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Carnevali, E, Godin, A, Lucarelli, S et al. (2020) Productivity growth, Smith effects and Ricardo effects in Euro Area's manufacturing industries. Metroeconomica, 71 (1). pp. 129-155. ISSN: 0026-1386

https://doi.org/10.1111/meca.12270

Productivity Growth, Smith Effects and Ricardo Effects in Euro Area's Manufacturing Industries

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Updated: 7th July 2019 (Version No. 7)

Abstract. We analyse the determinants of labour productivity across (a sample of) EA member-states. We focus on the divergent dynamics before and after the financial crisis, and of core countries relative to peripheral countries. We ground our empirical analysis in Paolo Sylos-Labini's productivity equations. We test different models, including a Panel 2S-LS model and a Panel VAR model. Our preliminary findings confirm and strengthen Sylos-Labini's main insights. Labour productivity in manufacturing industries is strongly and positively correlated with the market size (Smith effect), the relative cost of labour (Ricardo effect), the absolute cost of labour (organisation effect), and past investment, whereas it is negatively correlated with current investment. Furthermore, we find evidence that the crisis has affected the size of these effects. Focusing on the core-periphery dichotomy, the signs of the effects are the same for both groups of countries, although the Smith, Ricardo and long-run investment effects are usually stronger for core countries compared to peripheral countries. The opposite holds for the organisation effect, while investment effects are less clear.

Keywords: labour productivity, Sylos-Labini, EA imbalances

JEL codes: E24, O47

We thank the anonymous referees and the editor for their useful comments and suggestions.

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1. Introduction

The gap in productivity growth rates between core and periphery countries is frequently mentioned, along with the difference in growth rates of employee compensations, as the main driver of the imbalances in the balance of payments among member-states of the European Area (EA) (e.g. Draghi 2013). That very gap provides the rationale for structural reforms, which are called for to enhance competitiveness of peripheral countries, particularly through the increase of labour market flexibility. While we recognise that labour productivity is determined endogenously, we question the idea that labour market reforms would be the main means to increase productivity. We believe a thorough examination of a variety of other possible factors is needed. Our work provides an analysis of the determinants of labour productivity in selected EA member-states in the period 1996-2016. We focus on the divergent developments in manufacturing industries of "core" countries relative to "peripheral" countries.[1] Our empirical examination is grounded in Paolo Sylos-Labini's "productivity equations" (Sylos-Labini 1983, 1995). We test a number of simple theoretical models accounting for the endogenous nature of labour productivity. As mentioned, we look at possible differences and divergences across EA countries, particularly across early member-states.

Labour productivity developments in manufacturing industries of some selected EA member-states are portrayed in Figure 1 and Figure 2. As stressed by the President of the ECB Mario Draghi (2013), a slower growth rate in labour productivity of peripheral countries compared to core countries is apparent since the early 2000s, particularly when Ireland is not taken into account. National trends within the group of deficit countries are quite heterogeneous though. From mid-1990s to mid-2000s, Italy and Spain were both marked by a flat trend in labour productivity. Greece and Portugal, in contrast, were characterised by a rapid catching up. After the US financial crisis, labour productivity has increased remarkably in Spain and Portugal, whereas it has remained flat in Italy. Greece has been marked by a collapse in labour productivity over the same period instead. The development of labour productivity rates looks more homogenous across core countries. All of them are marked by an increasing trend before the US financial crisis, followed by a general decrease in 2007-2009, and then a recovery since 2009.

[PLEASE INSERT HERE FIGURE 1 AND FIGURE 2]

As mentioned, the examination of the factors underpinning recent (different) developments in labour productivities across EA-members' manufacturing industries is the main target and the original contribution of this research. For this purpose, the rest of the manuscript is organised as follows. In section 2, the theoretical framework is discussed. Drawing from Sylos-Labini (1983, 1995), we link labour productivity with technological innovation. The latter, in turn, is connected dynamically with the size of the goods market (i.e. demand conditions), the absolute cost of labour, the relative cost of labour (i.e. the trend in compensation of employees relative to the cost of machinery), and the investment level. In section 3, both the data used and the main methodological features of the benchmark model are discussed. In section 4, we present the main findings of our empirical analysis. In section 5, we extend the model developed in previous sessions to investigate the gap between core countries and peripheral countries. Section 6 is devoted to the development of a panel VAR model, aiming at addressing bi-causality issues with the benchmark model. Section VII provides some final remarks.

2. The theoretical framework: Sylos-Labini's productivity equations

The theoretical starting point of our empirical investigation is the simple model developed by Sylos-Labini (1983, 1995). While the Sylos-Labini model has been applied to Italian regions and sectors (e.g. Guarini 2007, Guarini 2009, Corsi and D'Ippoliti 2013), it is hardly ever tested on other European countries at the sectorial level. There are a few exceptions: Sylos-Labini (1993) presented econometric estimates of the productivity equation concerning the manufacturing sector for different countries, while Lucarelli and Romano (2016) used a similar model to focus on Germany and Italy.

The model proposed by Sylos-Labini is based on the idea that labour productivity growth in manufacturing industries arises from innovation. The latter, in turn, is driven by four factors. The first factor, which Sylos-Labini called the "Smith effect", is the size of the domestic market, as pioneeringly emphasised by Adam Smith. This principle echoes the so-called "Kaldor-Verdoorn law". It postulates that the rate of technical progress is endogenous. More precisely, it states that labour productivity growth rate is a positive function of the growth rate of the economy or of the industries considered (e.g. Kaldor 1961, 1978, Verdoorn 1949, 1980). This is a key relationship of the Keynesian economics school (Lavoie 2014) and has been validated by many empirical works (e.g. McCombie and Thirlwall 1994, McCombie 2002). The second factor leading firms to innovate is the growth in the absolute cost of labour in real terms. While many different formulations are possible, the absolute cost of labour is simply defined here as the ratio between the wage rate and the price level.[2] An increase in the absolute cost of labour leads the firms to improve the allocation of labour inputs to increase efficiency. The new, more efficient, organisation, triggered by the rise in real wages, is expected to bring about an increase in labour productivity.[3] The third factor is the growth in the cost of labour relative to the price of investment goods, say, machines. An increase in the relative cost of labour leads the firms to replace workers with machines. Such a result is defined by Sylos-Labini as the “Ricardo effect”.[4] The fourth factor affecting labour productivity is the real investment level.[5] The impact of investment on productivity is twofold: on one hand, a “disturbance effect” is possible in the short run, as the new machinery takes time to be used effectively; on the other hand, investment is expected to improve labour productivity in the medium to long run.[6]

Using a “dot” to denote growth rates, the average real labour productivity function can be defined by means of the expression below, which is linear in the parameters:

$$\dot{PR} = \alpha + \beta_1 \cdot \left(\dot{V}_{€} - \dot{P}\right) + \beta_2 \cdot \left(\dot{W}_{€} - \dot{P}\right) + \beta_3 \cdot \left(\dot{W}_{€} - \dot{P}_k\right) +$$
$$+\beta_4 \cdot \frac{INV}{Y} + \beta_5 \cdot \frac{INV_{-\lambda}}{Y_{-\lambda}} \qquad (1)$$

where $V_{€}$ is the nominal value added of the economy considered (including both domestic demand components and export), P is the general price level, $W_{€}$ is the nominal wage rate, P_k is the price of machines, INV stands for new (or current) real investment level, Y is current gross domestic product, and the subscript “$-\lambda$” denotes past (or lagged) variables.

We can simplify equation (1) by using $V = V_{€}/P$, $U = W_{€}/P$, $W = W_{€}/P_k$, and $I = INV/Y$. We obtain:

$$\dot{PR} = \alpha + \beta_1 \cdot \dot{V} + \beta_2 \cdot \dot{U} + \beta_3 \cdot \dot{W} + \beta_4 \cdot I + \beta_5 \cdot I_{-\lambda} \qquad (2)$$

where β_1 captures the Smith effect, β_2 measures the organisation effect, β_3 captures the Ricardo effect, β_4 measures the short-run disturbance effect of newly-undertaken real investment, and β_5 is meant to capture the long-run effect of real investment on labour productivity. Notice that coefficients above are all expected to be positive, except for β_4. On a close inspection, Sylos-Labini's theoretical model may well be regarded as an implementation and extension of the Kaldor-Verdoorn law, where the effect of the size of the market on technical progress is *one out of four* determinants of labour productivity (e.g. Sylos Labini 1984).

3. Data and methodological issues with the benchmark model

Our dataset covers a subset of current EA member-states from 1996 to 2016 on a quarterly basis at the country level. Due to the lack of available data, we focus on eight countries, notably Austria, France, Greece, Germany, Italy, Netherlands, Portugal, and Spain. Definitions and data sources are all provided by Table A1 in the Appendix. Estimates have been made using different techniques and different clusters of countries (namely "core" vs "peripheral" countries). Heteroskedasticy-robust standard errors and covariances have been used, unless otherwise stated. Serial correlation was checked and rejected.[7] The hypothesis that there were no time trend in productivity growth rates was checked (by a Wald test) and not rejected. In order to rule out spurious regressions, we checked the stationarity of variables by using a Levin-Lin-Chu test for unit roots in panel datasets.[8] Variables of the model are all stationary except for investment (taken as a ratio to GDP), which is not expressed as a growth rate (see Table A2).

