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Link between Tangible Investment Rate and Labour Productivity in the European Manufacturing Industry

Summary: This paper analyses the link between the tangible investment rate and apparent labour productivity in the European manufacturing industry. The research results show a negative and opposite relation between apparent labour productivity and investment rate, that is, changes in apparent labour productivity cause changes in investment in tangible assets but not vice versa. The findings do not show any significant differences among European countries when the relation between apparent labour productivity and investment rate is analysed. However, when analysing the gross investment in tangible goods, as well as in machinery and equipment, period effects are observed. A crisis and economic slowdown reduce investment in tangible capital. Meanwhile, the growth of the economy spurs more investment. The negative correlation between apparent labour productivity and investment rate indicates that investment in tangible assets is ineffective. An analysis on individual countries is required in order to reach more nuanced conclusions.

Keywords: Labour productivity, Investment rate, Tangible investment, Manufacturing industry.

JEL: D24, D92, J24, L60.

The issue of long-term productivity growth has gained much scientific attention when aiming to substantiate the differences of labour productivity in manufacturing industries of different countries and to justify the key factors affecting productivity growth. It is commonly expected that higher investment in capital will help improve labour productivity. The Solow model is likely the most popular in describing the relation between these indicators. In the so-called Solow growth accounting model, changes in labour productivity are due to technical change and changes in the capital-labour ratio (known as capital deepening). A major criticism against structural growth models is that variables that plausibly affect growth are left out (Sai Ding and John Knight 2009). For this reason, the link between capital investment and labour productivity remains an open question. In this paper, we seek to expand the empirical research on factors affecting labour productivity by focusing on a more detailed analysis of the relation between investment rate and labour productivity.

The purpose of this empirical research is to analyse the link between investment rate and labour productivity by employing the panel data on European manufacturing industry in 2005-2014. This research is based on the business investment rate, which is defined as gross investment (gross fixed capital formation) divided by gross value added of non-financial corporations. This ratio relates the non-financial businesses' investment in fixed assets (buildings, machinery, etc.) to the added value created during the production process. The analysis of the link between investment rate and labour productivity involves the strength and direction of the relation, its variation across countries and time, and the significance of the delayed effect. Previous research mainly analyses the strength of the relation between investment in tangibles and labour productivity, while the direction is not tested as it is defined by the Solow model, that is, productivity depends on investment in capital but not *vice versa*. The novelty of our research is our test of the direction of this relation. We seek to confirm or reject the causality defined by the Solow model, based on the European manufacturing data.

The remainder of this paper is organised as follows. In Section 1, we review the scientific literature. In Section 2, we introduce our methodology and data on the empirical study. In Section 3, we present the research results and the findings of the analysis. In Section 4, we draw the main conclusions.

1. Literature Review

Productivity is a key economic indicator, which is believed to be a critical driver or factor in accounting for economic growth and prosperity (Tomaš Volek and Martina Novotna 2015). Productivity also serves as one of the main criteria of a country's competitiveness and may be used at both macro and micro levels (Peter J. Buckley, Christopher L. Pass, and Kate Prescott 1988). Productivity is affected by physical capital, human capital, natural resources and technological knowledge (Gregory N. Mankiw and Mark P. Taylor 2008). Many theoretical and empirical studies focus on labour productivity in relation to endogenous factors, such as intangible investment in human resources, knowledge and staff training systems (Sandra E. Black and Lisa Lynch 2001; Kathryn Shaw 2004; Cecilia Jona-Lasinio, Massimiliano Iommi, and Stefano Manzocchi 2011; Carol Corrado et al. 2014; Tatiana M. Muntean 2014), investment in information and communication technologies (ICTs) (Yoshihito Saito 2000; Thomas Strobel 2011), investment in research and development (R&D) (Zvi Griliches 1998; Dominique Guellec and Bruno van Pottelsberghe de la Potterie 2001; Urlich Doraszelski and Jordi Jaumandreu 2013), labour productivity and wages (Harvey Leibenstein 1957; Robert Solow 1979; Lawrence F. Katz 1986; Eric K. Peach and Tom D. Stanley 2009; Zekeriya Yildirim 2015), and labour productivity and exports (Marc J. Melitz 2003; Andrew B. Bernard and Bradford J. Jensen 2004; Rod Falvey et al. 2004; Mahmut Yasar, Carl H. Nelson, and Roderick M. Rejesus 2006; Joachim Wagner 2007; Chandan Sharma and Ritesh K. Mishra 2009). Other empirical studies analyse the links between labour productivity and exogenous factors, such as foreign direct investment (Simeon Djankov and Bernard Hoekman 2000; Ben Ferrett 2004; Priit Vahter 2004; Argentino Pessoa 2007; Ragnhild Balsvik and Stefanie A. Haller 2011), national education and training system (Pedro Carneiro and James Heckman 2002), and inflation (Yildirim 2015). Our literature review reveals that most of the studies target the industrial sector by employing the manufacturing industry panel data (Katz 1986; Melitz 2003; Bernard and Jensen 2004; Falvey et al. 2004; Vahter 2004; Yasar, Nelson, and Rejesus 2006; Sharma and Mishra 2009; Balsvik and Haller 2011; Strobel 2011; Doraszelski and Jaumandreu 2013; Yildirim 2015) and emphasising the significance of the manufacturing sectors for overall economic development.

The fundamental significance of investment has led to a large number of theoretical and empirical studies that explore the links among investment, productivity and economic growth. Previous empirical studies suggest evidence of the relation between labour productivity and investment. The significance of investment processes, the role of physical assets, advanced technologies and technological innovations, changes in the scales of outputs, capacity utilisation rates, the abundance of natural resources and improvements in resource allocation, human knowledge, skills and abilities are largely substantiated in early and recent scientific literature, explaining that the mentioned components are necessary for efficient production, high economic value and growth of labour productivity (John W. Kendrick 1961; Edward F. Denison 1962; Black and Lynch 2001; Shaw 2004). Considering the link between investment and productivity, Kevin J. Stiroh (2000) distinguishes among several approaches. One of them is Solow's (1956, 1957) neoclassical framework, which uses an aggregated production function to describe the relation between an economy's output and primary inputs, for example, tangible capital and labour. Following the neoclassical model, accumulation of resources largely depends on productive tangible investment and formation of gross fixed capital. Solow assumes an aggregated production function as $Y = A*f(K, L)$, where Y denotes output, K and L represent tangible inputs of capital and labour, A is a measure of technical change, and $f(..)$ is a linearly homogeneous function. One can derive the neoclassical relation between investment and labour productivity growth, defined as output per hour worked, because linear homogeneity means that $Y/L = A*f(K/L,1)$. Thus, growth in the average labour productivity directly depends on the rate of per hour capital accumulation. However, Solow (1956) developed an economic growth model under several assumptions. Based on these assumptions, it is inferred that a country's economic growth would converge to a steady state and that poor countries would catch up with rich countries. However, the available evidence on the Solow model varies from one study to another, and the two assumptions – the exogenous technological progress and the decreasing returns on capital – have been controversial since then (Kai Chen, Xiaoju Gong, and Richard D. Marcus 2014). As a result, various modifications of the Solow model are presented in existing research (e.g., Mankiw, David Romer, and David N. Weil 1992; Chen, Gong, and Marcus 2014).

