those other studies have tested whether the estimated models lead to lower correlation between growth of output and the technology residual from the production model estimates as in Basu and Fernald (2001). Furthermore, industry-specific demand-side instruments are introduced to better correct for simultaneity bias in estimation.

The results cast doubt on the success of the Basu and Fernald (2001) model in accounting for procyclical productivity growth. At the aggregate level, the correlation between the technology residual from the production function estimates and output growth goes down in France, Germany and the U.S., but not in the Netherlands. Furthermore, the results show that even in France, Germany and the United States many industries still have procyclical technology residuals. Since the underlying theoretical model tries to explain firm behaviour, the failing of the empirical model for many industries is worrisome.

This is not the first paper to cast doubt on the popular explanations for procyclical productivity growth. Basu and Fernald (1997) raised questions about the prevalence of increasing returns to scale in the U.S., while Sbordone (1997) showed that the dynamic behaviour of output and productivity is not consistent with externalities. The main justification for looking at input utilization is the presence of adjustment costs for labour and capital. However, in recent work, Hall (2004) finds strong evidence against important adjustment costs to labour and capital over a time horizon of a year or more. As a result, it is not clear whether firms will vary utilization very much in response to shocks. The finding of Baily, Bartelsman and Haltiwanger (2001) that long-run downsizing plants show more procyclicality during downturns than upsizing plants also argues against input utilization: downsizers would have much fewer incentives to hoard labour or conserve capital. This paper provides some direct evidence that unmeasured input utilization is unable to account for procyclical productivity growth in many settings. One possible reason for this may be that average hours worked per person is not a very good proxy for unmeasured input utilization in most industries, especially outside the U.S. and in the services sector.

This raises the question where to go from here. One avenue might be to try and find better measures for unmeasured input utilization, especially outside manufacturing. The type of customers of an industry (business versus consumers) may be important as well as Hart and Malley (1999) find less evidence of procyclicality in investment-goods industries. Further theoretical research may also provide useful new directions for empirical research. Ultimately, firm-level studies, especially extending Baily, Bartelsman and Haltiwanger’s (2001) work beyond U.S. manufacturing, may be needed to understand how firms adjust to changing demand.

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**Table A1, Correlation between annual output growth and total factor productivity growth at the industry level, France, Germany, Netherlands and U.S., 1979-2001**

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| Agriculture, forestry and fishing | 0.87* | 0.92* | 0.65* | 0.93* |
| Mining and quarrying | 0.82* | 0.65* | 0.45* | 0.32 |
| Food products | 0.05 | 0.32 | 0.38 | 0.54* |
| Textiles, clothing and leather | 0.50* | 0.63* | 0.32 | 0.39 |
| Wood products | 0.44* | 0.69* | 0.31 | 0.45* |
| Paper, printing and publishing | 0.30 | 0.66* | 0.64* | 0.50* |
| Petroleum and coal products | 0.82* | 0.39 | 0.40 | -0.01 |
| Chemical products | 0.82* | 0.47* | 0.63* | 0.58* |
| Rubber and plastics | 0.86* | 0.51* | 0.37 | 0.35 |
| Non-metalic mineral products | 0.39 | 0.88* | 0.45* | 0.65* |
| Metal products | 0.64* | 0.59* | 0.84* | 0.78* |
| Machinery | 0.61* | 0.75* | 0.77* | 0.73* |
| Electrical and electronic equipment & instruments | 0.78* | 0.70* | -0.09 | 0.78* |
| Transport equipment | 0.68* | 0.57* | 0.68* | 0.35 |
| Furniture and miscellaneous manufacturing | 0.68* | 0.79* | 0.14 | 0.53* |
| Electricity, gas and water | 0.69* | 0.77* | 0.42 | 0.31 |
| Construction | 0.58* | -0.12 | 0.07 | 0.67* |
| Wholesale trade | 0.19 | 0.44* | 0.75* | 0.35 |
| Retail trade | 0.61* | 0.19 | 0.68* | 0.17 |
| Hotels and restaurants | 0.44* | 0.60* | 0.74* | 0.10 |
| Transport & storage | 0.73* | 0.54* | 0.78* | 0.36 |
| Communications | 0.31 | 0.70* | 0.73* | 0.66* |
| Financial intermediation | 0.80* | 0.54* | 0.66* | 0.26 |
| Business services | 0.17 | 0.71* | 0.05 | 0.35 |
| | | | | |
| Market economy | 0.64* | 0.82* | 0.55* | 0.77* |

Note: Total factor productivity growth is calculated as growth of gross output minus growth of a Törnquist aggregate of intermediate inputs, capital and labour.

