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The exposure of technology and knowledge intense sectors to the business cycle

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Abstract

This paper studies the business cycle sensitivity of industries using different industry groupings. The results show that technologically intense industries are heavily affected by business cycles. While the overall importance of business cycles for long-run growth seems to be rather limited, we observe for industries with high technology intensity that business cycles may have persistent long-run effects on sectoral performance.

JEL classification numbers: E32, C32, O11, O40
Keywords: technology shocks, business cycle, long-run restrictions, sectoral response, structural change

1 Introduction

In the immediate aftermath of the financial and economic crisis of 2008 the OECD has urged policy makers to invest into research and innovation in order to restore long-term growth (cf. OECD 2009). Chief reason for this call to focus public support on research and innovation was that technology intense industries are very sensitive to economic downturns. The main arguments presented in favor of supporting technology intensive sectors were:

- R&D is typically financed by the cash flow of firms. A fall in earnings and value added is likely to affect R&D and other innovation investments negatively and causes R&D investments to vary pro-cyclically.
- Economic downturns have negative impact on entrepreneurship and business dynamics as venture capital dries up. This may affect the economic performance of entire industries as fewer new and innovative firms are created.

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- Technology intensive firms have intangible capital to offer as collateral, which makes procuring external finance difficult. This problem is exacerbated during the economic downswings, as banks become more selective in granting loans. As a consequence firms refrain from or postpone investments, especially in the expansion of own activities, such that employment growth at the industry level is negatively affected.
- The reduction of employment in R&D and other business services causes a depreciation of human capital, which is then no longer available in phases of economic upswings, and has to be regained through substantial training.

The economic literature argues that the above factors are principal factors behind long term growth. They are likely to weigh on the performance of the economy as a whole, and in particular on industries with high technological and knowledge intensity. The recommendation therefore was to enhance the resilience of R&D spending and innovative business creation over the cycle instead of supporting ailing industries. The latter would have only the effect of postponing necessary industrial restructuring.

While these arguments and the implied recommendations are plausible, there is up to now little systematic evidence that knowledge or technology intense industries are more heavily affected by economic cycles than others. Given the importance policy makers generally attribute to these sectors it is however worth taking a closer look at this issue. This paper therefore attempts to answer the following two questions:

1. Are knowledge- and innovation intense sectors more or less exposed to the business cycle and what is its effect on employment and value added growth?
2. Do sector specific changes in productivity and demand, which are more closely related to long-run structural change, outweigh short run output variations due to business cycles?

To address these questions, the paper applies the methodology proposed by Hölzl and Reinstaller (2007, 2011) to study structural change in an economy. The method decomposes changes in productivity and output at the industry level into sector specific changes to productivity and demand that are independent of aggregate output fluctuations, and changes that are related to business cycles. We give an overview on this approach in Section 2. The basic data source is the EUKLEMS data base, last updated in 2011, which are available up to the year 2007 in a consistent panel for the NACE 1.1 sector classification. We discuss the data in Section 3. Section 4 presents the results to the principal research questions, and in Section 5 we draw conclusion and develop some policy implications.

2 Estimation of the exposure of industries to business cycles and their contribution to the recovery

To estimate the exposure of industries to business cycles and their contribution to the recovery, we consider changes in employment and value added growth at the industry level in response to aggregate output variations. To separate factors that reflect variations in industry-specific productivity and demand related to business cycles from idiosyncratic changes unrelated to aggregate cyclical variations, we:

1. identify aggregate output variations over the business cycle across countries,
2. identify idiosyncratic variations in industry specific productivity and demand that are not related to aggregate variations, and
3. estimate the impact of aggregate output variations over the business cycle and idiosyncratic variations on employment growth and value added.

2.2 Identifying output variations over the business cycle

To obtain a degree of aggregate capacity utilization, or the current position of an economy in the business cycle, we use estimates of the aggregate output gap, i.e. the difference between the potential output an economy can achieve given its resources and the measured output. We estimate the potential output by using a Hodrick-Prescott (HP) filter on the aggregate output series. The HP filter decomposes time series in their long-run trend and cyclical components. The underlying assumption for the identification of business cycles using a statistical filter is that the potential output varies only over very long periods, whereas the output gap fluctuates at higher frequencies.

2.3 Identifying idiosyncratic changes in productivity and demand at the industry level across countries

It is well known that both productivity and demand change as a result of business cycles (cf. Basu 1998). However, these changes are not related to technical progress or changes in industry-specific demand related to long run changes in consumer preferences. To assess the impact of business cycles on industry performance it is therefore necessary to disentangle these two aspects.

To identify idiosyncratic variations in productivity and demand growth, we use bi-variate structural vector autoregressive (SVAR) models with long run restrictions (c.f. Blanchard and Quah 1989) for each industry in each country in the sample. It is possible to show that the growth of productivity in an industry over time is determined by deterministic and stochastic trend components consisting of productivity shocks with permanent effect on productivity levels and productivity variations due to transitory changes in the degree of capital utilization. The latter do not reflect genuine productivity changes (cf. Hölzl and Reinstaller 2007). Controlling for business cycle variations and imposing the long run restriction that changes in hours worked have only transitory effects on labour productivity levels (cf. Galí 1999, p. 255 ff.) it is possible to extract technology shocks and non-technology shocks from the data. Several studies show that aggregate technology shocks estimated in this way are highly correlated to other measures of technical change such as modified (cost- rather than revenue-based) Solow residuals. Non-technology shocks have been shown to be related to changes in demand (cf. Galí 1999, Alexius and Carlsson 2005, Hölzl and Reinstaller 2005). Hölzl and Reinstaller (2005, 2007, 2011) provide evidence that these findings hold also at the industry level.[3] Controlling for business cycle fluctuations in the sectoral SVAR regressions ensures that the recovered industry specific technology and demand shocks are uncorrelated with business cycle fluctuations. This procedure has been proposed by Hölzl and Reinstaller (2007) and has been applied in this paper.