Before we present our main findings, three possible issues are worth discussing. The first issue concerns the definition of labour productivity. While, in principle, an engineering measure of productivity would be the first best option, such measure is usually unavailable. This is the reason we opted for an economic definition of productivity (PR), in line with the available literature. We defined PR as real GDP per person employed (at constant prices of 2010). Since the real value added of the economy (V) is included among the predictors of the model, endogeneity issues may well be raised. More precisely, the value of the coefficient β_1 could be biased, because of the possible loop of causality between PR and V. This is a well-known issue that the researchers face when estimating the Smith-Kaldor-Verdoorn effect. As a result, many attempts at fixing it have been made in the last three decades (e.g. McCombie et al. 2002), using cointegration methods (e.g. Gambacorta 2004), feasible generalized spatial two-stage least squares estimators (e.g. Angeriz et al. 2008), two-stage ordinary least square estimators (e.g. Corsi and D'Ippoliti 2016), pooled cross-section OLS and limited information maximum likelihood estimators (e.g. Millemaci and Ofria 2016). Overall, the existence of a strong effect of real value added on labour productivity has been observed whatever the correction method chosen. We addressed the possible endogeneity by using the (average quarterly change in) crude oil price as an instrumental variable. Asymmetric though it is, the effect of oil price shocks on economic growth is widely recognised in the literature (e.g. Jiménez-Rodríguez 2008; Jiménez-Rodríguez and Sánchez 2005, 2009) and it is commonly used in the works on the Smith-Kaldor-Verdoorn law (e.g. Millemaci and Ofria 2014). While oil price affects the value added, labour productivity is unlikely to affect the oil price directly.[9] Accordingly, we ran a two-stage least square regression by instrumenting for the oil price. We found that the effect of a change in the real value added of the economy on labour productivity growth is in line with the literature on the Kaldor-Verodoorn effect.

A second possible issue is that the relationship between labour productivity and output growth in manufacturing industries is expected to be cyclical and driven by output fluctuations when labour protection is high. This was the case of major European countries up until the early 1990s. However, labour market reforms (which have been introduced ever since) have made employment more sensitive to output fluctuations, while weakening the possible impact on labour productivity. As mentioned, we depart from the Sylos-Labini model in Section 6, where we consider all the interdependencies among our variables using a VAR model.

A third issue concerns the specification of the model proposed by Sylos-Labini. The point is that we cannot exclude that other variables could affect innovation and labour productivity – think of the price of raw materials, State-led innovation policies, differences in employment rates, and labour market conditions. While we take explicitly into consideration labour protection (as this is one of the most mentioned factors in the literature), we assume that State-led policies are mirrored by government spending, and therefore are completely captured by the Smith effect. We are aware that this is a controversial assumption, which should be investigated in future researches. In addition, we neglect the possible impact of raw material prices (other than oil price) on innovation and productivity. We also assume away the negative relationship between employment rates and productivity rates across nations.[10] However, this choice should not affect our findings, as there is evidence that the trade-off between productivity growth and job creation has been weakening since the 1980s in most OECD countries (Cavelaars 2005). Overall, the rationale of the simplifying assumptions above is to stick as much as possible to the original Sylos-Labini model, thus anchoring it to a sound theoretical structure. Our key findings are discussed in the next section.

4. Productivity determinants in EA8 countries: a simple Panel OLS model

Overall, our empirical analysis supports Sylos-Labini (1983, 1995)'s theoretical insights. Key variables have all a strong impact on labour productivity growth rates across EA countries. The extended functional form we estimated is:

$$d(\log(PR_{it})) = \alpha_i + \beta_1 \cdot d(\log(V_{it})) + \beta_2 \cdot d(\log(U_{it})) + \beta_3 \cdot d(\log(W_{it})) + \\ +\beta_4 \cdot I_{it} + \beta_5 \cdot I_{it-\lambda} + D_t + LPI_{it} + \epsilon_{it} \quad (3)$$

where subscript "i" stands for country, "t" stands for time, $\log(\cdot)$ is natural logarithm, λ is the investment time lag, α_i are country fixed effects (if any, where: $\alpha_i = \bar{\alpha}$ if no specific effects are found), and ϵ_{it} are error terms. We used dummies, D_t, to account for the effect of the US financial crisis on the world economy, and the labour protection index, LPI_{it}, to take into consideration the possible impact of labour market conditions on productivity.

As mentioned, estimates have been made by using different models and different clusters of countries. Initially, we focused on the whole sample (EA8 hereafter), including both peripheral countries (notably, Greece, Italy, Portugal, and Spain) and core countries (notably, Austria, Germany, France, and the Netherlands). In accordance with Sylos-Labini's theory, estimates are made for the manufacturing industry. Results are reported in Table 1.

[PLEASE INSERT HERE TABLE 1]

The proportion of response variation of productivity growth explained by the models' regressors is rather high, as coefficients of determination (i.e. *Adjusted* R^2) are all above 68%. Model 1 is the simplest model we tested. Coefficients are all statistically significant at the 1% threshold and below. The market size (Smith effect), the relative cost of labour (Ricardo effect), and the organisation effect, have all a positive impact on the real productivity of labour, thereby supporting Sylos-Labini insights. However, model 1 could be affected by misspecification. Some possible productivity drivers identified by Sylos-Labini are not taken into account, the most important one being the investment level. The impact of current and past investment (meaning one-lag investment) is considered by model 2.[11] Coefficients are all statistically significant. Signs are all consistent with Sylos Labini's theory (meaning a positive sign for the Smith Effect, the organisation effect, the Ricardo Effect, and the long-run effect of real investment, and a negative sign for the short-run disturbance effect of newly-undertaken real investment).[12]

Models 1 and 2 are pooled OLS estimations based on the assumption that there is a common constant term for all countries included in our sample. In principle, it would be possible to introduce some degree of heterogeneity by using a cross-country fixed effects estimator. This is made by model 2bis in the Table 1. The validity of the fixed effects method is assessed through an F-test, comparing the fit of model 2 with that of model 2bis. Since it is not possible to reject the null hypothesis that the country-specific dummy variables are not jointly statistically different from zero, we stick to the pooled OLS estimator model with a common constant term (model 2).[13]

Another factor that could have affected productivity levels across European countries is the so-called "European sovereign debt crisis" following the US financial crisis. Model 3 is augmented with a dummy variable to take into account the outbreak of the economic and financial crisis, which has been taking place since the third quarter of 2008. Clearly, both the choice of the date and the way the crisis should be accounted for are anything but trivial. In principle, the crisis can be modelled in many ways. The first one consists in spotting a conventional date for the beginning of the crisis (for instance, the bankruptcy of *Lehman Brothers*) to be used as a point of discontinuity in the productivity rates of selected countries. This echoes the stance that the Global Financial Crisis was the beginning of a new economic era, characterised by a "secular stagnation" (e.g. Summers 2014). We tested this hypothesis by using a dummy variable that splits the period into two sub-periods: up to 2008Q3, and 2008Q4 onwards. As the dummy variable was not statistically significant at 10% level and below (see model 3), we tried also an alternate solution. We focused on the European Sovereign Debt Crisis, lasting roughly from the beginning of Greece's debt crisis (December 2009) to Draghi's "whatever it takes" public statement (July 2012), meaning the period 2010Q1 to 2012Q3. Once again, the dummy was not statistically significant at 10% level and below (see Table A5). A third solution is to take into account each single quarter in which the Euro Area has recorded a negative growth rate of the GDP. These quarters are grouped in two different periods: 2008Q2 to 2009Q2 and 2011Q1 to 2013Q1, respectively. Result are showed by Table A6. This time the dummy variable is statistically significant at 1% and below. The lagged investment is no longer statistically significant. However, it becomes significant (and positive) at the 1% level if a number of lags > 2 is used. In addition, the adjusted R^2 of the model improves (see Table A7).

Using a dummy variable to account for the crisis allows checking whether the position of the n-dimension surface of the OLS estimator had shifted during the crisis relative to other periods. While our findings led us to reject any country-specific fixed effect, we found some evidence of the impact of the

European Sovereign Debt Crisis on productivity rates across selected countries. The impact of the crisis was also tested by allowing every coefficient to change following the shock. In other words, we tested the presence of a "structural break" in the model. For this purpose, we split our sample into two main periods. The third quarter of 2008, marking the collapse of *Lehman Brothers*, was chosen as the critical threshold. Two different models, a pre-*Lehman* model and a post-*Lehman* one, were set up and compared.[14] Results are shown in Table A3. Notice that we used just one lag for past investment, as this option is the one that offers the best performance in absence of a crisis dummy variable. As expected, coefficient values for the two models are remarkably different. While some regressors are no longer significant (i.e. lagged investment in pre-*Lehman* model and the real wage for the post-*Lehman* one), signs are all consistent with Sylos-Labini's theory. More specifically, the crisis has reduced the Smith effect and the organisation effect relative to the pre-crisis period, whereas it has boosted the Ricardo effect and the disturbance effect of investment in the short run. We used a Chow test to check whether the difference between the two models is statistically significant. The test confirmed that a structural break occurred at 1% confidence level and below.[15]

A possible explanation for the organisation effect is that firms are encouraged to use labour in a more efficient way as it becomes more expensive, i.e. as the real wage increases. This can result in an increase in labour productivity. Another explanation is the so-called "incentive effect" or "efficiency wage theory". It could be named also the "Marshall effect", because Alfred Marshall was the first author to link workers' efficiency rates with their wage rates (Marshall 1890). In short, higher wages attract highly productive workers and encourage them to be more efficient (e.g. Shapiro and Stiglitz 1984). The impact of wages on productivity depends also on the market structure of the economy. For instance, firms may well charge the higher costs of production to the consumers. The higher the monopoly power of firms, the higher the unit price, and hence the lower the real wage that firms are implicitly willing to pay. The point is that the organisation effect depends on "market forms, on intensity of foreign competition, and on the economic policy – including the foreign exchange rates policy – adopted by the government" (Sylos-Labini 1984, p. 170). The recession suffered by most European countries after 2008 has affected deeply their market structures, through bankruptcies, mergers and takeovers. This process of "natural selection" has increased concentration and reduced competition in the manufacturing industries, thus bringing about lower "organisation effect" coefficients (because firms have become less sensitive to absolute labour costs). In addition, the reduction in the demand for labour is usually smaller than the reduction in output, as long as the latter is expected to be a temporary phenomenon.[16] Firms accept a lower product per worker, due to the lower demand for products, as they do not want to lose their workers' "knowhow". In fact, rigid nominal wages coupled with decreasing prices can even result in a negative relationship between real wages and productivity during slumps. The third column of Table A3 shows that, not only is the organisation effect coefficient lower after the crisis relative to its pre-crisis value, but it is no longer statistically significant.