Mankiw, Romer, and Weil (1992) suggest an augmented Solow model whereby the differences in *per capita* income among countries should be explained by the variability in physical and human capital investments and labour growth. The new endogenous growth theory contributors (Robert E. Lucas 1988; Paul M. Romer 1990; Gene M. Grossman and Elhanan Helpman 1991) disagree on taking technological change as an exogenous variable and extend the analysis of the role of investment as a source of productivity. Both Lucas (1988) and Romer (1990) state that higher investment in human capital leads to a larger growth rate of income *per capita* and that in the long-run, the economy that has developed science and human resources will have a larger economic growth rate than the economy that has not done so. Stiroh (2000) points out that the neoclassical framework focuses on internal returns to investors who appropriate the benefits of new investments, while the new growth theory emphasises external effects as productivity gains' spillover to others. In the scientific literature regarding the new growth theory, it is argued that investment benefits largely accrue to the economic agents who undertake the investment, but it is certainly possible that difficult measurement and identification issues obscure the importance of spillovers.

Other scholars extend the investment theory by arguing on the role of any accumulated input in labour productivity, while productivity growth may be boosted by investment in the factors that can be improved and expanded. In the scholarly literature, investment is divided into several groups: investments in tangible assets, intangible assets, human capital and knowledge, R&D and ICTs (Strobel 2011; Hyunbae Chun et al. 2015). The analysis on labour productivity growth commonly covers the effects of the main productivity determinants. A large proportion of productivity growth originates in the manufacturing sector and depends, among others, on the availability of high-quality upstream inputs, which include machinery and intermediate parts and components, as well as a range of service inputs (Cosimo Beverelli, Matteo Fiorini, and Bernard Hoekman 2017). A country's common external macro factors, such as staff qualification, technical changes, diffusion of technologies and general business environment, are general criteria that determine different productivity levels in developed and developing countries. Productivity growth can occur as a result of capital accumulation, adaption of new technologies and R&D (Sharma and Mishra 2009).

Various empirical studies cover different findings in this scientific area. Douglas S. Meade (1998) analyses the relations among capital investment prices, capacity utilisation prices and labour productivity at the industrial level. He employs the model based on a Generalised Leontief (GL) cost function, which proposes that the most promising cost function is a measure used to relate capital investment and capacity utilisation to price change and labour productivity in an integral framework. Øivind A. Nilsen et al. (2009) find that the labour productivity changes that are associated with the investment spikes are small; in turn, this indicates that productivity improvements are not related to instantaneous technological changes through investment spikes. Matilde Bini, Leopoldo Nascia, and Alessandro Zeli (2014) employ a multilevel regression model to detect the relation between firms' current level of labour productivity and a set of indicators, including tangible and intangible investments. Based on Italian data, they find a positive relation between investment and future productivity. Their results show an immediate positive impact of intangible investment on labour productivity and a lag-distributed positive impact on tangible investment. Novotna, Volek, and Jana Fučikova (2014) test the links between the growth of fixed assets and labour productivity in small and medium-sized enterprises in the Czech Republic. Correlation analysis does not prove any linear link between the changes in fixed assets and the changes in labour productivity for any group of the studied firms. On the contrary, correlation analysis proves the link between the changes in the capital-labour ratio and growing amounts of fixed capital.

Mar Salinas-Jimenez, Inmaculada Alvarez-Ayuso, and Jesus Delgado-Rodriguez's (2006) research, based on the European Union (EU) data between 1980 and 1997, indicates that some European countries, especially cohesion countries, suffer from the problems of productivity growth. The scholars state that once the gaps in capital endowments have been reduced, development policies in these countries should focus on promoting efficiency and technological progress. The researchers find that less productive economies tend to grow slightly faster than more productive ones, which leads to a weak process of convergence in the area of labour productivity in the EU economies. Technological progress tends to contribute to the divergence of labour productivity. In other words, the positive regression slope between output per worker and technological change suggests that advanced economies gain greater benefits from technological progress than less productive economies. In contrast, capital accumulation seems to have positively contributed to labour productivity convergence. Physical and human capital accumulation also appears to be the main driver of labour productivity convergence since a strong inverse relation between capital deepening and the initial levels of output per worker can be observed.

Economies or sectors face problems when their productivities lag behind those of other economies or sectors (Volek and Novotna 2015). With reference to the research, the tendencies of aggregate productivity convergence can be observed. Rolf Fare, Shawna Grosskopf, and Dimitri Margaritis (2006) find that aggregate productivity converges in countries but diverges in sectors. Technical change is a source of divergence. The countries with access to the same technologies, similar volumes of trade, investment and other economic relations may differ in their abilities to innovate and adopt new technologies.

A growing interest in green technologies promotes a growing number of investigations into the relation between investment in environmentally oriented equipment and productivity. Roberto Antonietti and Alberto Marzucchi (2014) estimate the impact of green tangible investment strategies on the level of productive efficiency. Their results show that investment in environmentally oriented tangible technologies has a positive effect on a firm's productivity but only when environmental objectives are combined with the intent to increase the firm's revenues, for example, by introducing new products, developing existing ones or increasing production volumes to address higher demands.

Some evidence indicates that a firm's investment behaviour depends on peer firms' investment decisions. Shenglan Chen and Hui Ma (2017) find that a one standard deviation increase in peer firms' investments is associated with a 4% increase in firm *i*'s investment in China. Both types of investment (i.e., tangible and intangible) are sensitive to the investment policies of peer firms, but the peer effect is more pronounced in the areas of investments in property, plant and equipment. A one standard deviation increase in this tangible investment made by peer firms leads to a 14.4% increase in such type of investment made by firm *i*. It can be explained by the firms' aspiration to keep up with other participants in the market and remain competitive. However, the problem is that not all companies are able to exploit their funds efficiently. Therefore, it is important to test whether investment in tangible assets is effective, that is, whether it contributes to labour productivity increase.

In concluding this literature review, it is clear that the results of research on the relations between tangible investment and labour productivity vary due to different levels of economic development in selected countries, dissimilar rates of tangible investment in different manufacturing industries, environmental factors and behaviours of individual companies. In this paper, we aim to reveal the main characteristics of the relation between tangible investment rate and labour productivity in the European manufacturing industry and to find out if this link does not differ among countries and is stable over time.