2.4 Estimating the exposure of industries to business cycles and their contribution to economic recovery

We rely on a regression analysis to establish the magnitude of the impact of aggregate business cycles shocks on employment and value added growth of industries, and to assess their importance relative to idiosyncratic changes in productivity and demand. We regress the output gap indicators for each country, industry specific technology and demand shocks and sector and country dummies upon the rates of change of employment and value added across industries and countries. The estimated baseline model is a pooled regression for each sector *i:*

$$y_{i,j,t} = \alpha_{i,j} + \beta_1 z_{j,t} + \beta_2 ts_{i,j,t} + \beta_3 ds_{i,j,t} + \gamma\eta_j + e_{i,j,t}.$$

In this model $y_{c,i,t}$ denotes the growth rate of employment or value added in industries *i* across countries *j*, $z_{j,t}$ are the estimated country specific output gaps and $ts_{i,j,t}$ and $ds_{i,j,t}$ represent the industry specific productivity and demand shocks recovered from the SVAR regressions. The dummy η_j controls for country effects not accounted for by other indicators in the regression. The term $e_{i,j,t}$ is the error term. We have standardized the continuous right hand side variables ($z_{j,t}, ts_{i,j,t}, ds_{i,j,t}$) in the regressions to have zero mean and unit standard deviation. In this way it is possible to compare the magnitude of the impact of the business cycles and idiosyncratic industry shocks directly, and to rank industries by the magnitude of the impact of business cycles. In order to estimate the impact of economic downturns on industries as well as their contribution to economic recovery the above model is estimated separately for negative and positive changes in business cycle. This permits accounting for possible asymmetries in the industry specific reaction to downswings an upturns that are not taken into account by the baseline model.

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[3] The assumption that business cycle shocks and structural shock are uncorrelated is one possible shortcoming of this method used in this study insofar as it is violated when there are permanent effects of business cycles on long-run growth. If such effects exist, then the chosen method is likely to underestimate their effect. One has to be aware of this issue when interpreting the results of our analysis.

3 Data

3.1 The data

Estimates presented in this paper use the EU KLEMS dataset (release November 2009).[4] The industry data for the most recent release are available either at the NACE 2-digit level or at higher levels of aggregation. Our methodological approach requires that time series are sufficiently long (> 25 observations). For this reason data for some countries could not be included in the analysis. Table 1 gives an overview on the country, time and industry coverage of this study.

Table 1: Overview on the data coverage

Countries (abbreviations following ISO 3166 – 3 digit)	AUS, AUT, BEL, DNK, ESP, FIN, FRA, GER, GRC, IRL, ITA, JPN, KOR, NLD, PRT, SWE, UK, USA
Time coverage	1975-2007 (annual frequency); PRT,JPN: 1975-2006; USA: 1979-2007
Industry coverage (following NACE 1.1)	15t16, 17t19, 20, 21t22, 23, 24, 25, 26, 27t28, 29, 30t33, 34t35, 36t37, 50, 51, 52, 60t63, 64, 70, 71t74, AtB, C, E, F, H, J, L, M, N, O

3.2 Variables

Table 2 lists the main variables from the EU KLEMS dataset used in this study. The principal variables for the SVAR analysis (see Section 2.3) at the sector level are hourly productivity and hours worked.[5] In addition the SVAR analysis makes also use of the output gap variable. The growth rates of value added and employment at the industry level are used to capture industry performance. These are the key variables from the EU KLEMS database. The other variables used in the analysis are based on transformations of these data series. The output gap variable is recovered from the application of the HP filter on the aggregate series for real value added. The idiosyncratic industry specific demand and productivity shocks are extracted through a decomposition procedure from the residuals of the sectoral SVAR regressions described in the previous section.

[4] www.euklems.net

[5] Panel unit root and cointegration tests show that the series are integrated of order one and stationary in log differences, and that they are not cointegrated.

Table 2: Variables derived from the EU KLEMS database

VA $_{i,j,t}$	gross value added at current basic prices (in millions of local currency)
VA_P $_{i,j,t}$	gross value added, price indices, 1995=100: Deflator at the industry level
EMP $_{i,j,t}$	number of persons engaged (in thousands)
H_EMP $_{i,j,t}$	total hours worked by all persons engaged (in millions); domestic concept
Indices i,j,t for sector, country and time.	
Constructed variables:	
$p_{i,j,t} = \left(\frac{VA_{i,j,t} * 100}{VA\_P_{i,j,t}} \right) \Big/ H\_EMP_{i,j,t}$	Hourly labour productivity, where $\frac{VA_{i,j,t} * 100}{VA\_P_{i,j,t}}$ equals real value added
grVA $_{i,j,t}$ $= \ln(p_{i,j,t}) - \ln(p_{i,j,t-1})$	growth in real value added in country j, sector i at time t
grEMP $_{i,j,t}$ $= \ln(EMP_{i,j,t}) - \ln(EMP_{i,j,t-1})$	employment growth in country j, sector i at time t
lnh = ln (H_EMP $_{i,j,t}$)	log hours worked in country j, sector i at time t
lnp = ln ($p_{i,j,t}$)	log productivity in country j, sector i at time t

The idiosyncratic demand and productivity shocks at the industry level are standardized to a mean of zero and standard deviation of one, whereas the output gap has also mean close to zero, but a much smaller standard deviation. To compare the magnitude of the impact of aggregate business cycles and idiosyncratic industry shocks on industry performance it would be necessary to standardize all these variables. For this reason we also standardize the output gap.

3.3 Industry classifications

In order to assess whether knowledge or innovation intense sectors are more or less exposed to variations in the business cycle and how business cycle shocks affect the performance of these sectors we use four principal taxonomies that classify industries along:

- the innovation characteristics of industries,
- the educational intensity of industries,
- the main industry groupings (MIGS), and
- the main economic sectors.

An overview on these classifications is given in Appendix A.1. The classification of industries based on innovation characteristics draws upon an extended and updated version of the well-known Pavitt taxonomy (cf. Pavitt 1984) by Miozzo and Soete (2001) that includes also service sectors. It captures supplier relationships and inter-sector interdependencies that might be important in the impact and propagation of business cycles. According to the extended Pavitt taxonomy, manufacturing and service industries are classified as scale intense, supplier dominated, specialized suppliers or science based. This taxonomy is used in this paper because it captures the predominant production techniques, supply relationships and the specialisation of industries.