The different impact of the real wage on productivity over the business cycle can also help explain the differences in Smith effect coefficients, which are reported by Table A3. During the boom, the increasing extent of the market triggers economies of scale, learning by doing, and innovation, which boost labour productivity. During the crisis, the reduction in productivity due to the fall in trade is likely to be slower, because firms' adjustment to the new conditions is usually more prudent and gradual. By contrast, Riccardo effect is remarkably higher in the post-crisis scenario (we refer again to Table A3). A possible explanation is that exceptionally low interest rates made firms more sensitive to changes in the relative cost of labour. For, other things being equal, a lower cost of credit makes it cheaper for firms to purchase capital goods relative to labour inputs. Finally, the disturbance effect of investment in the short run is (slightly) stronger in the after-crisis period. Interestingly, investment to GDP ratios of most EA countries have reduced compared to their pre-crisis values, despite the lower GDP growth rates. This can explain why the short-run impact of investment is asymmetrical: when investment is high and increasing, the disturbance effect of an additional unit of investment is proportionally lower; when investment is low and decreasing, the disturbance effect is higher.

We tested also the impact of labour market conditions on productivity (model 4). Although this effect was not advocated by Sylos-Labini, the implementation of labour market reforms has been frequently said to foster productivity (e.g. Scarpetta and Tressel 2002, 2004; Bassanini *et al.* 2009; Kang 2015; European Commission 2015). To test the impact of labour market conditions, we used the labour protection index (LPI) provided by the OECD. Our findings do not support the view that a reduction in labour protection would promote labour productivity. The LPI coefficient is not statistically significant (model 4). We obtained the same result using the change in LPI (instead of its absolute level) and/or using lags (up to 6) to account for the possible mismatch between legislative changes and their effects on the labour market.[17] The lack of significance of labour market conditions (at the macroeconomic level) is coherent with the (microeconomic) finding that "more flexibility in labour relations appears to be without problems in Silicon Valley-type garage businesses. […] flexible working has no impact on innovation among young and small firms. In industries that tend towards a routinised innovation model, however, such flexibility appears to be harmful" (Kleinknecht *et al*. 2014, p. 10-11; see also Vergeer and Kleinknecht 2014). However, the LPI is only available on annual basis. In fact, it is quite stable over time, for it usually changes following major reforms of the labour market. As a result, the LPI is only a rough indicator of the impact of labour market institutions on productivity. To address this problem, we used the early-2000s reforms of the German labour market (the so-called Hartz IV) to check for a structural break in our model, using data for Germany. The Chow test revealed that one cannot reject the null hypothesis that the parameters of the restricted model (estimated for the whole sample) equalled the parameters of the unrestricted model (based on the discontinuity after the implementation of Hartz IV).[18] This provides us with additional evidence about the non-significant impact of labour market reforms on productivity. Interestingly, Germany's average productivity growth rate was 0.82% per quarter before the discontinuity point (i.e. from the third quarter of 1996 to first quarter of 2006), whereas it was only 0.35% in the subsequent decade. Our interpretation is that the US financial crisis, and then the European Sovereign Debt Crisis, have affected productivity growth rates across Europe. The impact of the two crises was arguably less dramatic in Germany relative to other EA member-states. However, our tests suggest that economic growth and the other factors identified by Sylos-Labini were the main drivers of productivity, not labour market legislation.

Finally, we addressed the possible endogeneity issue concerning the real value added by using the oil price growth rate and the one-period lagged real value added as instrumental variables within a two-stage least square estimation (model 5).[19] We found that the Smith effect coefficient is statistically significant and lower compared with previous estimations. Its value (0.57) is now very close to the value estimated by the most recent literature on the Kaldor-Verdoorn's effect (e.g. McCombie et at. 2002, Magacho and McCombie 2017). In fact, comparing models 1-4 with model 5 shows the importance of using instruments when estimating the impact of the value added of the economy on labour productivity. The point is that simple OLS models overestimate value added coefficients, thus overvaluing returns to scale in manufacturing industries. Notice also that the organisation effect and the Ricardo effect are both positive and statistically significant, although investment variables are no longer statistically significant in the 2S-LS model.[20] Table A8 in the Appendix shows our results when a 2S-LS approach is used for all the models. Overall, key qualitative findings are confirmed, even though coefficient sizes are different. The Smith effect is always smaller than in OLS-estimated models. As mentioned, its value is now close to the value estimated by the most recent literature on the Kaldor-Verdoorn's effect.

5. Productivity determinants in peripheral countries vs. core countries

We can now focus on the different productivity trends of periphery and core countries, respectively. The first group includes those countries that have been hit most by recent crises, and have been forced to adopt structural reforms, particularly in the labour market.[21] The second group includes the two dominant European nations (Germany and France) and other EA members that are strongly interconnected with the Franco-German chain of value. Core countries have been characterised, on average, by a quicker recovery compared to periphery countries. The key divide between the two groups is the different trend in current (and financial) accounts of the balance of payments. That divide is possibly mirrored by the parameters of productivity equations. Estimates about periphery countries are displayed by Table 2.

[PLEASE INSERT HERE TABLE 2]

It is worth noticing that the coefficients of determination have remarkably decreased, as they are now all between 53% and 54%. Sylos-Labini's regressors are usually highly significant, the only exceptions being current and lagged investments.

Turning to core countries, estimates are reported by Table 3.

[PLEASE INSERT HERE TABLE 3]

Coefficients of determination have increased significantly. They are all above 85%. Sylos-Labini's regressors are usually highly significant, including current investment. The only exception is lagged investment, which is never significant. Interestingly, both the Smith and the Ricardo effects seem to be stronger when focusing on core countries. By contrast, the organisation effect looks stronger for peripheral countries. In other words, core countries seem to be more sensitive to changes in the size of the market and the relative cost of labour (meaning the wage to machine price ratio). Peripheral countries, in turn, seem to be more sensitive to changes in the absolute cost of labour. Finally, current investment affects labour productivity of core countries, but it does not seem to affect labour productivity in peripheral countries' manufacturing industries. However, the null hypothesis that parameter values are identical across the two groups cannot be rejected.[22]

An alternative way to test the difference between core and peripheral countries is to use dummy variables. Using model 2 as the benchmark model, we introduced a dummy variable (1 for core countries; 0 for periphery countries) to assess the unobserved heterogeneity between periphery and core countries (Model A). We also assessed each individual coefficient (Model B), to cope with the "degrees of freedom" issue affecting the Chow test. Our findings are displayed by Table 4.

[PLEASE INERT HERE TABLE 4]

Although not statistically significant, the differences between the two groups of countries can be explained by the fact that a higher research intensity (of core countries relative to peripheral countries) leads to higher returns to scale and thus a higher Kaldor-Verdoorn coefficient (e.g. Romero and Britto 2017). Similarly, higher research intensity can make manufacturing firms more prone (and capable) to replace workers with machines, when the wage growth rate outstrips the machine price growth rate (Ricardo effect). Finally, the lower research intensity can explain also the higher sensitivity of peripheral countries to the absolute cost of labour (organisation effect), as wage cuts become the main way to enhance competitiveness.

6. A Panel VAR model

As mentioned, Sylos Labini's theory is based on a single equation that explains labour productivity as the result of five determinants. Clearly, the assumed causality is from the five independent variables (value added, absolute cost of labour, relative cost of labour, current investment and past investment) to labour productivity. However, reverse causality effects cannot be ruled out. For instance, productivity should be expected to affect competitiveness and therefore export, aggregate demand, and the value added of the economy. In fact, one of the possible issues with the Smith-Kaldor-Verdoorn effect is that a cumulative causation between aggregate demand and supply conditions is likely to occur. This means that labour productivity *causes and is caused* by the value added of the economy. In other words, there is a problem of endogeneity, possibly affecting OLS estimations. Similarly, labour productivity changes may well affect real wage rates bargained by workers with their employers. Real wages and the growth rate of GDP, in turn, can influence the investment plans of the firms.