2. Methodology

A standard Solow (1956) model, where the Cobb-Douglas production function is used, is considered. Accordingly, output Y_t is given by:

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \tag{1}$$

where K_t denotes physical capital, A_t represents multifactor productivity or efficiency of labour, L_t signifies labour, and α is the capital share in production and is bounded between zero and one. This equation can also be written as follows:

$$\frac{Y_t}{L_t} = A_t\left(\frac{K_t}{A_t L_t}\right)^{\alpha} = A_t\left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}. \tag{2}$$

Calculating logarithms for Equation (2) allows coming up with the linear regression:

$$ln\left(\frac{Y_t}{L_t}\right) = lnA_t + \frac{\alpha}{1-\alpha} ln\left(\frac{K_t}{Y_t}\right). \tag{3}$$

Equation (3) indicates that apparent labour productivity increases when capital rises. Various types of investment are analysed: gross investment in tangible goods, gross investment in land, gross investment in existing buildings and structures, gross investment in construction and alteration of buildings, gross investment in machinery and equipment, and net investment in tangible goods.

In this empirical study, we use the annual data of manufacturing industries in 29 European countries for the period 2005-2014. All the data are obtained from Eurostat.

The following research methods are employed:

- The correlation analysis shows how strong the relation is between apparent labour productivity and investment rate.
- The Granger causality test defines the direction of the relation between labour productivity and investment rate; delayed effects (lags) are also evaluated.
- The panel regression analysis gives the expression of the relation between the indicators. The evaluation of cross-section effects lets us answer the question of whether significant changes among countries exist. The evaluation of time effects shows whether the relation between apparent labour productivity and investment rate is influenced by time.

The Granger approach to the question of whether *x* causes *y* is used to find how much of the current *y* can be explained by past values of *y* and then to determine whether the addition of the lagged values of *x* can improve the explanation. The variable *y* is said to be Granger-caused by *x* if *x* helps to predict *y*, or equivalently if the coefficients of the lagged *x* are statistically significant. The effect of five previous years (five lags of variables) is examined. Since panel data are analysed, Granger causality testing specific to the panel data is selected. The bivariate regressions in a panel data context take the following form:

$$y_{i,t} = \alpha_{0,i} + \alpha_{1,i} y_{i,t-1} + \cdots + \alpha_{5,i} y_{t-5} + \beta_{1,i} x_{i,t-1} + \cdots + \beta_{5,i} x_{i,t-5} + \varepsilon_{i,t}, \quad (4)$$

$$x_{i,t} = \alpha_{0,i} + \alpha_{1,i} x_{i,t-1} + \cdots + \alpha_{5,i} x_{t-5} + \beta_{1,i} y_{i,t-1} + \cdots + \beta_{5,i} y_{i,t-5} + \varepsilon_{i,t}, \quad (5)$$

where *t* denotes the time period dimension of the panel, and *i* represents the cross-sectional dimension.

Two approaches are commonly employed to obtain the parameter estimates in the Granger causality test. First, the observations on all panel units (countries) can be pooled in a large data set (hereafter referred to as a stacked test). This approach relies on the assumption that the parameters are identical across the different panel units, that is, $\beta_i = \beta$, and $\delta_i = \delta$ for $i = 1, ..., N$. Second, Granger causality tests can be performed for each country separately, and the corresponding test statistics are averaged across groups (hereafter referred to as the Dumitrescu-Hurlin test). This research is based on the first approach. The Granger causality test is performed in the standard way, with the exception of not letting the data from one cross-section enter the lagged values of the data from the next cross-section. This method assumes that all coefficients are the same across all cross-sections, that is:

$$\alpha_{0,i} = \alpha_{0,j}, \alpha_{1,i} = \alpha_{1,j}, \alpha_{2,i} = \alpha_{2,j}, \alpha_{3,i} = \alpha_{3,j}, \text{ for all } i \text{ and } j, \quad (6)$$

$$\beta_{1,i} = \beta_{1,j}, \beta_{2,i} = \beta_{2,j}, \beta_{3,i} = \beta_{3,j}, \text{ for all } i \text{ and } j. \quad (7)$$

The null hypothesis is that *x* does not Granger-cause *y* in regression (6), and *y* does not Granger-cause *x* in regression (7).

The relation between apparent labour productivity and investment rate can also be described by the regression model. According to the results of the Granger causality test, lagged values of a particular investment rate, as well as lags of apparent labour productivity, can also have a significant impact. For this reason, distributed lag models and autoregressive distributed lag models are developed.

Testing for the existence of any cross-section (individual) or time effects is important in panel regression settings since accounting for the presence of these effects is necessary for the correct specification of the regression and proper inference. The Lagrange multiplier test is performed to find out whether inclusion of random effects can improve the models. This test considers the disturbances of the two-way error components:

$$u_{i,t} = \mu_i + \lambda_t + v_{i,t}. \quad (8)$$

For cross-sections $i = 1, ..., N$ and periods $t = 1, ..., T_i$, the symbol μ_i refers to unobservable individual effects, λ_t denotes unobservable time effects, and $v_{i,t}$ signifies the remaining idiosyncratic disturbance. The null hypotheses to be tested are as follows: no individual effects (H_0^{μ}: $\sigma_{\mu}^2 = 0$), no time effects (H_0^{λ}: $\sigma_{\lambda}^2 = 0$) and no individual and time effects ($H_0^{\mu\lambda}$: $\sigma_{\mu}^2 = \sigma_{\lambda}^2 = 0$).

The central assumption of the estimation of random effects is that these are uncorrelated with the explanatory variables. The Hausman test is employed to test this assumption. It allows comparing the fixed and the random effects of the estimates of particular coefficients.

A significance level of 0.05 is employed for all the tests on the hypothesis. Calculations are made by employing EViews software.

3. Results

Gross investment in tangible goods is growing in the EU. It accounted for 258 billion euro in all 28 EU member states and increased by 13.6% between 2012 and 2015. Meanwhile, apparent labour productivity increased by 5.6% from 2012 to 2014 (gross investment in tangible goods increased by 3.5% during the same period). The amount of gross investment in tangible goods is significant as it accounted for 4.4% of the total production value and 18.5% of value added at factor cost of the entire manufacturing industry in 2014. If investment in tangible goods does not contribute to labour productivity, then the growth of this type of investment is groundless and can reflect insufficient utilisation of investment. Especially, it is relevant for new members of the EU, as an obvious gap in labour productivity can be observed and investment in tangible goods is high in comparison to the other EU countries.