These aspects are likely to play a role in the propagation of business cycle shocks and their impact on industry performance. For instance, one may think of reasons why scale intensive industries are likely to adjust more slowly to short run variations in aggregate demand. Given the scale intensity firms in these sectors may have an incentive to reduce production and employment to keep capital utilization high. This would imply that cyclical downswings affect value added growth more heavily than employment growth. On the other hand, specialised suppliers may be harder hit by business cycles as they tend to deliver specialised inputs to supplier dominated firms. If firms in these sectors postpone investments, business cycles would propagate more heavily in specialised supplier industries, heavily affecting both value added and employment growth. These aspects will be explored in the analyses using this taxonomy.

The classification of industries by educational intensity draws upon a study by Peneder (2007) that has classified industries based on the education attainment levels extracted from the European Labor Force Survey. This classification divides industry into five different classes of educational intensity. Sectors with a high share of employment of people with high educational attainment are classified as having high educational intensity. This is followed by industries with either intermediate-high or intermediate-low educational intensity and industries with low and very low shares of employment with high educational attainment. The original classification distinguishes also between sectors with very high and high education intensity, that in the present study are subsumed into one class (high) in order to have more equally balanced classes in terms of the size of sector aggregates. The reason for evaluating the impact of business cycles on industry performance using this classification is that several studies have provided evidence that over the past two decades a marked structural change towards industries with high educational intensity has taken place in the most advanced economies in Europe and worldwide (see Peneder 2007 for an overview). This raises the question whether any particular pattern of propagation of business cycles can be observed for these industries. When using this taxonomy we include also public services. These are typically very educationally intense sectors, and as they are part of the public sector, they might also show specific reaction patterns to business cycles that reflect fiscal policies that in the aggregate attenuate the effects of changes in employment and output.

Of the last two classifications one corresponds to the definition of the Main Industrial Groupings (MIGS) based on the statistical classification of economic activities in the European Community. This classification discriminates between industries in function of their position in the overall value chain. Hence, it distinguishes between the energy sector, investment and intermediate goods sector, as well as the consumer goods sector. This classification excludes most of the service sectors. Overall one would expect for this classification that especially the intermediate and investment goods sectors that provide the principal inputs for production should be more heavily affected as variations in aggregate output and changes in expectations on the economic development have an

immediate impact on the investment and production plans of firms that revise accordingly.
The final classification groups the NACE sector definitions into a few principal groups according to their main economic activity: agriculture, industry, commerce and trade, construction, public services and business services. This group is introduced to verify the validity of this very generic and frequently used classification for the assessment of the impact of cyclical variations in output. Apart from specific patterns for the construction industry and public services it is unlikely that these broad sector aggregates will show distinctive patterns in reactions to output variations as they group very heterogeneous industries such that distinctive developments are likely to average out. Despite these potential limitations we present results also for this sector grouping because of its widespread use in policy debates.

4 The impact of business cycles on industry performance and the effect of sector specific developments

To assess the impact of business cycles on industry performance we first rank industries in terms of the magnitude of the effect short run changes in aggregate output have on the growth of value added and employment at the industry level across countries. In a second step we establish then an identical ranking based on economic downturns and upswings. Finally, we present then these effects for the different industry classes presented in the previous section.

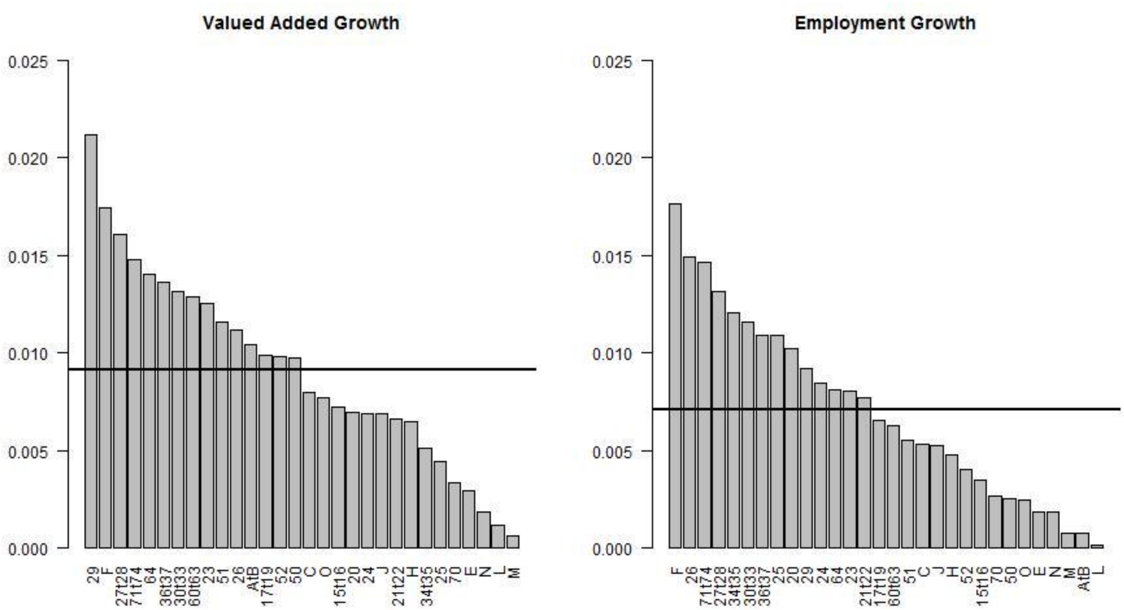

Figure 1: Impact of business cycles on value added and employment growth by sector
Note: EU KLEMS data; Own calculations;

Figure 1 presents the ranking of industries in terms of the magnitude of the effect a change in the aggregate business cycle has on industry specific value added and employment growth. When interpreting these values one has to keep in mind that the output gap has unit variance. The interpretation therefore is that a change in output gap in the order of one standard deviation causes the growth rate of the performance indicator to change by the value shown in Figure 1 (or the percentage point change if this value is multiplied by 100).

