Kaldor 3.0: an empirical investigation of the Verdoorn-augmented technical progress function

Abstract

Consistently with the neoclassical theory, the recent slowdown in labour productivity is generally regarded as one of the main causes of the current phase of economic stagnation. On the contrary, Post-Keynesian economics, inspired by Kaldorian insights, looks at labour productivity growth as positively affected, along with capital accumulation, by the rate of growth of output. By focusing on this alternative perspective, our paper is grounded on the 'Verdoorn-augmented technical progress function', according to which labour productivity growth is endogenously shaped by both the output dynamics and the rate of growth of the capital-labour ratio. We empirically verify such a relationship through a Structural Vector Autoregressive (SVAR) model for G7 countries for the 1970–2017 period. Our findings, concerning both the total economy and the manufacturing sector, generally support the validity of the augmented technical progress function, thus indicating that both the rate of growth of output and the process of capital accumulation per worker exert positive effects on the labour productivity growth.

Keywords: Labour Productivity; Technical Progress Function; Investment; Increasing Returns; SVAR.

JEL classification: O47; D24; E22.

> *"most, though not all, technical innovations which are capable of raising the productivity of labour require the use of more capital per man"* (Kaldor, 1957, p. 595)
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> *"improved knowledge is, largely if not entirely, infused into the economy through the introduction of new equipment"* (Kaldor, 1961, p. 207)
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> *"technical progress enters into [the scale of output] and is not just a reflection of the economies of large-scale production"* (Kaldor, 1966, p. 106)

1. Introduction

The slowdown in labour productivity growth experienced in most developed economies in the last decades is commonly regarded as one of the main causes of the current phase of economic stagnation. As shown in Figure 1, productivity growth for G7 countries was about 2% yearly on average during the 1970s and the 1980s, while is currently experiencing lower dynamics (1.5% between the 1990s and the 2000s, and 0.5% on average after the outbreak of the global economic and financial crisis). Such a slackening has been particularly strong in Japan, where labour productivity grew over 3.5% per year until the beginning of the 1990s, while its recent pace is virtually zero. An even worst situation occurred in Italy, where a negative productivity growth has been experienced during the last decades. Similarly, a productivity slowdown is observed in United Kingdom, Germany and France, whereas the United States and Canada have shown the better performances.

[Figure 1 about here]

Such stagnation has led researchers to carry out a several theoretical and empirical works aimed at identifying the long-run determinants of productivity growth. In particular, mainstream analyses, which are generally based on the neoclassical theory of growth,[1] have regarded the slowdown in labour productivity – usually considered *exogenous* with respect to economic growth – as (almost exclusively) determined by supply-side factors. On the contrary, an alternative strand of research, grounded on Verdoorn and Kaldor insights as well as on the Keynesian principle of effective demand (and its extension to the long run),[2] offers a different perspective for modelling labour productivity growth. According to this view, labour productivity – and therefore technical progress – is *endogenously* determined by the rate of growth of output as well as by the process of capital accumulation. It is within this framework that we wish to situate our contribution. Such a perspective is grounded on two cornerstones of Post-Keynesian economics, namely the technical progress function proposed by Kaldor (1957), and the well-known Verdoorn law (Verdoorn, 1949; Kaldor, 1966). The former asserts that labour productivity growth is positively affected by the growth rate of capital per worker, "since improved knowledge is, largely if not entirely, infused into the economy through the introduction of new equipment" (Kaldor, 1961, p. 207). The latter postulates the existence of a positive relationship between output growth and the dynamics of labour productivity. In this framework, the extension of the market is able to positively stimulate labour productivity through a number of factors capable to generate economies of scale (e.g. labour division, positive externalities, specialization and learning by doing processes) and because of embodied technical progress.