In sections 4 and 5, we addressed endogeneity by using the oil price and the lagged value added of the economy as instrumental variables. However, reverse causality is not necessarily at odds with Sylos-Labini's approach. Sylos-Labini himself pointed out that "productivity increases as cause and effect of the increase of real wages: *cause*, since the increase in productivity induces trade unions to demand higher wages and, at the same time, allows the firms to pay them (...); *effect*, since firms try to offset wage increases by saving labour either in absolute terms by rationalizing the productive process, or in relative terms by introducing machines capable of increasing productivity" (Sylos Labini 1984, p. 169). He also observed that the "level of investment depends primarily on demand pressure" (Sylos

Labini 1984, p. 172), meaning the size of the market (captured by the value added in our model). Building upon these preliminary insights, we chose to test other bi-directional causality effects. For instance, since the average real wage rate mirrors the bargaining power of the labour force, an increase in real wages may well lead the firms to replace workers with machines. In other words, investment plans are likely to be affected by the wage level. After all, firms buy machinery (also) to ensure "discipline" and "political stability" in the workplace (e.g. Kalecki 1943). We can name this mechanism the "Marx-Kalecki effect".

The point is that causalities are multiple. In addition, both dominant and reverse effects can take time to show up, as causalities come into play with a certain number of lags. To address this cumulative causation issue, some authors have suggested to use vector autoregression (VAR) models, in which all variables are treated as endogenous and interdependent (e.g. Coad *et al*. 2011, Forges-Davanzati *et al*. 2016). We opted for a VAR model with 8 lags (two years) and a sample size of 560 observations.[23] This allowed us to account for lagged effects, while retaining a sufficient number of observations. In formal terms, the new model can be written as:

$$\mathbf{x}_{i,t} = \mathbf{A}_{0i}(t) + \mathbf{A}_i(\ell)\,\mathbf{X}_{t-1} + \mathbf{u}_{i,t} \qquad i = 1,2,\dots,N \quad t = 1,2,\dots,T$$

where $\mathbf{x}_{i,t}$ is the $M \times 1$ vector of endogenous variables for country i in period t, $\mathbf{A}_{0i}(t)$ is a vector that captures all the deterministic components of the data for country i, $\mathbf{A}_i(\ell)$ is a polynomial in the lag operator that defines the coefficients for country i, $\mathbf{X}_t$ is the stacked version of $\mathbf{x}_{i,t}$, meaning that $\mathbf{X}_t = \left(\mathbf{x}'_{1,t}, \mathbf{x}'_{2,t}, \dots, \mathbf{x}'_{N,t}\right)'$, and $\mathbf{u}_{it}$ is the vector of random disturbances. Notice that $M = 5, N = 9$, and $T = 79$ in our model. Results of the Granger causality test are reported in Table A4. Overall, lagged variables are all statistically significant for every equation.[24] This is coherent with the hypothesis of multiple causality. Impulse response functions and variance decomposition are displayed by Figure 3 and Figure 4, respectively. Focusing on each individual variable, labour productivity is affected by lagged value added, while value added is affected by lagged productivity. Both effects are positive and, therefore, consistent with Sylos-Labini's theory. However, notice that the resemblance of the first equation of the

VAR model with Sylos-Labini's productivity equation is only superficial, for it is based on lagged (not current) values of independent variables.[25] Turning to the value added, we identified two different effects: a "real time effect", captured by Sylos-Labini's original equation, and a "medium term effect", captured by the first equation of the VAR model. The former embodies the immediate impact of internal and external economies to scale. Productivity improves as the extension of the market and the size of the production process increase. The latter embodies "learning by doing" processes and other innovation factors that affect productivity in the medium run.

[PLEASE INSERT HERE FIGURE 3 AND FIGURE 4]

In addition, our Granger causality test suggests that lagged investment positively affects labour productivity. Once again, this finding is coherent with Sylos-Labini's equation. Investment, in turn, is affected by demand pressure. By contrast, our estimates do not support the hypothesis that a reverse causality exists between labour productivity and the absolute cost of labour. This finding is not necessarily at odds with Sylos-Labini's theory. On the contrary, it might reflect the radical change in the political environment that has characterized the European countries since the 1980s. As is well known, the last three decades have been marked by the decline in the bargaining power of trade unions and in the unionisation rate of the working force. Our findings suggest that, while the employers have managed to offset the rise in real wages by increasing productivity through technological and organisational innovations, the reverse has not occurred. In other words, wage earners have not benefited from labour productivity gains. Finally, the panel VAR model does not support the hypothesis that the absolute cost of labour affects the real level of investment.

7. Conclusions

We examined the determinants of labour productivity within a sample of EA member-states. We focused on the divergent dynamics of core countries relative to peripheral countries. Our empirical analysis was grounded in Paolo Sylos-Labini's endogenous theory of labour productivity. We tested different Panel OLS models. A Panel VAR model was tested as well. Overall, our findings confirm Sylos-Labini's main insights. Labour productivity in manufacturing industries is strongly and positively correlated with the market size (Smith effect), the relative cost of labour (Ricardo effect), the absolute cost of labour (organisation effect), and past investment, whereas it is negatively correlated with current investment. No correlation with the labour protection index was found instead. Our findings hold for both groups of countries. While the null hypothesis that parameter values are identical across the two groups cannot be rejected, both the Smith effect and the Ricardo effect are stronger for core countries. By contrast, the organisation effect is stronger for peripheral countries. In other words, core countries seem to be more sensitive to changes in the size of the market and the relative cost of labour (meaning the wage to machine price ratio). Peripheral countries, in turn, seem to be more sensitive to changes in the absolute cost of labour. Finally, while current investment affects labour productivity of core countries, it does not seem to influence productivity of manufacturing industries in peripheral countries. However, the negative effect of the investment on labour productivity is stronger in peripheral countries than in core countries in the short run. This is possibly linked with the technological gap affecting the EA periphery, which can hardly be bridged by increasing further labour market flexibility.

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Tables and figures

Table 1. Estimates of productivity function in EA8 – dependent variable: $d(\log(PR_t))$

	Model 1	Model 2	Model 2bis	Model 3	Model 4	Model 5
$d(\log(V_t))$	0.7322724***	0.7550214***	0.7582034***	0.7592724***	0.7598966***	0.572887***
$d(\log(U_t))$	0.1528584***	0.1423471***	0.1409087 *	0.1431701***	0.1278014***	0.2170521***
$d(\log(W_t))$	0.299599***	0.3228984***	0.3284804***	0.3217206***	0.3260761***	0.2450983***
I_t		-0.0045496 **	-0.0046588***	-0.0043409**	-0.0055402***	-0.0016923
$I_{t-\lambda}$		0.0033162*	0.0033197***	0.0033599*	0.0036523*	0.0006741
D_{crisis}				0.0013609		
LPI_t					0.0011929	
Adjusted R^2	0.68511566	0.694650806	0.692604799	0.694830764	0.718122506	0.6847 (*n-adj.*)

Notes: White cross-section standard errors & covariance (d.f. corrected). Significance: *** 1% threshold, ** 5% threshold, * 10% threshold. Models 1-2 and 3-4 method: pooled OLS, no cross-country fixed effects. Model 2bis method: pooled OLS, cross-country fixed effects. Model 5 method: 2S-LS, no cross-country fixed effects, no robust errors. Investment lag: $\lambda = 1$. D_{crisis}: crisis dummy (2008Q3-2016Q1). Observations: Model 1 = 640; Model 2, 2bis, 3, 5 = 632; Model 4 =560.

Table 2. Estimates of productivity function in peripheral countries – dependent variable: $d(\log(PR_t))$

	Model 1	Model 2	Model 3	Model 4	Model 5
$d(\log(V_t))$	0.6024748***	0.6364563***	0.6497951***	0.6529111***	0.499133***
$d(\log(U_t))$	0.1858531***	0.1801424***	0.1744017***	0.1685258***	0.22862***
$d(\log(W_t))$	0.2687922***	0.2878414***	0.2906792***	0.2932799***	0.231357***
I_t		-0.0041905	-0.0035691	-0.0058853**	-0.0021383
$I_{t-\lambda}$		0.0029152	0.0030893	0.0032663	0.0011025
D_t			0.0032512		
LPI_t				0.0010435	
Adjusted R^2	0.5321597	0.5389713	0.540254313	0.5819139	0.5383 (*n-adj.*)

Notes: White cross-section standard errors & covariance (d.f. corrected). Significance: *** 1% threshold, ** 5% threshold, * 10% threshold. Models 1-2 and 3-4 method: pooled OLS, no cross-country fixed effects. Model 2bis method: pooled OLS, cross-country fixed effects. Model 5 method: 2S-LS, no cross-country fixed effects, no robust errors. Investment lag: $\lambda = 1$. D_{crisis}: crisis dummy (2008Q3-2016Q1). See section 4 for details about the crisis dummy, D_t. Observations: Model 1, Model 2, 2bis, 3, 5 = 316; Model 4 =280.