The horizontal line represents the average effect of a change in the business cycle on an indicator across industries and countries. A one standard deviation change in the output gap changes value added growth by about 0.9 percentage points on average. The figure is lower for employment growth (about 0.7%). This reflects the higher sensitivity of value added growth to changes in the business cycle. Lower sensitivity of employment growth may reflect labor hoarding either due to the expectations of employers that cyclical variations are temporary, or due to legal restrictions limiting the possibility of firms to hire or fire.

The magnitude of the impact of business cycle fluctuations varies greatly across industries. For example, the impact of a change in the business cycle on value added growth of manufacture of machinery and equipment ("29") is about four times higher than for manufacture of transport equipment ("34t35"). Considering the impact of a cyclical shock on employment growth for the same industries one sees that the effects are rather similar and their relative position is inverted. The industry most heavily affected by changes in the business cycle in terms of employment growth is the construction industry ("F") followed by the related "manufacture of non-metallic mineral products" ("26") that comprises industries producing construction materials. Strongly affected in both performance dimensions are business service ("71t74") and the manufacture of basic metal products and fabricated metal products ("26"). The business services sector comprises also R&D services. The sectors least affected by business cycles both in terms of value added and employment growth are related to the public sector (education, health, public administration). This is in line with other accounts of sectoral volatility such as Afonso - Furceri (2009).

Looking separately at negative and positive deviations in the cycle on industry performance, Figure 2 shows that the ranking of the industries changes. However the picture changes little with regard to the industries that are most heavily affected by cyclical variations in aggregate output. Figure 2also shows an asymmetry in the reaction to upswings and downturns. In general industries tend to react more heavily and with a larger variation across industries to downturns both in terms of value added and employment growth, than during upswing periods. The industries that react most to changes in the business cycle in terms of changes in employment are construction ("F"), the metalworking industry ("27t28"), the transport equipment industry ("30t33"), industries producing largely consumer goods ("36t37") and the business services sector ("71t74"). Next to these industries also the oil industry ("23") and the mechanical engineering industry ("29") are heavily affected in terms of value added growth. The industries related to the public sector fluctuate anti-cyclically both in terms of value added and employment growth. In these industries employment is created during downturns and is reduced (even though to a much lesser extent) during upswings. This hints at anti-cyclical employment creation in the public sector in the countries studied here.

The likely reason for the observed asymmetries lies in the different impact of cyclical changes on structural adjustments. In economic downturns firms will experience a fall in demand and turnover. This affects negatively value added if costs cannot be adjusted immediately due to contractual agreements with supplier or other rigidities on the factor markets. However, firms will try to adjust employment in order to cut cost and restore profitability. In upswing phases, instead, firm are likely to be more conservative with regard to the expansion of the labour force (especially if labour laws make subsequent firing difficult). In place of hiring new employees, they scale up overtime work and increase pay, on the other hand the pressure to cut costs diminishes and hence value added and employment growth do not react as strongly to upswings than to downswings.

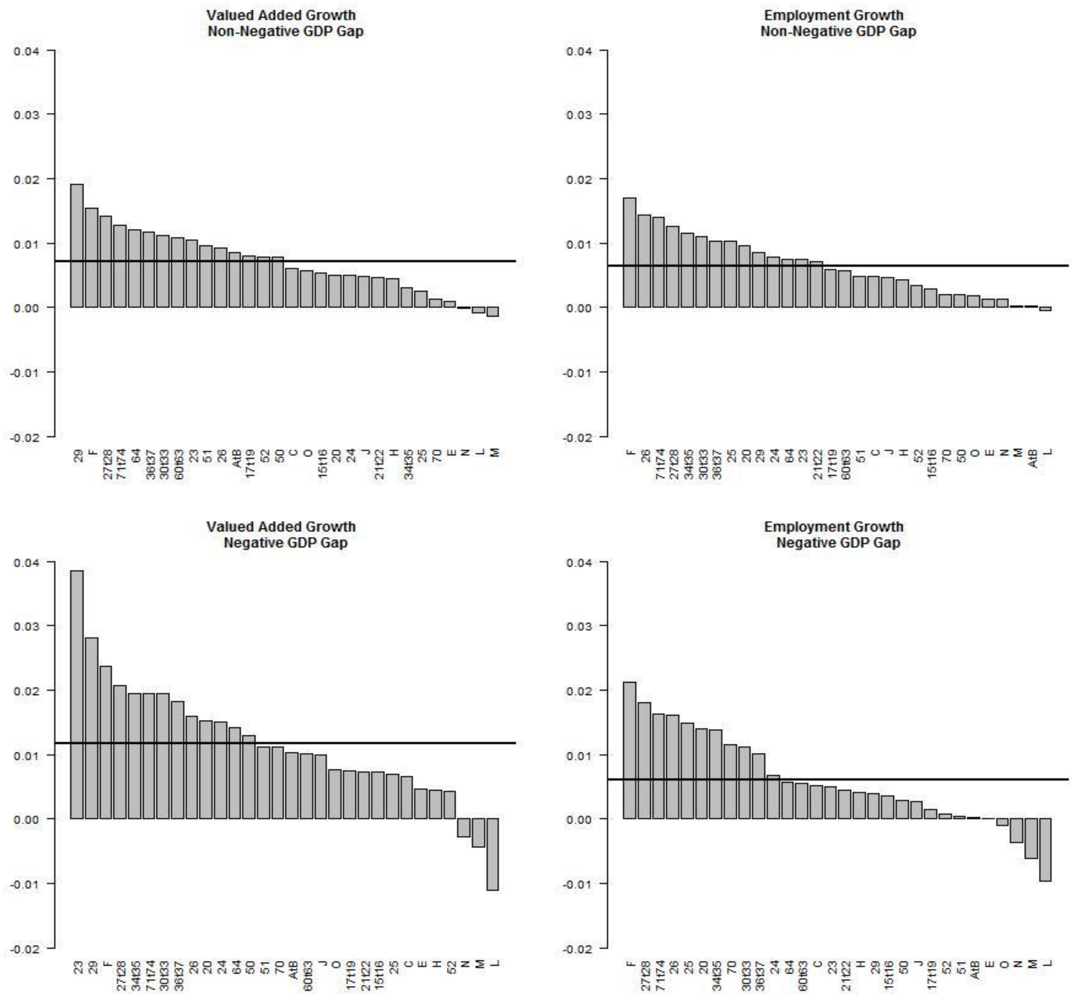

Figure 2: Impact of business cycles on value added and employment growth: differences in economic downturns (negative GDP gap) and upswings (non-negative GDP gap)