Starting from this alternative perspective, the aim of our paper is to empirically investigate the determinants of labour productivity growth by considering, on the one hand, the role played by the size of the market and the extension of the scale of production, and, on the other hand, the effects arising from the intensification of capital accumulation processes. Specifically, this

[1] The causal relationship between productivity and output is usually based on a theoretical approach that has a canonical representation in the neoclassical Solow's growth model, where output growth is exclusively determined by supply-side factors.
[2] See Cesaratto (2015) and Lavoie (2016) for surveys of this literature.

work will estimate a 'Verdoorn-augmented technical progress function' by allowing the traditional technical progress function – originally proposed by Kaldor (Kaldor, 1957; 1961; McCombie, 2002) – to contemplate increasing returns to scale.[3] To this purpose, in line with the Post-Keynesian tradition (see among others, Lavoie, 2014; McCombie and Spreafico, 2015), we will consider both the dynamics of capital accumulation per worker (as in the Kaldor's technical progress function) and the rate of growth of the economy (as in the Verdoorn's law) as determinants of labour productivity growth. Such an analysis is grounded on the seminal paper carried out by Michl (1985) and its recent reappraisal by Lavoie (2014) and McCombie and Spreafico (2015), which aimed at overlapping the Verdoorn's law with the Kaldorian technical progress function. To this aim, a Structural Vector Autoregressive (SVAR) model is estimated for G7 countries for the 1970–2017 period by considering both the total economy and the manufacturing sector.

To the best of our knowledge, this paper presents three main innovations in terms of data, methods and findings compared to the existing literature. Particularly, the paper will: (i) empirically test the validity of the augmented technical progress function for each G7 country; (ii) use a SVAR model based on a suitable identification strategy which allows us to isolate exogenous shocks and assess the effect of each shock on productivity growth, by thus overcoming any endogeneity issues existing in single equation models; (iii) provide elements suggesting the dependence of productivity dynamics from output shocks, while not the other way-round.

The remainder of this paper goes as follows. In Section 2, we provide a reconstruction of the Post-Keynesian approach on the determinants of labour productivity growth, focusing on its relations with Verdoorn and Kaldor intuitions. In Section 3, we overview the empirical

[3] Markedly, McCombie and Spreafico (2015) underlined that the original Kaldor technical progress function (Kaldor, 1957) was featured by decreasing returns to scale, "because new ideas are exploited first and there are limits to the capacity to absorb these", and hence "the increase in induced productivity growth will be at a diminishing rate" (p. 1120).

literature on the drivers of labour productivity growth. Section 4 presents data and methods and Section 5 discusses our findings. Section 6 concludes and derives some policy implications to deal with the current phase of stagnating labour productivity.

2. The Verdoorn-augmented technical progress function

The causes of the recent fall in labour productivity growth can be investigated, both theoretically and empirically, from two different main strands of though. The first approach, grounded on the standard neoclassical models of growth, considers the pace of labour productivity almost exclusively determined by exogenous factors not related to output dynamics. Among these factors, on the one side, an appropriate regulatory environment and the flexibility of the labour market (Saint-Paul, 2000; Bassanini and Ernst, 2002) are supposed to enhance productivity: accordingly, the stagnation of labour productivity is often attributed to inefficient institutions (Acemoglu, 2006) and/or a too strong regulation (Nicoletti and Scarpetta, 2003) which reduce business efficiency.[4] On the other side, when the 'new growth' models are considered, a sort of endogenous technical progress is admitted (see among others, Arrow, 1962; Romer, 1994; Barro and Sala-i-Martin, 2004) and this can take place through investment in human and social capital (Baumol, 1990; Becker et al., 1990; Barro, 2001), as well as through private R&D expenditure (Romer, 1990) able to foster innovation – especially in ICT sectors (Aghion et al., 2001; Preenen et al., 2017).[5] However, within this perspective, no role is recognised to output growth in affecting labour productivity. On the contrary, it is

[4] According to this view, labour market deregulation is supposed to increase productivity also by reducing labour *misallocation* (Papageorgiou, 2014). Nevertheless, empirical works demonstrated that increasing labour market flexibility could have encouraged the adoption of labour intensive techniques to the point that possible positive effects on employment (where obtained) could have occurred at the expense of lower productivity growth (Gordon and Dew-Becker, 2008; Enflo, 2010; Daveri and Parisi, 2010).