Table 3. Estimates of productivity function in core countries – dependent variable: $d(\log(PR_t))$

	Model 1	Model 2	Model 3	Model 4	Model 5
$d(\log(V_t))$	0 .8320443***	0.8444334***	0.8436645***	0.8431201***	0.6480371***
$d(\log(U_t))$	0.1297303***	0.1162122***	0.1146351***	0.103079**	0.210841***
$d(\log(W_t))$	0.3144876***	0.3280044***	0.3295726***	0.3374841***	0.2456501***
I_t		-0.0034004**	-0.0034337**	-0.0034743*	0.0002152
$I_{t-\lambda}$		-0.0006404	0.0023001	0.0022832	-0.0010901
D_t			-0.0003882		
LPI_t				0.0012096	
Adjusted R^2	0.85257607	0.855349551	0.860235711	0.85897149	0.8511 (*n-adj.*)

Notes: White cross-section standard errors & covariance (d.f. corrected). Significance: *** 1% threshold, ** 5% threshold, * 10% threshold. Models 1-2 and 3-4 method: pooled OLS, no cross-country fixed effects. Model 2bis method: pooled OLS, cross-country fixed effects. Model 5 method: 2S-LS, no cross-country fixed effects, no robust errors. Investment lag: $\lambda = 1$. D_{crisis}: crisis dummy (2008Q3-2016Q1). Observations: Model 1, Model 2, 2bis, 3, 5 = 316; Model 4 =280.

Table 4. Estimates of productivity functions in EA8

	Model A	Model B
$d(log(V_t))$	0.7550404***	0.7202433***
$d(log(U_t))$	0.14114***	0.1078035
$d(log(W_t))$	0.3243579***	0.3167399***
	-0.0045006**	-0.0082297***
I_{t-1}	0.0033641*	0.0068762***
D_t	0.0008289	-0.0014681
$D_t \cdot d(log(V_t))$		0.0593097
$D_t \cdot d(log(U_t))$		0.04177
$D_t \cdot d(log(W_t))$		0.0062069
$D_t \cdot I_t$		0.0045082
$D_t \cdot I_{t-1}$		-0.0042305

Notes: observations = 632.

Appendix

Table A1. Data definitions and sources

Variable	Full name	Frequency	Unit / Measure	Source
H	Hours worked, manufacturing	Quarterly	1000 hours	Eurostat
INV	Machinery and equipment, gross value	Quarterly	Percentage of GDP, s.a.	Eurostat
P	Price index, implicit deflator	Quarterly	Index (2010=100), s.a.	Eurostat
P_k	Domestic price of capital goods	Quarterly	Index (2010=100) [s.a.]	Eurostat
$V_€$	Gross value added, manufacturing	Quarterly	Current prices, million €, s.a.	Eurostat
$\widehat{W}_€$	Wages and salaries, manufacturing	Quarterly	Current prices, million €, s.a.	Eurostat
$PR = V \cdot 1000/H$	Real gross value added per person employed	Quarterly	Real product per hour	Our calculations
$U = W_€/P$	Wages and salaries, manufacturing	Quarterly	Real wages	Our calculations
$V = V_€/P$	Gross value added, manufacturing	Quarterly	Real gross value added	Our calculations
$W = W_€/P_k$	Relative wages and salaries, manufacturing	Quarterly	Relative labour cost	Our calculations
$W_€ = \widehat{W}_€ \cdot 1000/H$	Wages and salaries, manufacturing	Quarterly	Hourly wages	Our calculations
COP	Crude oil price (WTI)	Quarterly	Average, USD per barrel	US Energy Information Administration
LPI	Strictness of employment protection – individual and collective dismissals (regular contracts)	Annual	Index	OECD

Table A2. Levin-Lin-Chu test for unit roots

	Adjusted t statistic	p-value
$d(log(PR_t))$	-18.7305	0.0000
$d(log(V_t))$	-12.7818	0.0000
$d(log(U_t))$	-17.0619	0.0000
$d(log(W_t))$	-18.7446	0.0000
I_t	-0.8066	0.2100

Table A3. Chow test for structural breaks

	Before the crisis (SS 384)	After the crisis (SS 248)
$d(log(V_t))$	0.8769042***	0.7252588***
$d(log(U_t))$	0.1716455***	0.0704691
$d(log(W_t))$	0.2519336***	0.4747626***
I_t	-0.0034317*	-0.0058785*
I_{t-1}	0.0023487	0.0047082
Adjusted Rsquare	0.70289906	0.700093887

Table A4. Granger causality test

Equation	Excluded	p-value	Reject null hypothesis with ***% significance
$d(log(PR_t))$			
	$d(log(V_t))$	0.069	*
	$d(log(U_t))$	0.495	
	$d(log(W_t))$	0.796	
	I_t	0.004	***
	All	0.000	***
$d(log(V_t))$			
	$d(log(PR_t))$	0.026	**
	$d(log(U_t))$	0.023	**
	$d(log(W_t))$	0.365	
	I_t	0.102	
	All	0.001	***
$d(log(U_t))$			
	$d(log(PR_t))$	0.039	**
	$d(log(V_t))$	0.168	
	$d(log(W_t))$	0.026	**
	I_t	0.007	***
	All	0.000	***
$d(log(V_t))$			
	$d(log(PR_t))$	0.088	*
	$d(log(V_t))$	0.307	
	$d(log(U_t))$	0.087	
	I_t	0.297	
	All	0.092	*

I_t			
	$d(log(PR_t))$	0.010	**
	$d(log(V_t))$	0.000	***
	$d(log(U_t))$	0.955	
	$d(log(W_t))$	0.021	**
	All	0.000	***

Table A5. "Whatever it takes" dummy (SS 632)

Variable	Coefficient
$d(log(V_t))$	0.7541616***
$d(log(U_t))$	0.1416935***
$d(log(W_t))$	0.3245793***
I_t	-0.0043348**
I_{t-1}	0.0032409*
D_{crisis}	0.0021427
Adjusted R^2	0.695244196

Table A6. "Euro crisis" dummy (1-lag investment) (SS 632)

Variable	Coefficient
$d(log(V_t))$	0.8097337***
$d(log(U_t))$	0.133341***
$d(log(W_t))$	0.3374925***
I_t	-0.0035524**
I_{t-1}	0.0026449
D_{crisis}	0.0086136***
Adjusted R^2	0.708961501

Table A7. "Euro crisis" dummy (4-lag investment) (SS 608)

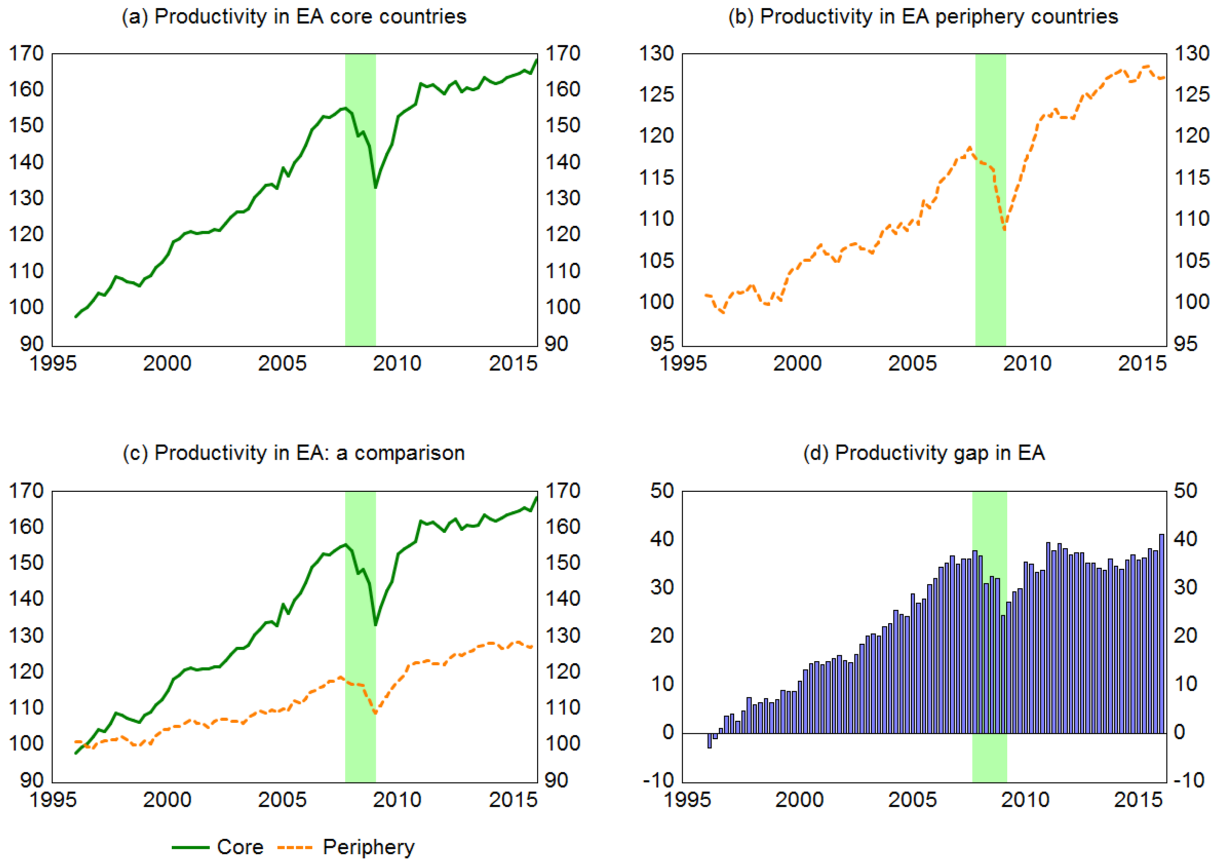
Variable	Coefficient
$d(log(V_t))$	0.8178032***
$d(log(U_t))$	0.1442562***
$d(log(W_t))$	0.3290716***
I_t	-0.004427***
I_{t-1}	0.0037852***
D_{crisis}	0.00777***
Adjusted R^2	0.721791713

Table A8. 2SLS estimates of productivity function in EA8 – dependent variable: $d(\log(PR_t))$

	Model 1	Model 3	Model 4
$d(\log(V_t))$	0.5115759***	0.5714866***	0.5427365***
$d(\log(U_t))$	0.2154949***	0.2444413***	0.232371***
$d(\log(W_t))$	0.2417666***	0.2176769***	0.2194812***
I_t		−0.0016649	−0.0019033
$I_{t-\lambda}$		0.0006534	0.0002351
D_{crisis}		0.0000267	
LPI_t			0.0009822
Adjusted R^2	0.667661758	0.684457461	0.701967348

Notes: White cross-section standard errors & covariance (d.f. corrected). Significance: *** 1% threshold, ** 5% threshold, * 10% threshold. Pooled OLS, no cross-country fixed effects. Investment lag: $\lambda = 1$. D_{crisis}: crisis dummy (2008Q3-2016Q1). Observations: Models 1 and 3 = 316; Model 4 =280.