Note: EU KLEMS data; Own calculations;

Figure 3 shows the average responses of industries grouped by the taxonomies described in the previous section. Looking at the figure grouping industries based on the extended Pavitt taxonomy first, we see that in terms of value added growth the industries characterized as specialized suppliers (SS) is most heavily affected. This is due to the inclusion of the mechanical engineering industry in this group. It is followed by the science based business (SBS) services sector, which comprises the business services ("71t74"). In terms of employment growth the science based service (SBS) industry is most heavily affected by changes in aggregate output. It is followed by the scale intensive industries (SI) and the specialized supplier industries (SS). Overall it is the specialized supplier and the science based service industries that are most heavily exposed to the business cycle. These are also the most technology intense industries in terms of their average R&D shares.

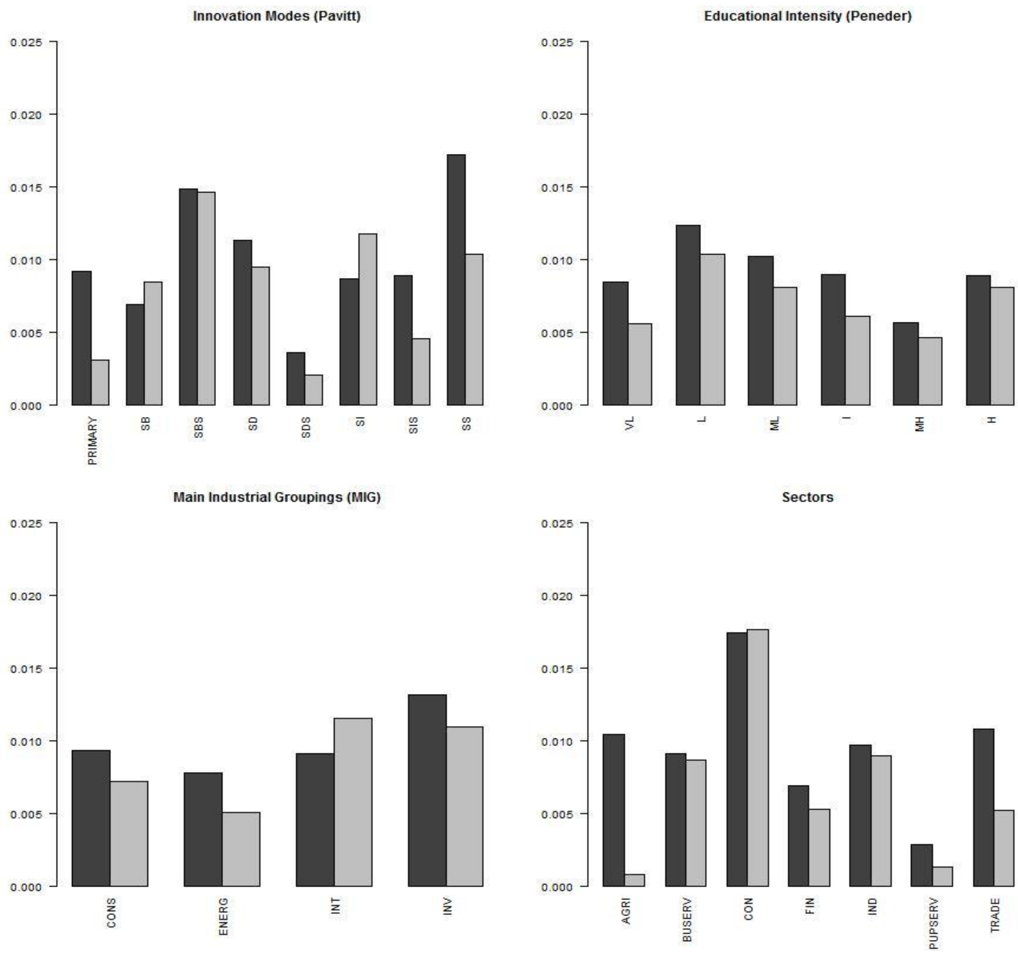

Figure 3: Impact of business cycles on value added and employment growth by industrial classification
Note: EU KLEMS data; WIFO calculations; Dark bars: impact on value added growth; light bars: impact on employment growth

Looking at the industries classified by educational intensity, we see that the sectors most heavily exposed to the business cycle are the sectors with medium-low to low educational intensity and the sectors with high educational intensity. For the industries with high educational intensity the result is determined on the one hand by the business services industry and on the other hand by industries related to the public sector. Hence, the reaction of the industries with high educational intensity is considerably lower than if one would look at the technology intensive sectors of the extended Pavitt taxonomy as the effect of public sector employment tames the response of this aggregate to cyclical fluctuations.

The panels for the main industry groupings and the classification according to the main economic activities in the business sector in Figure 3 round up the picture: Investment good and intermediate goods industries are most heavily exposed to the business cycle, as is the construction industry. A considerable divergence between the reactions to cyclical fluctuations in terms of value added and employment emerges for the agricultural sector and the sectors related to commerce where reactions are considerably more pronounced in value added than in employment.

To summarise, the results presented in this section show that the magnitude of the impact of cyclical variations on sectoral employment and value added growth vary considerably across industries. Specialized supplier and the science based service industries are most heavily exposed to the business cycle. These industries have also a high share of highly educated in the workforce. The same holds true for industries with low educational intensity of their workforce. However, the reactions to cyclical variations are not symmetric. The results show that sectors with high educational intensity related to public services even fluctuate anti-cyclically.

4.1 The relative importance of business cycle shocks and industry specific changes in demand and productivity

We now assess the impact of business cycles relative to industry specific changes in productivity and demand on the long run growth of industries. Tables 3 and 4 show the outcome of a regression analysis used to explore the relationship between cyclical output changes and non-cyclical industry specific changes on the one hand and value added growth and employment growth on the other hand.