[5] Although the R&D has to be considered as a determinant of innovation processes and then a supply-side factor, R&D spending can also be considered as a part of aggregate demand. As stated by Cesaratto et al. (2003) and Deleidi and Mazzucato (2018), R&D is considered as expenditure of firms, different from investments, and it does not create productive capacity.

the growth of factors productivity (labour and capital) which determines the growth of output,[6] and therefore it is considered the slowdown in labour productivity the main cause of economic stagnation.[7]

The second approach, which admits the role played by capital accumulation in increasing the labour productivity growth, assumes and empirically supports an opposite relationship, moving from output growth to the growth rate of labour productivity. Specifically, in parallel to the role of capital accumulation in fostering technical progress, in the spirit of Smith (1776) this view considers the effects of a greater scale of production. This evidence has to be referred to the prominent contributions of Verdoorn (1949; 1956) and Kaldor (1957; 1966) and their recent reappraisal (see among others, McCombie, 2002; Lavoie, 2014; McCombie and Spreafico, 2015; Deleidi et al., 2018) within a theoretical framework that considers output growth as determined by aggregate demand, both in the short- and long-run.[8] Notably, by making use of the insights of the Keynesian principle of effective demand (Keynes, 1936) and the idea of an economic growth driven by demand (Kaldor, 1975), this approach has gained momentum in Post-Keynesian economics by allowing the growth rate of output per unit of labour to be a positive function of the rate of growth of the output, which unambiguously "makes technical progress an endogenous variable" (Lavoie, 2014, p. 428).

A number of studies have supported the idea of an endogenous technical progress which materialises in a labour productivity growth. Initially, Verdoorn (1949, p. 28) found that "the average value of the elasticity of productivity with respect to output is approximately 0.45" and theoretically motivated this evidence by stating that the correlation between labour

[6] This mainly depends on the fact that canonical growth models assume full employment equilibrium and a production function where capital and labour are regarded as endowments and the only variables which determines the level of economic activity.
[7] Recently, a re-emerging line of research based on the so-called Baumol effect (Baumol, 1967) considers the shift towards the tertiary sector as an additional causes of slow productivity growth. According to Szirmai and Verspagen (2015, p. 47), "a transfer of resources from manufacturing to services may provide a structural change burden if many service activities indeed have little potential for productivity increase".
[8] It should be underlined, however, that Verdoorn (1949; 1956) did not regard the output as determined by aggregate demand, as instead advocated by supporters of the Keynesian tradition as Kaldor (see Palumbo, 2015).

productivity and output is due to the division of labour, which "only comes about through increases in the volume of production". Few years later, Kaldor (1966) delved into this evidence by focusing on the manufacturing sector. Specifically, he found a positive long-run relationship between the growth rate of output and that of labour productivity, arguing that the Verdoorn law can be seen as "a dynamic rather than a static relationship – between the rates of change of productivity and of output, rather than between the level of productivity and the scale of output – primarily because technical progress enters into it and is not just a reflection of the economies of large-scale production" (Kaldor, 1966, p. 106). A similar perspective is also backed by McCombie (2002, p. 97), who maintained that "the Verdoorn law is a long-term relationship in the sense that a faster trend rate of growth of output, both through induced technical progress, and static and dynamic increasing returns to scale, leads to a higher trend rate of growth of productivity (and a faster induced rate of capital accumulation)".[9] As also explained by Bianchi (2002), this long-run relationship between output and productivity reflects both *static* and *dynamic* increasing returns to scale. On the one hand, the static or 'reversible' increasing returns explain the dynamics of labour productivity as a consequence of the increase in the scale of production and the decrease in costs per unit of output (Kaldor, 1972; McCombie, 2002). On the other hand, the dynamic increasing returns are related to specialisation, learning-by-doing practises, and, more significantly, to embodied technical

[9] Concerning the estimation problems, McCombie (2002, p. 97) affirmed that "a number of studies have used time-series data. The problem is that, over the cycle, variation occurs in the intensity of use of both labour (labour hoarding occurs during the downswing of the cycle) and the capital stock. This will lead to a positive relationship between the growth of productivity and output, but one that is due merely to these short-term cyclical factors and has nothing to do with the presence of increasing returns to scale. This short-term relationship is known as Okun's law". In other words, the Verdoorn's law explains the long-run productivity growth rate whereas the Okun's law determines the short-run productivity growth rate, influenced by cyclical factors as the flexibility of the degree of capacity utilization and the intensity of labour use (see Okun, 1962). For a discussion on this parallelism see Jeon and Vernengo (2007).