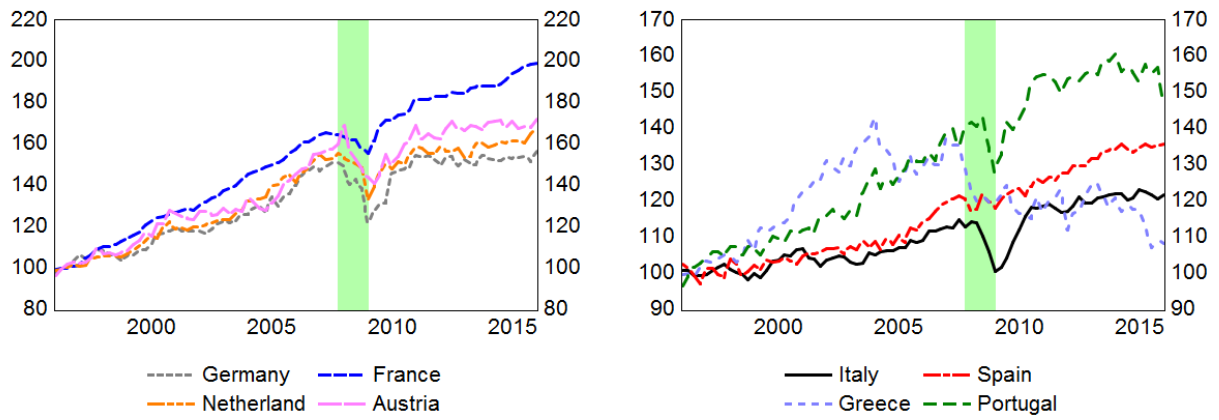
Figure 1. Productivity development in periphery vs. core areas



Notes: 1996 = 100. Manufacturing industry. Real value added per employee at 2010 reference level (real GDP-weighted average by country group). Quarterly data. Shaded areas show the impact of the 2007 crisis.

Source: our elaboration on Eurostat data 2016.

Figure 2. Productivity development in selected EA countries

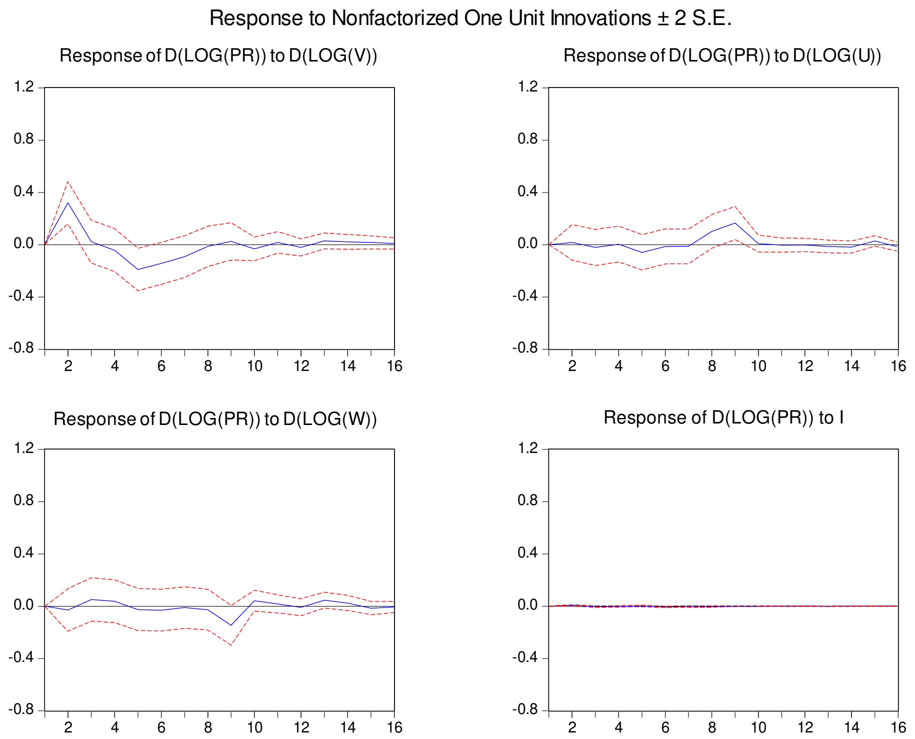


Notes: 1996 = 100. Manufacturing industry. Value added per employee at 2010 reference level. Quarterly data. The shaded area shows the impact of the 2007 crisis.

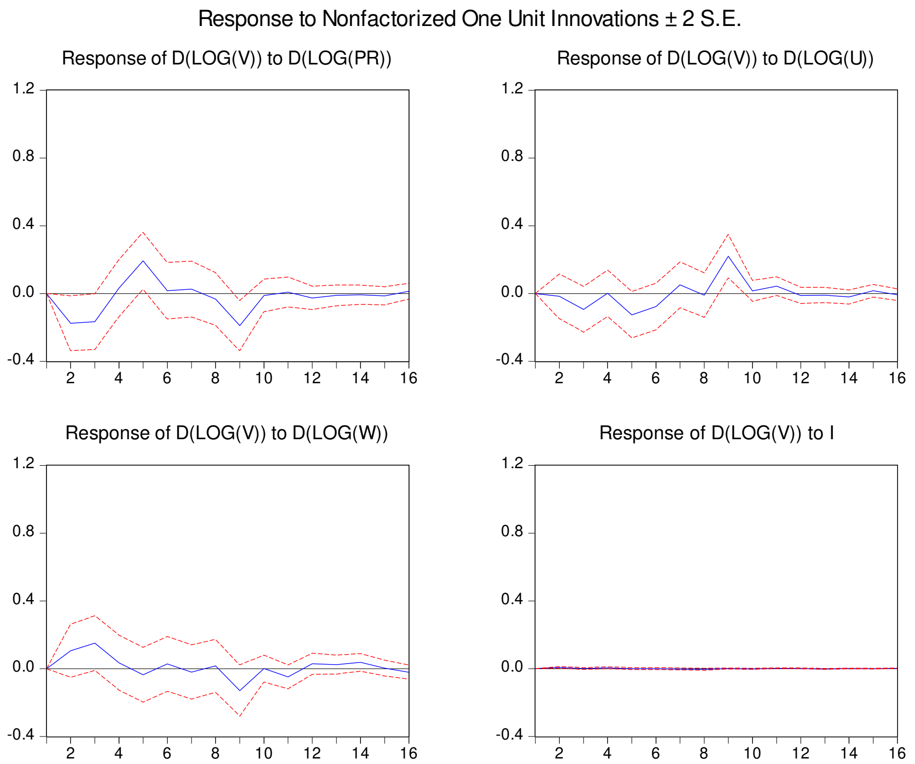
Source: our elaboration on Eurostat data 2016.

Figure 3. Impulse response functions of Panel VAR for EA8 (16 steps head, Cholesky ordering: PR, V, U, W, I)

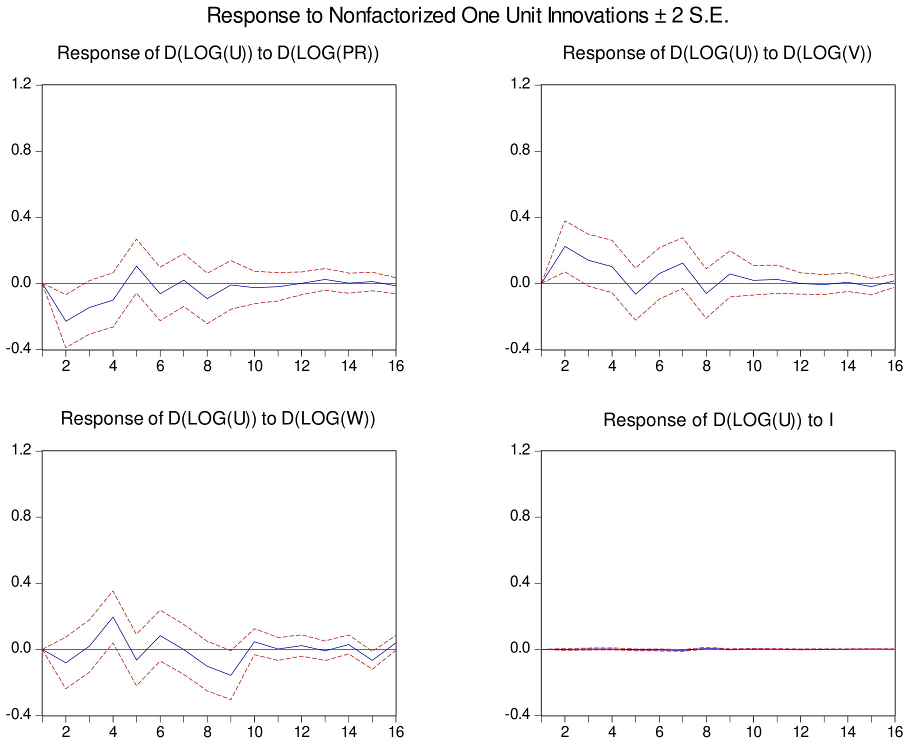
Response of productivity (PR) to a unit shock in value added (V), absolute cost of labour (U), relative cost of labour (W), and investment (I)