The average apparent labour productivity (ALP) of the manufacturing industry in 29 European countries for the period 2005-2014 amounted to 49,000 euro and varied in a comparatively large interval, that is, from 5,000 to 206,000 euro (Table 1). The highest apparent labour productivity was reached in Ireland, Switzerland and Norway. Meanwhile, Bulgaria, Romania, Latvia and Lithuania were distinguished by having the lowest apparent labour productivity. These countries still have not shown any significant improvement in the area under research.

Low gross value added (VA) in Bulgaria, Romania, Latvia and Lithuania caused a high ratio of investment and value added at factor cost, that is, investment rate (IR). The lowest investment rate was observed in Ireland in 2010. Considering the newest data, the lowest investment rate in 2014 belonged to Cyprus and was equal to 7. It was also low in Denmark, Finland and Norway, accounting for approximately 11 in 2014.

Switzerland was the leader in gross investment in existing buildings and structures (GIEBS). The second highest value of gross investment in existing buildings and structures in 2014 belonged to Belgium, where it amounted to 1024 million euro, while the United Kingdom ranked third with 811 million euro. Meanwhile, gross investment in existing buildings and structures in Norway and Romania was under 1 million euro in 2014.

Although apparent labour productivity in Germany was not so far from the mean in Europe, Germany was one of the leaders in various types of investment. In 2013-2014, Germany had the highest values of gross investment in tangible goods (59611 million euro in 2014), gross investment in construction and alteration of buildings

(6822 million euro in 2013), gross investment in machinery and equipment (50736 million euro in 2013) and net investment in tangible goods (56169 million euro in 2013). Gross investment in tangible goods (GITG) was also high in France (28542 million euro in 2014) and Italy (24475 million euro in 2013). Gross investment in construction and alteration of buildings (GICB) and gross investment in machinery and equipment (GIME) were also high in the United Kingdom (5225 and 16736 million euro, respectively, in 2014) and Italy (3307 and 17997 million euro, respectively, in 2013). Net investment in tangible goods (NITG) was also high in the United Kingdom (20526 million euro in 2014) and France (13092 million euro in 2014) but was negative in Italy in 2013.

Table 1 Summary Statistics for the Variables

Variable	Mean	Median	Minimum	Maximum	Std. dev.	IQ range
Apparent labour productivity (thousand euro)	48.9	34.8	5.0 (Bulgaria, 2005)	205.9 (Ireland, 2012)	36.3	53.7
Gross investment in tangible goods (million euro)	8214.0	4312.2	57.3 (Cyprus, 2014)	62526.7 (Germany, 2008)	11868.1	6342.6
Gross investment in land (million euro)	144.4	65.9	0.1 (Luxembourg, 2013)	1252.6 (Italy, 2008)	197.5	161.0
Gross investment in existing buildings and structures (million euro)	295.0	74.0	0.0 (Romania, 2008)	5770.3 (Switzerland, 2014)	647.9	201.1
Gross investment in construction and alteration of buildings (million euro)	1122.3	580.7	-0.1 (Switzerland, 2014)	7128.4 (Germany, 2008)	1446.7	935.4
Gross investment in machinery and equipment (million euro)	5658.3	2501.6	41.5 (Cyprus, 2013)	54332.1 (Germany, 2008)	9296.7	5 094.7
Net investment in tangible goods (million euro)	6494.8	3217.9	-30645.5 (Italy, 2013)	59158.1 (Germany, 2008)	10575.4	5936.3
Ratio of gross investment in tangible goods to value added (%)	20.1	16.6	0.0 (France, 2005)	69.5 (Romania, 2007)	11.0	11.3
Ratio of gross investment in land to value added (%)	0.5	0.3	0.0 (Luxembourg, 2013)	6.0 (Romania, 2008)	0.7	0.5
Ratio of gross investment in existing buildings and structures to value added (%)	0.8	0.4	0.0 (Romania, 2008)	6.5 (Switzerland, 2014)	1.0	0.6
Ratio of gross investment in construction and alteration of buildings to value added (%)	4.3	3.2	0.0 (Switzerland, 2014)	19.1 (Latvia, 2008)	3.7	3.4
Ratio of gross investment in machinery and equipment to value added (%)	13.3	12.0	1.3 (Ireland, 2012)	36.2 (Romania, 2012)	5.9	5.9
Ratio of net investment in tangible goods to value added (%)	16.4	14.7	-15.4 (Italy, 2013)	52.8 (Romania, 2008)	9.1	8.6

Source: Own elaboration based on Eurostat data.

The countries with the lowest net investment in tangible goods, gross investment in tangible goods and gross investment in machinery and equipment in 2014 were Cyprus (44, 57 and 44 million euro, respectively), Luxembourg (326, 357 and 284 million euro, respectively) and Latvia (451, 493 and 251 million euro, respectively). The countries with the lowest gross investment in construction and alteration of buildings in 2014 were Switzerland (less than 1 million euro), Cyprus (11 million euro) and Luxembourg (62 million euro). Gross investment in land (GIL) in 2013-2014 was the highest in the United Kingdom (483 million euro in 2014), followed by Spain (477 million euro in 2014) and Germany (456 million euro in 2013), while it was the lowest in Luxembourg (1 million euro) and Cyprus (1 million euro), and Lithuania ranked the third lowest (6 million euro).

The main statistics of all the variables under investigation are presented in Table 1. Summarising the tendencies of the researched indicators, this preliminary conclusion can be drawn: a negative relation between apparent labour productivity and investment rates (various types of investment divided by value added) exists.

Correlation analysis is conducted to quantify the strength of the relation between apparent labour productivity and investment rates. The results are presented in Table 2. The strongest correlation (-0.63) is between apparent labour productivity and the ratio of gross investment in tangible goods to value added. Apparent labour productivity also strongly correlates with the ratio of gross investment in construction and alteration of buildings to value added (-0.61), the ratio of gross investment in machinery and equipment to value added (-0.60), as well as the ratio of net investment in tangible goods to value added (-0.57). It should be noted that all the correlation coefficients are negative. This means that the higher the investment rate, the lower the apparent labour productivity.

Table 2 Results of Correlation Analysis

Indicator	GITG/VA	GIL/VA	GIEBS/VA	GICB/VA	GIME/VA	NITG/VA
Correlation	-0.6315	-0.3635	-0.0152	-0.6073	-0.5972	-0.5702
p-value	0.0000	0.0000	0.8443	0.0000	0.0000	0.0000

Notes: Correlation coefficients are presented in the first row, while probabilities of H_0 are presented in the second row; for H_0, the correlation coefficient is equal to zero.

Source: Own elaboration based on Eurostat data.

The results of the correlation analysis indicate that a simultaneous relation between apparent labour productivity and investment rates exists. The Granger causality test is performed to test the impact of the delayed effect. The results of the stacked test (common coefficients) are presented in Table 3. Calculations are made when a lag varies in the interval from 1 to 5. The bold values of probabilities in Table 3 show a significant causality between indicators at the significance level of 0.05.