The tables present the regression coefficients for the standardized changes in output gap, the standardized changes in industry specific productivity and demand (non-technology shocks). The constant can be interpreted directly as the long run growth trend over the 35 year period of the analysis. For instance, the coefficient of the constant for the textile industry ("17t19") in Table 3 is equal to - 0.0296. This means that over the past 35 years employment in this industry has shrunk by -2.96 percentage points on average each year. The other coefficients reflect the effect of a one standard deviation change of the variable on the growth rate of employment or value added. The relative magnitude of the different coefficients can be inferred directly from the coefficients. Looking again at industry "17to19" one can see that the impact of non-technology or demand shocks on long run output growth is about four times bigger than that of changes in the output gap.

Table 3 presents the results for value added growth at the industry level. It largely confirms the evidence for the employment growth rate discussed below. The principal difference is that here the industry specific changes in productivity unrelated to the business cycle have a positive impact on value added growth. Another important difference is that all industries, except textiles, have experienced a positive long run trend in value added growth on average across all countries. This implies that while some industries do not contribute to employment growth they still contribute to aggregate welfare. The contribution to aggregate value added growth has been highest for a number of service industries (post and telecommunications “64”, real estate and business services “70” and “71t74”), financial intermediation “J”, health “N”, sales, maintenance and repair of motor vehicles “50”). In the manufacturing sector science based and scale intensive industries have had the highest contributions to value added across countries.

With respect to the relative importance of industry specific changes in productivity and demand as opposed to changes induced by business cycles on value added growth the results are similar to the previous ones. In all countries and industries idiosyncratic productivity changes outweigh the effect of the business cycle on long run growth in value added by a factor of seven. The relative impact of idiosyncratic changes in demand is somewhat lower than for employment growth. However, the impact of industry specific changes in demand is still on average about 4.6 times larger than that of business cycles.

Table 4 presents the results for employment growth at the level of industries. The coefficient of the constant capturing the long term growth trend shows that employment in a number of industries has contracted steadily. The trend was most accentuated for the textile industry (“17t19”) and the non-metallic mineral products industry (“26”) that includes amongst others the glass and the brick industries. On the other hand the industries in which employment growth was highest in the 35 year period analysed here were the business services and the real estate service industries (“71t73” and ”70” respectively). This evidence captures long run structural change away from some manufacturing industries towards services. However, the long run loss of employment has been least accentuated mostly in specialized supplier and science based industries. On the other hand, it employment gains have been highest in the scale intensive and science based services.

Looking at the idiosyncratic productivity and demand shocks it is interesting to note that across all industries productivity changes have a negative impact on employment growth whereas sector specific changes in demand affect it positively. This is in line with results by Hölzl and Reinstaller (2007, 2011) for Austria. For almost all sectors with the exception of the public administration, business services and real estate as well as the production of beverages and tobacco the coefficients for the industry specific demand shocks are larger than the coefficients for the aggregate output shocks. Looking at the relative importance of the industry specific changes in productivity and demand as opposed to the changes induced by business cycles the results clearly show that industry specific changes outweigh the impact of business cycles on long run employment growth in absolute terms. The effect of technology shocks across industries and countries is about seven times larger and that of demand shocks is close to eight times larger.

To sum up, the results presented in this section indicate that sector specific changes in productivity and demand that are not related to short run cyclical variations outweigh considerably the impact induced by business cycles on long-run industry performance. They are, on average across industries and countries between five to eight times larger. This lends support to theoretical considerations that the factors driving structural change such as technological progress or varying income elasticities of demand are considerably more important for long run industry performance than short run variations in aggregate output growth (Pasinetti 1993). It is however important to note that the impact of the business cycle is in all cases small, but in almost all cases statistically significant and in the order of about 1% across sectors and countries for both value added and employment growth when the business cycle indicator changes by one standard deviation. This hints at persistent effects of business cycles on sectoral performance indicators. Mechanisms which link the business cycle to longer-term economic development have been suggested inter alia by Aghion et al. (2010) in the form of credit constraints. These are likely to result as a consequence of the long run impact of cyclical fluctuations of value added.

5 Concluding remarks

We have assessed the exposure of knowledge- and technology intense sectors to the business cycle, and the role of business cycles in long run development of industries. The results show that the magnitude of the impact of business cycles on value added and employment growth varies greatly across industries. The industries in which business cycles have the strongest impacts are business service ("71t74") and the metal industry ("26"). The business services sector comprises also R&D services. The sectors that are least affected are the industries related to the public sector (education, health, public administration). The effects of economic downturns and upswings are asymmetric. In economic downturns valued added and employment fall more sharply across sectors, than they resume growth during upswings. These results suggest that business cycles have a strong impact on technology intense industries. However, fluctuations in aggregate output have the most pronounced impact on the industries with low educational intensity.

The results also indicate that the total contribution of technology intense manufacturing industries (science based industries and specialized suppliers) to aggregate employment growth is rather small compared to the service sector where the largest shares of aggregate employment growth originates. Among the technology intense sectors the science based service industries (business services) have had a sizable contribution to valued added growth. Both industries with high to intermediate educational intensity, as well as in industries with medium low and low educational intensity, the contribution to aggregate employment growth has been positive. Employment growth has been negative in industries with very low educational intensity.

When interpreting these results it is important to keep in mind that the high relative contribution of service sectors, and especially public services, to value added depends on value added generated in other sectors. Without the constant growth of value added, and by implication also tax revenue in other sectors, the fast expansion of the services sector would not be possible. These developments reflect Baumol's disease (Baumol 1967), i.e. the observation that it is systematically more difficult to improve productivity in services vis-a-vis manufacturing industries, such that a reallocation of employment from the latter to the former takes place.

The overall importance of business cycles for long run growth at the industry level is rather limited. The results indicate that sector specific changes in productivity and demand that are not related to short run cyclical variations outweigh considerably the impact induced by business cycles on long-run industry performance. They are, on average across industries and countries, between five to eight times larger. The factors driving structural change are considerably more important for long run industry performance than short run variations in aggregate output growth.