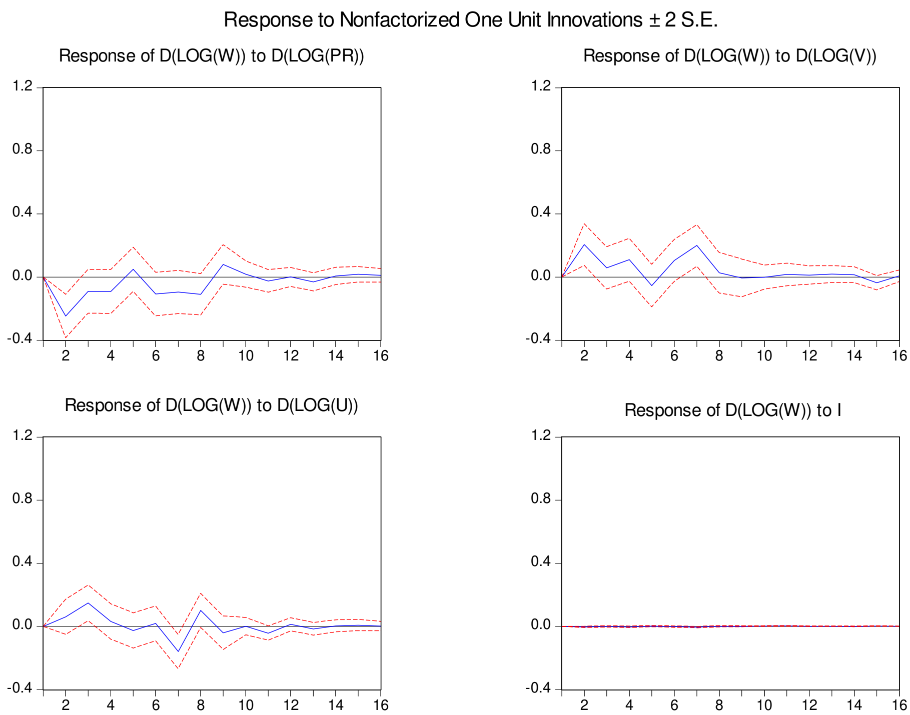
Response of value added (V) to a unit shock in productivity (PR), absolute cost of labour (U), relative cost of labour (W), and investment (I)



Response of absolute cost of labour (U) to a unit shock in productivity (PR), value added (V), relative cost of labour (W), and investment (I)



Response of relative cost of labour (W) to a unit shock in productivity (PR), value added (V), absolute cost of labour (U), and investment (I)



Response of investment (I) to a unit shock in productivity (PR), value added (V), absolute cost of labour (U), and relative cost of labour (W)

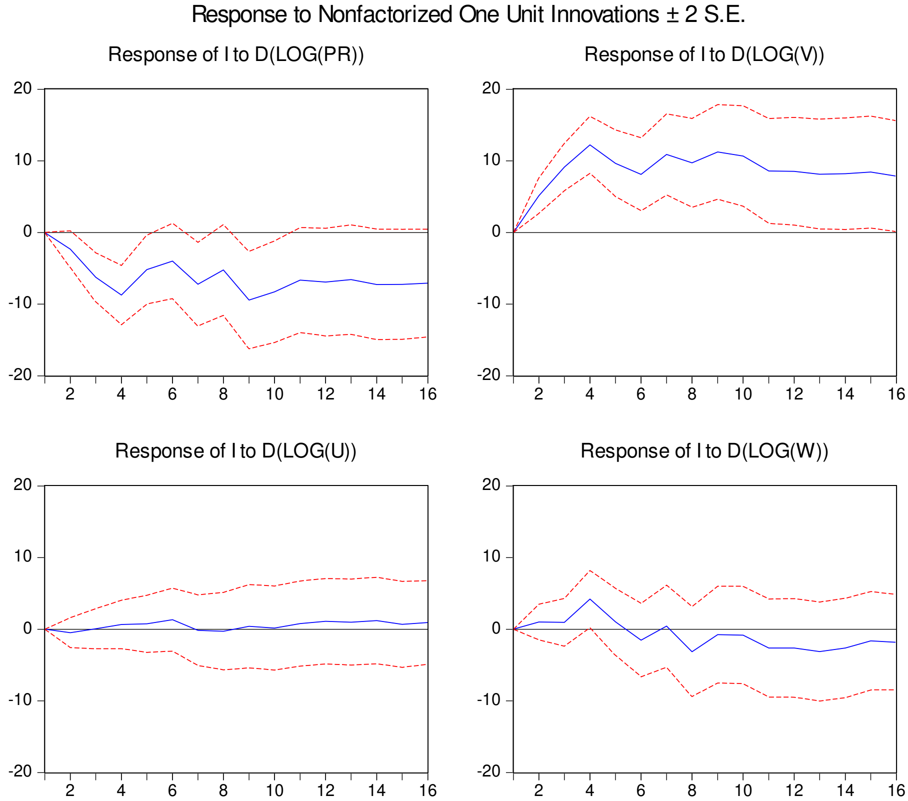


Figure 4. Forecast-error variance decomposition of Panel VAR for EA8 (10 steps head)

Forecast-error variance decomposition

Response variable and Forecast horizon	PR	V	W	U	I
			Impulse variable		
PR					
0	0	0	0	0	0
1	1	0	0	0	0
2	.9399478	.0422082	.0005558	.0000394	.0172488
3	.9387462	.0421296	.0009202	.0006724	.0175316
4	.9372354	.0432106	.0009367	.001114	.0175033
5	.9217689	.0500677	.0046727	.0033897	.020101
6	.9085478	.0570302	.0077289	.0033453	.0233479
7	.9040213	.0595019	.0088694	.0041432	.023464
8	.9019009	.0604237	.0088925	.0052646	.0235184
9	.8920306	.0591337	.0102415	.0125644	.0260298
10	.88846	.0601709	.011522	.0125209	.0273262

Forecast-error variance decomposition

Response variable and Forecast horizon	Impulse variable PR	V	W	U	I
V					
0	0	0	0	0	0
1	.5988532	.4011468	0	0	0
2	.575431	.4076611	.0030461	.000433	.0134288
3	.5579789	.418103	.0061555	.0044982	.0132644
4	.5589446	.4118109	.0064486	.004566	.0182298
5	.5508181	.4067686	.015073	.0093801	.0179602
6	.5500723	.4049882	.0164047	.0106675	.0178673
7	.5479418	.4051647	.0164846	.0114864	.0189224
8	.5463446	.4046003	.0164964	.0114503	.0211083
9	.5401826	.3917998	.0165275	.0294371	.0220529
10	.5398672	.391578	.0168042	.0297111	.0220395

Forecast-error variance decomposition

Response variable and Forecast horizon	Impulse variable PR	V	W	U	I
U					
0	0	0	0	0	0
1	.1963216	.0948361	.288423	.4204194	0
2	.1989369	.1281244	.2776152	.3953104	.0000131
3	.1948946	.1287997	.2807073	.3927631	.0028353
4	.1921027	.1283736	.2862855	.388134	.0051042
5	.1912061	.1276037	.2879768	.3857443	.007469
6	.1913663	.1278168	.2868392	.3840079	.0099698
7	.1936709	.1314861	.2808844	.3758396	.018119
8	.2054332	.1281538	.2725781	.3658207	.0280142
9	.2042354	.1295397	.2713654	.3661384	.0287211
10	.2029321	.1312177	.2703858	.3642901	.0311742

Forecast-error variance decomposition

Response variable and Forecast horizon	Impulse variable PR	V	W	U	I
W					
0	0	0	0	0	0
1	.111853	.2236341	.6645128	0	0
2	.1256534	.2411068	.6284086	.0033136	.0015176
3	.1230346	.2362061	.6189446	.0198122	.0020025
4	.1217074	.2339977	.6192268	.0213709	.0036973
5	.1212769	.2330289	.6181495	.0217135	.0058312
6	.121659	.2357543	.6133276	.0233309	.0059282
7	.1174074	.2463859	.5918736	.0330353	.0112979
8	.1220575	.2445242	.5854911	.036224	.0117032
9	.1220204	.2433636	.5869841	.035791	.011841
10	.1223731	.243301	.585296	.0358172	.0132128

Forecast-error variance decomposition

Response variable and Forecast horizon	Impulse variable PR	V	W	U	I
I					
0	0	0	0	0	0
1	.0448277	.010584	.0049602	.003421	.9362071
2	.0787413	.0432146	.0085515	.0034816	.866011
3	.0836043	.0909568	.0116234	.00286	.8109555
4	.0985829	.118652	.0328908	.0021323	.7477421
5	.1201505	.1353398	.0334818	.0017945	.7092336
6	.1319226	.142352	.0288322	.0017167	.6951766
7	.131989	.1598386	.0271497	.0014467	.6795759
8	.1322839	.1824776	.0234019	.001246	.6605906
9	.1257946	.200087	.0225808	.0012944	.6502432
10	.1232079	.2167677	.0221823	.0014339	.6364083

Footnotes

[1] Following a widely adopted classification (see De Santis and Cesaroni (2016) or Lapavitsas et al. (2010)), the group of core countries includes four EA's member-states, notably, Austria, France, Germany, and the Netherlands (we do not include Belgium and Luxemburg because of data availability reasons). The group of peripheral countries is made up of four EA's members, notably, Greece, Italy, Portugal, and Spain (we do not include Ireland because of data availability reasons).