The results indicate that none of the investment rates Granger-causes apparent labour productivity. However, there exists a significant opposite causality between these indicators. Apparent labour productivity Granger-causes the ratio of gross investment in construction and alteration of buildings to value added (when lag = 1 and 2), the ratio of gross investment in existing buildings and structures to value added (when lag = 1, 3 and 5), the ratio of gross investment in land to value added (when lag = 1), the ratio of gross investment in machinery and equipment to value added (when lag = 1 and 2) and the ratio of gross investment in tangible goods to value added (when lag = 2). Meanwhile, no causality is found between apparent labour productivity and the ratio of net investment in tangible goods to value added.

Table 3 Results of Granger Causality Test

Indicator (IR)	*H*[*]	*l* = 1	*l* = 2	*l* = 3	*l* = 4	*l* = 5
Ratio of gross investment in tangible goods to value added	IR→ALP ALP→IR	0.7698 0.1670	0.6436 **0.0182**	0.5302 0.2935	0.8516 0.6175	0.2839 0.6292
Ratio of gross investment in land to value added	IR→ALP ALP→IR	0.9597 **0.0224**	0.6271 0.8088	0.9616 0.8976	0.8267 0.8195	0.7236 0.4725
Ratio of gross investment in existing buildings and structures to value added	IR→ALP ALP→IR	0.1195 **0.0311**	0.7051 0.1275	0.7077 **0.0329**	0.6133 0.2222	0.5705 **0.0007**
Ratio of gross investment in construction and alteration of buildings to value added	IR→ALP ALP→IR	0.7673 **0.0030**	0.1139 **0.0351**	0.1047 0.5830	0.2722 0.0703	0.9424 0.8530
Ratio of gross investment in machinery and equipment to value added	IR→ALP ALP→IR	0.5483 **0.0039**	0.2240 **0.0077**	0.7478 0.2173	0.3596 0.8560	0.2906 0.4811
Ratio of net investment in tangible goods to value added	IR→ALP ALP→IR	0.7174 0.1328	0.0575 0.1990	0.3755 0.1302	0.2736 0.7159	0.1605 0.7251

Notes: The hypothesis that IR does not Granger-cause ALP (IR→ALP) is tested in the first row. The hypothesis that ALP does not Granger-cause IR (ALP→IR) is tested in the second row.

Source: Own elaboration based on Eurostat data.

Since apparent labour productivity and investment rates are negatively correlated, it means that investment in tangible assets depends on the number of persons employed in the manufacturing industry, and these indicators are positively correlated, that is:

$$if\ L \uparrow \Rightarrow ALP = \frac{Y}{L} \downarrow \overset{r<0}{\Longrightarrow} IR = \frac{K}{Y} \uparrow \Rightarrow K \uparrow,$$

where L denotes the number of persons employed, Y represents value added, and K signifies investment in tangible assets. The Granger causality test shows that an increase in apparent labour productivity causes a rise in gross investment in tangible goods after two years. Despite this, it is obvious that the increase in apparent labour productivity causes the growth of all components of gross investments in tangible goods (i.e., land, existing buildings and structures, construction and alteration of buildings, and machinery and equipment) even after a year.

According to the results of the Granger causality test, the relation between apparent labour productivity and investment rate should be rewritten as follows:

$$ln\left(\frac{K_t}{Y_t}\right) = \beta_0 + \beta_1 ln\left(\frac{Y_t}{L_t}\right). \tag{9}$$

As investment rates are caused by the delayed effect of apparent labour productivity, Equation (9) can also be expanded:

$$ln\left(\frac{K_t}{Y_t}\right) = \beta_0 + \beta_1 ln\left(\frac{Y_t}{L_t}\right) + \beta_2 ln\left(\frac{Y_{t-1}}{L_{t-1}}\right) + \beta_3 ln\left(\frac{Y_{t-2}}{L_{t-2}}\right) + \cdots, \tag{10}$$

where β_i are parameters of the regression model. The parameters of model (10) will be estimated by using the panel least squares method.

The unit root test shows that all the indicators under study are stationary. The ratio of gross investment in tangible goods to value added, the ratio of gross investment in construction and alteration of buildings to value added, the ratio of gross investment in machinery and equipment to value added and the ratio of gross investment in land to value added are stationary, without any intercept or trend in both of the following cases: a common unit root process and an individual unit root process. The ratio of gross investment in existing buildings and structures of buildings to value added and the ratio of net investment in tangible goods to value added are stationary when an intercept is included (in both of the following cases: a common unit root process and an individual unit root process). Meanwhile, apparent labour productivity is stationary when an intercept and a trend are included (in both of the following cases: a common unit root process and an individual unit root process). The stationary processes allow avoiding the spurious regression.

First, the logarithm of the ratio of gross investment in tangible goods to value added is analysed as a dependent variable. The estimates of the parameters of model (9) are presented in Table 4 (Model I). The results indicate that the ratio of gross investment in tangible goods to value added can be forecast by apparent labour productivity and that the model has moderate precision (i.e., $R^2 = 0.73$). However, the residuals of the model are autocorrelated (according to the Durbin-Watson statistic) and are not distributed by normal distribution (Jargue-Bera criteria = 57.32, and its p-value = 0.0000).

Table 4 Results of Regression Analysis for the Ratio of Gross Investment in Tangible Goods to Value Added

	Model I: panel least squares	Model II: distributed lag model		Model III: autoregressive distributed lag model	Model IV: period random effects	Model V: period fixed effects	Model VI: cross-section and period fixed effects
Coefficient	4.6989***	4.5651***	4.5767***	1.0990***	0.8557***	0.7826***	0.9511*
$\log(ALP_t)$	-0.4990***	0.0458					
$\log(ALP_{t-2})$		-0.5219***	-0.4785***	-0.1082***	-0.0775***	-0.0685**	0.1484
$\log(GITG/VA_{t-1})$				0.7428	0.7908***	0.8033***	0.4855***
R^2	0.7341		0.7158				
Adjusted R^2		0.7127		0.8697	0.8786	0.8965	0.9094
Durbin-Watson statistic	0.5467	0.5862	0.5765	2.0332	2.1807	2.2506	2.3351

Notes: * the parameter is significant at the significance level of 0.1; ** the parameter is significant at the significance level of 0.05; *** represents the significance level of 0.01.

Source: Own elaboration based on Eurostat data.

The Granger causality test shows the significant delayed effect of apparent labour productivity, so lags are also included in the model. The results of the distributed lag model are presented in Table 4 (Model II). Obviously, the lag value (period t-2) of apparent labour productivity is significant, but its value in the current period t becomes nonsignificant. If it is removed, the model's parameters and precision change only slightly. The precision of the model can be further improved if the lags of the dependent variable are included (see Model III, Table 4). The adjusted R^2 of the autoregressive distributed lag model is equal to 0.87, and residuals of the model are not autocorrelated, but still, residuals are not distributed by normal distribution (Jargue-Bera criteria = 25.06, and its p-value = 0.0000).