Despite the impact of the business cycle is small in all cases it is almost always statistically significant and in the order of about 1% across sectors and countries for both value added and employment growth when the business cycle indicator changes by one standard deviation. This hints at persistent effects of business cycles on sectoral performance indicators. Technology intense industries are among the industries in which long-rung growth in value added and to a lesser extent in employment is most strongly affected by cyclical variations. Our findings therefore support the arguments put forward by the OECD in favor of supporting these industries during sharp economic downturns.

An important result of the paper is that while some of the more technology or knowledge intensive sectors contribute significantly to long run employment and value added growth, several of them, such as “Business Services” (“71t74”) or the manufacture of electrical and optical equipment (“30t33”), also tend to respond more heavily to cyclical fluctuations. As these sectors typically absorb also the largest part of public support measures for research and innovation, strengthening their resilience of R&D spending and innovation over the business cycle seems to be adequate to minimize the impact of cyclical variations on long run employment and value added growth. On the other hand, the results also indicate that countries with an industrial structure where more knowledge – or technology intense sectors play a predominant role, may not only experience more dynamic growth in the long run, but also more pronounced cyclical fluctuations in the short run.

Table 3: Value added growth at the sectoral level: pooled regressions

Sector	agg. output gap		sect. technology shock		sect. non-tech shock		Constant		R^2
	coeff.	t value	coeff.	t value	coeff.	t value	coeff.	t value	
15t16	0.0073	(7.30)	0.0261	(25.74)	0.0217	(21.40)	0.0149	(3.59)	0.74
17t19	0.0099	(5.82)	0.0276	(16.02)	0.028	(16.24)	-0.0168	(-2.37)	0.56
20	0.0069	(4.10)	0.0537	(31.73)	0.0405	(23.92)	0.0086	(1.22)	0.75
21t22	0.0066	(3.47)	0.0439	(23.12)	0.0289	(15.22)	0.0236	(3.00)	0.63
23	0.0129	(1.10)	0.2363	(20.11)	0.0561	(4.77)	0.0467	(0.97)	0.50
24	0.0069	(3.03)	0.051	(22.03)	0.025	(10.79)	0.0212	(2.24)	0.60
25	0.0044	(2.45)	0.0514	(28.40)	0.0329	(18.15)	0.0229	(3.05)	0.70
26	0.0111	(7.58)	0.0395	(26.85)	0.0328	(22.27)	0.0235	(3.84)	0.73
27t28	0.0162	(12.19)	0.0318	(23.05)	0.0305	(22.13)	0.0196	(3.55)	0.78
29	0.0211	(9.38)	0.0444	(19.25)	0.0322	(13.95)	0.0085	(0.91)	0.66
30t33	0.0131	(5.09)	0.068	(26.36)	0.0385	(14.90)	0.0257	(2.40)	0.71
34t35	0.0051	(1.45)	0.0822	(23.25)	0.038	(10.75)	0.0221	(1.50)	0.58
36t37	0.0136	(6.52)	0.0582	(27.96)	0.0352	(16.91)	0.0161	(1.86)	0.68
50	0.0097	(5.51)	0.0463	(26.01)	0.0242	(13.62)	0.0402	(5.49)	0.63
51	0.0116	(9.35)	0.0356	(28.69)	0.0213	(17.20)	0.0243	(4.71)	0.70
52	0.0098	(9.11)	0.0287	(26.48)	0.0181	(16.71)	0.0297	(6.62)	0.66
60t63	0.0129	(12.06)	0.0267	(24.87)	0.0191	(17.79)	0.0333	(7.52)	0.71
64	0.014	(7.94)	0.0429	(24.20)	0.0256	(14.43)	0.0711	(9.69)	0.66
70	0.0036	(2.75)	0.0093	(6.98)	0.0174	(13.02)	0.0403	(7.41)	0.38
71t74	0.0148	(10.56)	0.0181	(12.77)	0.0236	(16.69)	0.0442	(7.60)	0.59
AtB	0.0104	(5.96)	0.0482	(26.35)	0.0276	(15.05)	0.0306	(4.21)	0.70
C	0.0074	(2.06)	0.0813	(22.36)	0.05	(13.75)	0.0394	(2.64)	0.61
E	0.0029	(1.50)	0.0481	(24.93)	0.0278	(14.41)	0.0318	(3.99)	0.65
F	0.0174	(11.19)	0.02	(12.48)	0.0308	(19.20)	0.0371	(5.73)	0.62
H	0.0065	(7.09)	0.0263	(28.65)	0.0231	(25.17)	0.0295	(7.74)	0.75
J	0.0068	(3.72)	0.0456	(24.78)	0.0244	(13.27)	0.045	(5.89)	0.65
L	0.0012	(1.47)	0.0107	(12.98)	0.0137	(16.67)	0.025	(7.46)	0.48
M	0.0006	(0.76)	0.0146	(17.72)	0.0135	(16.41)	0.0309	(9.31)	0.52
N	0.0019	(1.76)	0.0184	(17.19)	0.0132	(12.28)	0.0417	(9.49)	0.53
O	0.0077	(8.56)	0.0232	(25.55)	0.0181	(19.95)	0.0322	(8.64)	0.69

t-Statistics in parentheses, ** p<0.01, * p<0.05

Note: EU KLEMS data; Own calculations;