[2] Following Sylos-Labini, we use $U = W_{€}/P$ as an indicator of the absolute cost of labour (Sylos-Labini 1984, p. 173). However, unlike Sylos-Labini, but in line with Guarini (2007), we considered both $U = W_{€}/P$ and $W = W_{€}/P_k$ in our model. The former aims at capturing the organisation effect, while the latter aims at capturing the Ricardo effect.

[3] Some authors have stressed the link of Sylos-Labini's productivity equation with Schumpeter's analysis of innovation (e.g. Kleinknecht 1998; Lucidi and Kleinknecht 2010). The point is that changes in unit labour costs drive "natural selection" or "creative destruction" of firms. Routine firms and/or laggards are thrown out of the market, due to the higher costs of production, while innovative firms face the opportunity to increase their own market share.

[4] Sylos-Labini recovers and develops an idea originally formulated in chapters I and XXXI of the last edition of Ricardo's *Principles* (Ricardo 1821). In spite of the superficial resemblance, Sylos-Labini's rendition of Ricardo effect is at odds with the "neoclassical" hypothesis of smooth substitutability of inputs (and the claim that there would be a monotonic non-increasing relationship between the capital intensity of production techniques and the rate of profit). The latter expresses a static theory of allocation efficiency and income distribution, whereas the former underpins a dynamic theory of labour productivity growth's determinants. Notice that Sylos-Labini' interpretation of the "Ricardo effect" is controversial. It has been (implicitly) questioned by Gehrke (2003). However, we do not focus here on this theoretical and terminological dispute, due to the empirical nature of our work.

[5] Sylos-Labini suggests using both the real investment and the cost of labour relative to the price of investment goods as regressors, for "it is necessary to distinguish the determinants of [investment] level from those of its composition (labor-saving and capacity- increasing investment). The level of investment depends primarily on demand pressure, as expressed by the degree of utilized capacity; current profits, as the source of self-financing; the expected rate of profit; and the availability and the cost of external finance (Sylos-Labini, 1974, ch. 1). The composition of investment depends primarily on the relative cost of labor. However, it is impossible to say to what extent a labor-saving investment is stimulated by an increase in the w/Pm ratio, and to what extent it is independent of the increase. As it can be profitable to introduce labor-saving innovations even if that ratio holds firm, it would be wrong to assume that the changes in that ratio are the only reason, or even the main reason, for the labor-saving investment. Consequently, we cannot exclude one of the two variables on the ground that its influence is already fully contained in the other; it is advisable, instead, to include both variables" (Sylos Labini 1983, p. 172-173).

[6] Notice that the "directed technical change" literature draws insight on technological growth induced by pricing (and hence taxation) mechanisms (Acemoglu 1998, 2002). This has been applied to the so-called green transition from "dirty" production towards "clean" production in which input costs induce or not an investment in cleaner technological innovation (Acemoglu *et al.*, 2012, 2014). We do not look further into this, as we only concentrate on labour productivity gains. Hence, price mechanisms are already factored in via real wage and wage relative to capital costs effects.

[7] The Durbin-Watson statistic was always close to 2. When we found that error terms could be negatively correlated, a Breusch-Godfrey test was made. A Ljung-Box Q-statistic was used too.

[8] Since this is an adaptation of the Augmented Dickey-Fuller test to panel data, we selected the number of lags by using the AIC criterion (with at most 10 lags).

[9] The same point is made by Angeriz et al. (2008) who estimate the Kaldor-Verodoorn law using instrumental variables. Notice that the advantage of using an instrumental variable approach is that it allows controlling for variables that are unobserved or omitted from the equation, but possibly correlated with the real value added (Green 2012, p. 259).

[10] The fact is that a lower employment rate is usually associated with a higher estimate of productivity, as the people excluded from the labour market are likely to be the least qualified or educated (e.g. Piketty 2017).

[11] We chose the number of lags by comparing different models through the Akaike's information criterion. The best result (AIC = -3779.52) was obtained by using one lag. Notice that the sample narrows down as the number lags increases. Consequently, we chose to limit our analysis to 4 lags.

[12] It is worth mentioning here a recurring feature of investment coefficients. Our estimates are usually consistent with Sylos-Labini's theory, meaning that the short-run investment coefficient has a negative sign whereas the long-run one has a positive sign. However, coefficient values are generally rather low. This does not mean that the impact of investment on productivity is lower than the impact of other variables. Investment is taken as a ratio to GDP, while other regressors and the dependent variable are expressed as growth rates. However, Sylos Labini (1983, p. 173) stressed that the investment level represents the net addition to the stock of capital. Consequently, its behaviour conforms generally to that of the rate of change of capital stock. The point is that the impact of investment on productivity follows a longer historical path than the other dependent variables. This is also the reason response functions to investment shocks in figure 3 are rather flat.

[13] The critical value at 1% threshold is 2.6682148 (restrictions: 8; sample size: 632). This is well above the F statistic, which is 0.46.

[14] The fall in GDP growth rates since the third quarter of 2008 shows that, even though the collapse of *Lehman Brothers* took place in the US, it affected sharply Euro Area's member-states.

[15] The Chow statistic is 4.9448867, while the critical value of the F-statistic is 2.8305354 (restrictions = 6, sample size = 632). Therefore, we can reject the null hypothesis that pre-crisis coefficients are not statistically different from their post-crisis values.

[16] In principle, firms can also reduce their employees' working day. However, there are (country-specific) institutional constraints to this option.

[17] Arguably, a thorough analysis of the impact of labour market rigidities on productivity would require us to use other estimation techniques and/or to consider a variety of institutional features. For instance, Nickell (1997) uses cross-country institutional variables (e.g. replacement rates, benefit durations, active labour market policies, union coverage indices, etc.) to explain the differences between North American and European unemployment rates. Some of these rigidities affect productivity, while other rigidities may well entail a positive effect. For the sake of simplicity, we neglect this possible complication. Notice also that the OECD labour protection index has been questioned because of the arbitrary weighting system and the possible interactions of different components (e.g. a stricter EPL for permanent contracts is associated with an increase in temporary contracts) (Boeri and Van Ours 2013).

[18] The F statistic is 1.8047042, against a critical value of 2.2156941.

[19] As for the consistency of the 2S-LS estimation, we checked the possible weakness of instrumental variables through a F-test. The latter assesses the overall model significance of regressing the endogenous variable on the instrumental variables. Since we obtained a p-value = 0.0000, we rejected the null hypothesis of weak instruments. We also checked the possible correlation of instrumental variables with the residuals of the model (endogeneity). A Sargan instrument validity test was conducted. The null hypothesis of non-correlation was not rejected, thereby confirming the validity of the instruments chosen.

[20] We used Model 5 to check also the impact of real wages on productivity when different lags are applied. The reason is that a more efficient organisation takes time to be effective. Coefficients become positive after 4 lags (one year). Abstracting from the "spuriously simultaneous" case (lag = 0), the first significant coefficient (at 5% confidence level) shows up after 7 lags. Remarkably, both the sign and significance of coefficients are consistent with the results we obtained using the panel VAR model presented section 6.

[21] Due to institutional homogeneity and data availability concerns, Ireland was excluded from estimations shown by Tables 1 and 2. Consequently, peripheral countries are the Mediterranean countries. Notice *inter alia* that France and Italy could be regarded as somewhat "spurious" cases. The French economy shares some of the issues faced by peripheral countries, think

of the deterioration of the balance of trade since the launch of Euro. By contrast, the Italian economy has never performed as bad as other peripheral countries in terms of balance of trade. However, labour productivity has been stagnating in Italy during the last two decades.

[22] We used a Chow test in model 3 to assess whether the distinction between peripheral and core countries was significant. The F-statistic of the Chow test was 1.2034559, while the critical value (restrictions: 6; observation: 332) at the 1% threshold is 2.8310911 (or 2.1131859 at 5%). Interestingly enough, if France were included in the periphery, the F-statistic of the Chow test (3.9131603) would have largely outstripped the critical threshold.

[23] The 8-lag model is that with the highest coefficient of determination (0.9784) for $\lambda \leq 8$.

[24] Notice that the test entails a series of F-tests comparing the original model with amended models, in which either one "provisional independent" variable or all the other "independent" variables altogether are excluded.

[25] This means that it would be inappropriate to use a Granger causality test to test Sylos-Labini's theory.