Model III does not consider any fixed or random effects for cross-section or time. Nevertheless, testing for the existence of any cross-section (individual) or time effects is important in panel regression settings since accounting for the presence of these effects is necessary for correct specification of the regression and proper inference. The Lagrange multiplier test is performed to find out whether the inclusion of random effects can improve the model (see Figure A1, Appendix A). The first column in Figure A1, Appendix A indicates some unaccounted time random effects in the pooled estimator residuals in Model III. All of the time tests have *p*-values well below conventional significance levels. For testing cross-section specific effects, there is strong evidence that these effects cannot be observed, but both effects (time and cross-section) should also be considered.

Our calculations show that period random effects improve the prediction of Model III only slightly (see Model IV, Table 4). The central assumption of the estimation of random effects is the assumption that the random effects are uncorrelated with the explanatory variables. One common method to test this assumption is the Hausman test that allows comparing the fixed and the random effects of the estimates of particular coefficients. The statistic provides the evidence against the null hypothesis that there is no misspecification (see Figure A2, Appendix A). It means that the errors are correlated with the regressors, so the impact of the fixed effects should also be considered.

For this reason, the model with period fixed effects is verified. The results are presented in Table 4. The period fixed effects (Model V) also improve Model III slightly, but the Durbin-Watson statistic arises, too. If both (cross-section and period) fixed effects are included, the model has an even higher precision, but apparent labour productivity becomes nonsignificant. For this reason, Model V will be considered further.

To test the significance of time fixed effects of Model V, the test of redundant fixed effects is performed. The probabilities of "Period F" and "Period Chi-square", which evaluate the joint significance of the period effects by leaning on sums-of-squares (*F*-test) and the likelihood function (Chi-square test), strongly reject the null hypothesis that time effects are redundant (Figure A3, Appendix A).

Gross investment in tangible goods consists of four components: gross investments in land, existing buildings and structures, construction and alteration of buildings, and machinery and equipment. Therefore, it is useful to find out how these components depend on apparent labour productivity.

The estimates of the parameters of the model, where the logarithm of the ratio of gross investment in land to value added is a dependent variable, are presented in Table 5 (Model I). The results indicate a low precision of the model (i.e., $R^2 = 0.37$). Moreover, the residuals of the model are autocorrelated (according to the Durbin-Watson statistic) and are not distributed by normal distribution (Jargue-Bera criteria = 22.65, and its *p*-value = 0.0000).

As the Granger causality test shows the significant delayed effect of apparent labour productivity, lags are also included in the model. The results of the distributed lag model are presented in Table 5 (Model II). They show that apparent labour productivity and its lag value are not significant. If its value in period *t* is removed, the lag value becomes significant, but the model's precision changes only slightly. The model's precision can be further improved if the lags of the dependent variable are included (see Model III, Table 5). The stepwise regression method shows that the best model is obtained when the first and the second lags of the dependent variable are included, while apparent labour productivity and its lag values are not significant.

Table 5 Results of Regression Analysis for the Ratio of Gross Investment in Land to Value Added

	Model I: panel least squares	Model II: distributed lag model		Model III: autoregressive distributed lag model	Model IV: cross-section random effects
Coefficient	1.8188***	1.8458***	1.8253***		1.4515***
$log(ALP_t)$	-0.8224***	-0.2783			
$log(ALP_{t-1})$		-0.5648	-0.8390***		-0.7325***
$log(GIL/VA_{t-1})$				0.6340***	
$log(GIL/VA_{t-2})$				0.3562**	
R^2	0.3700		0.3972		0.1095
Adjusted R^2		0.3904		0.7443	
Durbin–Watson statistic	0.4370	0.4610	0.4671	2.3117	1.6381

Notes: ** the parameter is significant at the significance level of 0.05; *** represents the significance level of 0.01.

Source: Own elaboration based on Eurostat data.

Since the purpose is to test the impact of apparent labour productivity on the investment rate, Model III will not be analysed. Considering other models, Model II without variable $log(ALP_t)$ will be analysed further as it has the highest coefficient of determination. The Lagrange multiplier test is performed to find out whether inclusion of random effects can improve Model II. The first column in Figure B1, Appendix B indicates some unaccounted cross-section random effects in the pooled estimator residuals. All cross-section tests have *p*-values well below conventional significance levels. In testing time-specific effects, there is strong evidence that these cannot be observed.

Our calculations show that cross-section random effects do not improve the prediction of Model II (see Model IV, Table 5). The Hausman test provides the evidence that the null hypothesis is accepted, and it is not worth considering the impact of the fixed effects (Figure B2, Appendix B).

As a consequence, it can be stated that apparent labour productivity has a weak influence on the ratio of gross investment in land to value added. Nevertheless, it is significant, and the growth of apparent labour productivity causes the decrease in the gross investment in land after one year.

The results of the regression analysis, where the logarithm of the ratio of gross investment in existing buildings and structures to value added is a dependent variable, are presented in Table 6 (Model I). The results indicate a very low precision of the model (i.e., $R^2 = 0.03$). The residuals of the model are also autocorrelated (according to the Durbin-Watson statistic), but they are distributed by normal distribution (Jargue-Bera criteria = 5.92, and its *p*-value = 0.0517).

If lags of apparent labour productivity are included, most of the parameters become nonsignificant (Model II, Table 6). If nonsignificant parameters are removed, a significant model with the first and the fifth lags of apparent labour productivity is obtained, and its precision equals 0.32. The model's precision can be further improved if the lags of the dependent variable are also included (see Model III, Table 6). Stepwise regression shows that the best model is obtained when the fifth lag of apparent labour productivity and its current value, as well as the first and the fifth lags of the dependent variable, are included in the model. As the inclusion of the lag values of the ratio of gross investment in existing buildings and structures to value added significantly improves the model's precision, it means that this type of investment is quite inertial, that is, its increase causes further increase.

Table 6 Results of Regression Analysis for the Ratio of Gross Investment in Existing Buildings and Structures to Value Added

	Model I: panel least squares	**Model II: distributed lag model**		**Model III: autoregressive distributed lag model**
Coefficient	0.1751	-1.2467*	-0.7780	-0.9289**
log(ALP$_t$)	-0.2624**	2.8632		1.4209***
log(ALP$_{t-1}$)		2.7100	3.5212***	
log(ALP$_{t-3}$)		-2.7538**		
log(ALP$_{t-5}$)		-2.8703***	-3.6754***	-1.2826***
log(GIEBS/VA$_{t-1}$)				0.6297***
log(GIEBS/VA$_{t-5}$)				0.2519**
R^2	0.0343			
Adjusted R^2		0.3477	0.3165	0.8337
Durbin–Watson statistic	0.4611	1.0583	1.2411	2.6723

Notes: * the parameter is significant at the significance level of 0.1; ** the parameter is significant at the significance level of 0.05; *** represents the significance level of 0.01.