Table 4: Employment growth at the industry level: pooled regressions

Sector	agg. output gap		sect. technology shock		sect. non-tech shock		Constant		R^2
	coeff.	t value	coeff.	t value	coeff.	t value	coeff.	t value	
15t16	0.0035	(2.21)	-0.0178	(-11.02)	0.0141	(8.73)	-0.0012	(-0.18)	0.29
17t19	0.0065	(4.07)	-0.0121	(-7.48)	0.0255	(15.72)	-0.0296	(-4.46)	0.40
20	0.0102	(5.82)	-0.0127	(-7.26)	0.0308	(17.62)	-0.0003	(-0.04)	0.44
21t22	0.0077	(7.06)	-0.0102	(-9.32)	0.0243	(22.27)	0.0013	(0.29)	0.57
23	0.0080	(2.52)	-0.0357	(-11.15)	0.0513	(16.04)	0.0102	(0.78)	0.42
24	0.0085	(5.82)	-0.0185	(-12.50)	0.0208	(14.05)	-0.0045	(-0.75)	0.43
25	0.0109	(7.53)	-0.0130	(-8.99)	0.0321	(22.12)	-0.0040	(-0.67)	0.56
26	0.0149	(8.59)	-0.0132	(-7.63)	0.0242	(13.93)	-0.0253	(-3.52)	0.42
27t28	0.0132	(7.33)	-0.0167	(-8.91)	0.0211	(11.28)	-0.0098	(-1.31)	0.38
29	0.0092	(3.06)	-0.0189	(-6.15)	0.025	(8.13)	-0.0183	(-1.46)	0.25
30t33	0.0115	(7.58)	-0.0114	(-7.48)	0.0339	(22.30)	-0.0104	(-1.65)	0.55
34t35	0.0121	(6.88)	-0.0057	(-3.28)	0.0322	(18.36)	-0.0083	(-1.14)	0.49
36t37	0.0109	(6.50)	-0.0126	(-7.50)	0.0318	(18.93)	0.0197	(2.82)	0.48
50	0.0025	(1.71)	-0.0125	(-8.46)	0.022	(14.93)	0.0099	(1.63)	0.44
51	0.0055	(4.60)	-0.0123	(-10.32)	0.0167	(14.00)	0.0076	(1.54)	0.42
52	0.0040	(3.66)	-0.0094	(-8.55)	0.013	(11.79)	0.0216	(4.73)	0.38
60t63	0.0063	(7.25)	-0.0119	(-13.67)	0.0142	(16.31)	0.0147	(4.08)	0.49
64	0.0081	(7.03)	-0.0110	(-9.43)	0.0224	(19.29)	0.0099	(2.06)	0.56
70	0.0029	(1.19)	-0.0489	(-19.87)	0.0196	(7.95)	0.0438	(4.37)	0.48
71t74	0.0146	(9.05)	-0.0270	(-16.53)	0.0249	(15.21)	0.0534	(7.95)	0.53
AtB	0.0007	(0.78)	-0.0116	(-12.34)	0.0171	(18.22)	-0.0037	(-1.00)	0.47
C	0.0055	(2.07)	-0.0329	(-12.24)	0.0351	(13.06)	0.0236	(2.13)	0.39
E	0.0019	(1.25)	-0.0227	(-14.80)	0.0248	(16.20)	0.0003	(0.05)	0.48
F	0.0176	(11.27)	-0.0140	(-8.70)	0.0248	(15.41)	0.0185	(2.84)	0.46
H	0.0048	(3.16)	-0.0170	(-11.17)	0.0183	(12.05)	0.0319	(5.05)	0.36
J	0.0053	(4.90)	-0.0103	(-9.60)	0.019	(17.67)	0.0267	(5.98)	0.54
L	0.0001	(0.14)	-0.0098	(-9.47)	0.0085	(8.22)	0.0207	(4.91)	0.39
M	0.0008	(0.86)	-0.0075	(-8.19)	0.0081	(8.76)	0.0307	(8.28)	0.39
N	0.0018	(2.17)	-0.0076	(-8.96)	0.0138	(16.29)	0.0362	(10.39)	0.53
O	0.0025	(2.58)	-0.0100	(-10.28)	0.0167	(17.11)	0.0294	(7.34)	0.51

t-Statistics in parentheses ** p<0.01, * p<0.05

Note: EU KLEMS data; Own calculations;

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Appendix

A.1: List of sectors included in the paper and their classification

NACE Code (Rev 1.1)	Description	Extended Pavitt taxonomy	Peneder educational intensity	MIGS	Main sectors
15t16	Manufacture of food products, beverages and tobacco	supplier dominated	low	CONS	IND
17t19	Manufacture of textiles and textile products; manufacture of leather and leather products	supplier dominated	very low	CONS	IND
20	Manufacture of wood and wood products	supplier dominated	very low	INT	IND
21t22	Manufacture of pulp, paper and paper products; publishing and printing	scale intensive	interm.	CONS	IND
23	Manufacture of coke, refined petroleum products and nuclear fuel	supplier dominated	med. high	ENERG	IND
24	Manufacture of chemicals, chemical products and man-made fibres	science based	med. high	INT	IND
25	Manufacture of rubber and plastic products	scale intensive	med. low	INT	IND
26	Manufacture of other non-metallic mineral products	scale intensive	low	INT	IND
27t28	Manufacture of basic metals and fabricated metal products	scale intensive	low	INT	IND
29	Manufacture of machinery and equipment n.e.c.	specialised suppliers	interm.	INV	IND
30t33	Manufacture of electrical and optical equipment	specialised suppliers	high	INV	IND
34t35	Manufacture of transport equipment	scale intensive	interm.	INV	IND
36t37	Manufacturing n.e.c. (furniture, jewellery and related articles, musical instruments, sports goods, games and toys, other)	supplier dominated	med. low	CONS	IND
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	scale intensive services	low	n.c.	TRADE
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	scale intensive services	interm.	n.c.	TRADE
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	scale intensive services	med. low	n.c.	TRADE
60t63	Transport (land, water, air)	scale intensive services	med. low	n.c.	TRADE
64	Post and telecommunications	scale intensive services	interm.	n.c.	TRADE
70	Real estate activities	scale intensive services	interm.	n.c.	BUSERV
71t74	Business services	science based services	high	n.c.	BUSERV
AtB	Agriculture, forestry and fishing;	primary	very low	n.c.	AGRI
C	Mining and quarrying	primary	very low	ENERG	IND
E	Electricity, gas and water supply	scale intensive services	interm.	ENERG	IND
F	Construction	supplier dominated	low	n.c.	CON
H	Hotels and restaurants	supplier dominated services	very low	n.c.	TRADE
J	Financial intermediation	scale intensive services	high	n.c.	FIN
L	Public administration and defence; compulsory social security	supplier dominated services	med. high	n.c.	PUPSERV
M	Education	supplier dominated services	high	n.c.	PUPSERV
N	Health and social work	supplier dominated services	med. high	n.c.	PUPSERV
O	Other community, social and personal service activities	supplier dominated services	interm.	n.c.	PUPSERV

Note: n.c are non-classified sectors in the MIGS (Main Industry Groupings) classification.