### Table A2, F-statistics for the first-stage regression of instruments on input growth

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| Agriculture, forestry and fishing | 2.67 | 13.5* | 1.46 | 1.56 |
| Mining and quarrying | 1.08 | 9.40* | 0.29 | 1.51 |
| Food products | 19.4** | 3.36 | 13.8* | 11.1* |
| Textiles, clothing and leather | 8.84 | 18.3** | 6.76 | 5.99 |
| Wood products | 2.00 | 1.04 | 2.08 | 5.60 |
| Paper, printing and publishing | 18.9** | 26.4** | 6.53 | 16.7** |
| Petroleum and coal products | 1.54 | 2.40 | 0.91 | 1.20 |
| Chemical products | 8.63 | 4.75 | 6.26 | 6.69 |
| Rubber and plastics | 17.0** | 25.5** | 14.7** | 40.1** |
| Non-metalic mineral products | 15.0** | 0.48 | 2.56 | 7.63 |
| Metal products | 4.47 | 26.4** | 3.13 | 8.67 |
| Machinery | 9.22* | 12.9* | 21.5** | 7.69 |
| Electrical and electronic equipment & instruments | 22.5** | 18.7** | 29.6** | 18.6** |
| Transport equipment | 29.3** | 11.5* | 5.92 | 7.06 |
| Furniture and miscellaneous manufacturing | 0.23 | 2.97 | 8.31 | 5.96 |
| Electricity, gas and water | 10.3* | 5.25 | 8.95 | 1.02 |
| Construction | 9.91* | 4.71 | 10.8* | 5.03 |
| Wholesale trade | 3.08 | 6.12 | 28.0** | 6.04 |
| Retail trade | 12.8* | 0.89 | 19.1** | 12.2* |
| Hotels and restaurants | 27.9** | 32.4** | 12.5* | 17.2** |
| Transport & storage | 35.2** | 6.74 | 12.2* | 26.8** |
| Communications | 9.93* | 4.57 | 15.7** | 20.1** |
| Financial intermediation | 14.4** | 4.83 | 41.9** | 7.39 |
| Business services | 39.6** | 26.8** | 53.0** | 83.3** |
| | | | | |
| Market economy | 13.5* | 11.2* | 13.6* | 13.5* |

Note: *: bias is less than 10% of OLS bias, **: bias is less than 5% of OLS bias

Instruments are the current value and one lag of industry-specific downstream indicators. Significance is determined using critical values from Table 1 of Stock and Yogo (2004). Critical 5% value is 13.91, the 10% value is 9.08.

## Table A3, Returns to scale estimates at the industry level, based on equation (6a)

| | *Ind. Group* | France | Germany | Netherlands | US |
|---|---|---|---|---|---|
| Agriculture, forestry and fishing | NMFG | 1.69 | 2.10 | 0.49 | 1.41 |
| Mining and quarrying | NMFG | 1.53 | 1.65 | -0.23 | -0.73* |
| Food products | NDUR | 0.26* | 0.64 | -1.00 | 1.93 |
| Textiles, clothing and leather | NDUR | 1.64 | 1.19* | 1.02 | 1.19 |
| Wood products | NDUR | 1.09 | 1.21 | 0.75 | 0.99 |
| Paper, printing and publishing | NDUR | 1.00 | 1.15 | 1.21 | 1.12 |
| Petroleum and coal products | NDUR | 1.19 | 1.12 | 0.93 | 0.15* |
| Chemical products | NDUR | 1.25 | 1.30 | 0.75 | 1.30 |
| Rubber and plastics | NDUR | 1.57* | 1.11 | 1.18 | 1.10 |
| Non-metalic mineral products | DUR | 0.99 | 1.59* | 1.13 | 1.28 |
| Metal products | DUR | 1.19 | 1.10 | 1.37* | 1.20* |
| Machinery | DUR | 1.14 | 1.20* | 1.28* | 1.25* |
| Electrical and electronic equipment & instruments | DUR | 1.37* | 1.08 | 0.94 | 1.44* |
| Transport equipment | DUR | 1.31* | 1.16 | 1.15* | 1.11 |
| Furniture and miscellaneous manufacturing | DUR | 2.27 | 1.41* | 0.80 | 1.44 |
| Electricity, gas and water | SER/NMFG | 0.17* | 1.09 | 1.20 | 0.01 |
| Construction | SER/NMFG | 1.18 | 0.88 | 0.92 | 1.11 |
| Wholesale trade | SER/NMFG | 1.13 | 1.25* | 1.31 | 1.07 |
| Retail trade | SER/NMFG | 0.76 | -2.31 | 1.27 | 1.54 |
| Hotels and restaurants | SER/NMFG | 1.22 | 1.38* | 1.10 | 0.82 |
| Transport & storage | SER/NMFG | 1.24 | 1.24* | 1.22 | 0.84 |
| Communications | SER/NMFG | 0.83 | 0.95 | 0.86 | 0.71 |
| Financial intermediation | SER/NMFG | 0.55 | 0.79 | 0.37 | 0.63 |
| Business services | SER/NMFG | 1.02 | 1.34* | 1.05 | 1.08 |
| | | | | | |
| Market economy | | 1.15* | 1.09 | 1.01 | 1.11* |

Ind. Group denotes the group in which the industry is included. DUR = Durable manufacturing, NDUR = Non-durable manufacturing, SER = Services, NMFG = Non-manufacturing.

Notes: Table shows parameter estimates from a regression with output growth as the dependent variable and growth of inputs as independent variable; a constant was also included. Estimation is done industry-by-industry using two-stage least squares with the current value and one lag of the downstream indicator for each industry as instruments. Standard errors, consistent for heteroscedasticity and autocorrelation, are shown in parentheses. * denotes parameters significantly different from one at the 5% level.

## Table A4, Correlation between output and technical change, based on industry-by-industry estimates of returns to scale and unmeasured input utilization

| | France | Germany | Netherlands | US |
|---|---|---|---|---|
| *Market economy* | | | | |
| Constant returns to scale | 0.72* | 0.82* | 0.51* | 0.85* |
| Variable returns to scale | 0.17 | 0.37 | -0.00 | 0.25 |
| Variable returns to scale & utilization correction | 0.04 | 0.12 | -0.10 | -0.02 |
| | | | | |
| *Number of market industries with correlation significantly different from zero (5% level)* | | | | |
| Constant returns to scale | 18 | 20 | 14 | 13 |
| Variable returns to scale | 11 | 9 | 12 | 8 |
| Variable returns to scale & utilization correction | 5 | 8 | 8 | 5 |

Note: correlations between output growth and technical change residuals. * denotes a correlation significantly different from zero at the 5% level. The definitions of technical change residuals is similar to Table 6, only in this table the parameters are allowed to vary for each industry.

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