Source: Own elaboration based on Eurostat data.

The Lagrange multiplier test is performed to find out whether inclusion of random effects could improve Model III. The first and the second columns in Figure C1, Appendix C indicate no unaccounted cross-section and time random effects in the pooled estimator residuals.

Thus, apparent labour productivity has long-term influence on gross investment in existing buildings and structures. The growth of apparent labour productivity causes the rise in the current year's gross investment in existing buildings and structures, but it has a negative impact on the gross investment in existing buildings and structures after five years. The previous years' growth of gross investment in existing buildings and structures also supports the further increment.

The estimates of the parameters of the model, where the logarithm of the ratio of gross investment in construction and alteration of buildings to value added is a dependent variable, are presented in Table 7 (Model I). The results indicate a moderate precision of the model (i.e., $R^2 = 0.72$). The residuals of the model are autocorrelated (according to the Durbin-Watson statistic) and distributed by normal distribution (Jargue-Bera criteria = 0.41, and its *p*-value = 0.8129).

If the lags of apparent labour productivity are included, the model's precision increases only slightly, and the results indicate that the lag values are nonsignificant (Model II, Table 7). The model's precision can be improved if the lags of the dependent variable are included (see Model III, Table 7). However, in this case, the first lag of the ratio of gross investment in construction and alteration of buildings to value added is the most important, and stepwise regression indicates that apparent labour productivity does not improve the model. It means that this type of investment is also inertial, that is, its increase causes further growth.

Table 7 Results of the Regression Analysis for the Ratio of Gross Investment in Construction and Alteration of Buildings to Value Added

	Model I: panel least squares	Model II: distributed lag model	Model III: autoregressive distributed lag model	Model IV: cross-section random effects
Coefficient	4.2142***	4.1855***		4.1522***
$\log(ALP_t)$	-0.8358***	-1.0283***		-0.8187***
$\log(ALP_{t-1})$		0.6451		
$\log(ALP_{t-2})$		-0.4485		
$\log(GICB/VA_{t-1})$			0.9338***	
R^2	0.7239		0.8564	0.3970
Adjusted R^2		0.7325		
Durbin–Watson statistic	0.5200	0.5345	2.4207	1.1275

Notes: *** represents the significance level of 0.01.

Source: Own elaboration based on Eurostat data.

Since the purpose is to test the impact of apparent labour productivity on the investment rate, Model I is analysed further. The Lagrange multiplier test is performed to find out whether the inclusion of random effects could improve it. The first column in Figure D1, Appendix D indicates some unaccounted cross-section random effects in the pooled estimator residuals in Model I. All of the cross-section tests have *p*-values well below conventional significance levels. In testing time-specific effects, there is evidence that these cannot be observed, but both effects (time and cross-section) should also be considered.

Our calculations show that cross-section random effects do not improve the prediction of Model I (see Model IV, Table 7). The Hausman test provides the evidence that the null hypothesis is accepted, and it is not worth considering the impact of the fixed effects (Figure D2, Appendix D). Thus, the changes in apparent labour productivity have a simultaneous and negative impact on gross investment in construction and alteration of buildings.

The estimates of the parameters of the model, where the logarithm of the gross investment in machinery and equipment to value added is a dependent variable, are presented in Table 8 (Model I). The results indicate the model's moderate precision (i.e., $R^2 = 0.49$). The residuals of the model are autocorrelated (according to the Durbin-Watson statistic) and are not distributed by normal distribution (Jargue-Bera criteria = 9.50, and its *p*-value = 0.0086).

If lags of apparent labour productivity are included, the model's precision increases only slightly, and the results indicate that the values of period *t* are not significant (Model II, Table 8). If nonsignificant parameters are removed, only the second lag of apparent labour productivity is left, and the model's precision is almost the same as that of Model I. The model's precision can be further improved if the lags of the dependent variable are included (see Model III, Table 8). However, in this case, the first and the second lags of the ratio of gross investment in construction and alteration of buildings to value added are the most important, and stepwise regression indicates that apparent labour productivity does not improve the model. It means that this type of investment is also inertial, that is, its increase causes further growth.

Table 8 Results of Regression Analysis for the Ratio of Gross Investment in Machinery and Equipment to Value Added

	Model I: panel least squares	Model II: distributed lag model		Model III: autoregressive distributed lag model	Model IV: cross-section random effects	Model V: period random effects
Coefficient	3.8571***	3.7730***	3.7775***		3.8024***	3.8503***
log(ALP_t)	-0.3682***	-0.3866			-0.3548***	-0.3662***
log(ALP_{t-1})		0.6248**				
log(ALP_{t-2})		-0.5896**	-0.3537***			
log($GIME/VA_{t-1}$)				0.7666***		
log($GIME/VA_{t-2}$)				0.2173**		
R^2	0.4879		0.4896		0.1906	0.4987
Adjusted R^2		0.4938		0.7316		
Durbin–Watson statistic	0.5664	0.6295	0.5989	2.4332	1.2187	0.5089

Notes: ** the parameter is significant at the significance level of 0.05; *** represents the significance level of 0.01.

Source: Own elaboration based on Eurostat data.

Since the purpose is to test the impact of apparent labour productivity on the investment rate, Model I is analysed further. The Lagrange multiplier test is performed to find out whether the inclusion of random effects can improve it. The first and the second columns in Figure E1, Appendix E indicate some unaccounted cross-section and time random effects in the pooled estimator residuals in Model I.

Our calculations show that cross-section random effects do not improve the prediction of Model I (see Model IV, Table 8), while period random effects slightly increase it. The Hausman test for both types of effects provides the evidence that the null hypothesis is accepted, and it is not worth considering the impact of the fixed effects (Figure E2, Appendix E).

In general, the influence of apparent labour productivity on gross investment in machinery and equipment is similar to its impact on gross investment in construction and alteration of buildings. In other words, the increase in apparent labour productivity has a simultaneous and negative impact on gross investment in machinery and equipment of buildings.

4. Conclusions

Panel data analysis reveals significant differences in investment rates among countries and/or over time. The ratio of gross investment in tangible goods to value added significantly changes during the period under study. The ratio of gross investment in land to value added and the ratio of gross investment in construction and alteration of buildings to value added significantly vary among the countries. There are significant differences in the ratio of gross investment in machinery and equipment to value added among the countries and during the period under study, but there are no significant differences in the ratio of gross investment in existing buildings and structures to value added among the countries and during the analysed period.

Our analysis shows an opposite relation between apparent labour productivity and investment rate (i.e., investment in tangible assets divided by value added) in the European manufacturing industry, that is, the changes in apparent labour productivity causes the changes in investment in tangible assets but not *vice versa*. The Granger causality test shows that changes in apparent labour productivity cause the changes in gross investment in tangible goods after two years. Despite this, it is obvious that changes in apparent labour productivity cause the changes in all components of gross investments in tangible goods (i.e., land, existing buildings and structures, construction and alteration of buildings, and machinery and equipment), even after a year. Meanwhile, we do not find any causality between apparent labour productivity and the ratio of net investment in tangible goods to value added.

Although in general, a positive relation between labour productivity and capital is expected, our research shows a negative correlation between apparent labour productivity and the investment rate in the European manufacturing industry. It means that investment in tangible assets depends on the number of persons employed in the manufacturing industry. In other words, the larger the number of employees, the higher the investment in tangible assets.

Moreover, gross investment in tangible goods and its components are inertial processes. The inclusion of lag values of the investment rate significantly improves the prediction of future investment rates. However, the growth of apparent labour productivity has a stopping effect. The increase in apparent labour productivity causes the reduction in the ratio of gross investment in tangible goods to value added after two years. The rise of apparent labour productivity causes the simultaneous reduction in the ratio of gross investment in construction and alteration of buildings to value added and the ratio of gross investment in machinery and equipment to value added. Apparent labour productivity has a long-term influence on gross investment in existing buildings and structures. The growth of apparent labour productivity causes the current year's rise in gross investment in existing buildings and structures, but it has a negative impact on gross investment in existing buildings and structures after five years. The growth of apparent labour productivity has the least negative impact on the ratio of gross investment in land to value added.

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Appendix

A. Tests for the Ratio of Gross Investment in Tangible Goods to Value Added

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	0.134950 (0.7134)	67.89516 (0.0000)	68.03011 (0.0000)
Honda	-0.367355 (0.6433)	8.239852 (0.0000)	5.566696 (0.0000)
King-Wu	-0.367355 (0.6433)	8.239852 (0.0000)	7.234135 (0.0000)
Standardized Honda	-0.064366 (0.5257)	9.444452 (0.0000)	2.020832 (0.0216)
Standardized King-Wu	-0.064366 (0.5257)	9.444452 (0.0000)	4.655725 (0.0000)
Gourieroux, et al.*	--	--	67.89516 (0.0000)

Source: Authors' calculations.

Figure A1 Results of the Lagrange Multiplier Tests for Model III

Correlated Random Effects - Hausman Test
Equation: Untitled
Test period random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	6.783860	2	0.0336

Source: Authors' calculations.

Figure A2 Results of the Hausman Test for Model IV

Redundant Fixed Effects Tests
Equation: Untitled
Test period fixed effects

Effects Test	Statistic	d.f.	Prob.
Period F	7.255268	(7,162)	0.0000
Period Chi-square	46.903497	7	0.0000

Source: Authors' calculations.

Figure A3 Test of Redundant Fixed Effects for Model V

B. Tests for the Ratio of Gross Investment in Land to Value Added

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	241.7265 (0.0000)	1.292237 (0.2556)	243.0187 (0.0000)
Honda	15.54756 (0.0000)	-1.136766 (0.8722)	10.18997 (0.0000)
King-Wu	15.54756 (0.0000)	-1.136766 (0.8722)	5.611152 (0.0000)
Standardized Honda	16.26056 (0.0000)	-0.944598 (0.8276)	7.021223 (0.0000)
Standardized King-Wu	16.26056 (0.0000)	-0.944598 (0.8276)	2.825630 (0.0024)
Gourieroux, et al.*	--	--	241.7265 (0.0000)

Source: Authors' calculations.

Figure B1 Results of the Lagrange Multiplier Tests for Model II

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	1.251847	1	0.2632

Source: Authors' calculations.

Figure B2 Results of the Hausman Test for Model IV

C. Tests for the Ratio of Gross Investment in Existing Buildings and Structures to Value Added

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	2.893618	1.040893	3.934512
	(0.0889)	(0.3076)	(0.0473)
Honda	-1.701064	-1.020242	-1.924254
	(0.9555)	(0.8462)	(0.9728)
King-Wu	-1.701064	-1.020242	-1.351028
	(0.9555)	(0.8462)	(0.9117)
Standardized Honda	-1.277484	-0.726502	-6.894952
	(0.8993)	(0.7662)	(1.0000)
Standardized King-Wu	-1.277484	-0.726502	-5.346618
	(0.8993)	(0.7662)	(1.0000)
Gourieroux, et al.*	--	--	0.000000
			(1.0000)

Source: Authors' calculations.

Figure C1 Results of the Lagrange Multiplier Tests for Model III

D. Tests for the Ratio of Gross Investment in Construction and Alteration of Buildings to Value Added

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	134.1073	1.594070	135.7014
	(0.0000)	(0.2067)	(0.0000)
Honda	11.58047	1.262565	9.081398
	(0.0000)	(0.1034)	(0.0000)
King-Wu	11.58047	1.262565	6.147704
	(0.0000)	(0.1034)	(0.0000)
Standardized Honda	12.16533	1.630017	5.760135
	(0.0000)	(0.0515)	(0.0000)
Standardized King-Wu	12.16533	1.630017	3.346977
	(0.0000)	(0.0515)	(0.0004)
Gourieroux, et al.*	--	--	135.7014
			(0.0000)

Source: Authors' calculations.

Figure D1 Results of the Lagrange Multiplier Tests for Model I

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.083853	1	0.7721

Source: Authors' calculations.

Figure D2 Results of the Hausman Test for Model IV

E. Tests for the Ratio of Gross Investment in Machinery and Equipment to Value Added

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided
(all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	149.9678	6.451553	156.4194
	(0.0000)	(0.0111)	(0.0000)
Honda	12.24614	2.539991	10.45537
	(0.0000)	(0.0055)	(0.0000)
King-Wu	12.24614	2.539991	7.521296
	(0.0000)	(0.0055)	(0.0000)
Standardized Honda	12.83361	3.001206	7.194088
	(0.0000)	(0.0013)	(0.0000)
Standardized King-Wu	12.83361	3.001206	4.835192
	(0.0000)	(0.0013)	(0.0000)
Gourieroux, et al.*	--	--	156.4194
			(0.0000)

Source: Authors' calculations.

Figure E1 Results of the Lagrange Multiplier Tests for Model I

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	2.623658	1	0.1053

Correlated Random Effects - Hausman Test
Equation: Untitled
Test period random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	1.114484	1	0.2911

Source: Authors' calculations.

Figure E2 Results of the Hausman Test for Model IV and Model V

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