progress – which, differently from the static increasing returns, are *not* reversible (McCombie, 2002).[10]

The most widespread version of the Verdoorn's law is the 'dynamic' one, where output and labour productivity growth rates are analysed instead of their levels.[11] In its simplest version, the Verdoorn's law can be represented as in equation (1):

$$\dot{p} = \dot{\alpha} + \eta\dot{y} \quad (1)$$

where $\dot{p}$ is the rate of growth of labour productivity, $\dot{y}$ is the rate of growth of output, while $\dot{\alpha}$ typically represents exogenous technical progress. According to this formulation, η is the Verdoorn's coefficient capturing the relationship between $\dot{p}$ and $\dot{y}$ or, in a Kaldorian fashion, the range and the size of dynamic returns to scale. Kaldor (1966) showed that the estimation of the Verdoorn coefficient was of about 0.5 in the manufacturing sector in a panel of industrial countries from 1953 to 1964. The evidence of a positive coefficient was explained by emphasising the presence of increasing returns in the manufacturing sector of the economy.[12] Inspired by Young (1928), Kaldor (1966; 1972) affirmed that these occur due to specialisation processes both *between* and *within* firms, positive externalities *among* firms and industries (especially for the manufacturing sector), and, decisively, because of technical progress embodied in new capital goods (Kaldor, 1957; 1961; Kaldor and Mirrlees, 1962).[13]

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[10] A similar view can be also found in Verdoorn (1956, p. 434) through the idea of 'internal' and 'external' economies, with the former related to specialisation processes, whereas the latter explained by the development of skilled labour force and technological discoveries.

[11] For a discussion concerning the static and the dynamic version of the Verdoorn law, see McCombie (1982) and McCombie and Roberts (2007).

[12] Moreover, Kaldor (1966) found "a positive correlation between the overall rate of economic growth and the *excess* of the rate of growth of manufacturing output over the rate of growth of the non-manufacturing sectors. […] Since the differences in growth rates are largely accounted for by differences in rates of growth of productivity (and not of changes in the working population), the primary explanation must lie in the technological field" (p. 104).

[13] The work of Young (1928) was clearly inspired by Smith (1776), according to which labour productivity is determined by the division of labour, that in turn is influenced by the size of the market. Particularly, Smith "suggested that the division of labour leads to inventions because workmen engaged in specialised routine

With respect to the latter, it is worth noting that Kaldor (1966, p. 128) included in his estimations an additional term to the original specification by Verdoorn (1949) – namely, the investment to output ratio as a proxy of the rate of growth of capital – to explicitly consider the technical progress embodied in new capital goods.[14] To some extent, this represented an attempt to disentangle the effect of the capital accumulation process from the increasing returns to scale stemming from the extension of the market. Yet, despite the investment to output ratio allows to capture the innovation embedded in new installed capital goods, it should be noted that investment generally does not represent exclusively technical progress but the variation of the existing capacity. Moreover, while Kaldor himself considered investment as endogenously determined (Kaldor, 1972), in this specification the investment-output ratio has been treated as an exogenous variable (Kaldor, 1966, p. 128), and this is probably the reason why its coefficient was proved to be non-statistically significant (see Ofria, 2009).[15] However, in Kaldor (1957), the author used a different metric for representing the main driver of productivity, namely the dynamic of the capital-labour ratio.[16] As shown in equation (2), the Kaldor's original technical progress function postulates the existence of a positive relationship between the rate of growth of labour productivity ($\dot{p}$) and the rate of growth of the capital-labour ratio ($\dot{k}$):

$$\dot{p} = \dot{\alpha} + \lambda \dot{k} \ (2).$$

operations come to see better ways of accomplishing the same results. The important thing, of course, is that with the division of labour a group of complex processes is transformed into a succession of simpler processes, some of which, at least, lend themselves to the use of machinery. In the use of machinery and the adoption of indirect processes there is a further division of labour, the economies of which are again limited by the extent of the market" (Young, 1928, p. 530).

[14] As Kaldor's stylized facts provided for a constant relationship between output and capital stock, a proxy for capital accumulation has been traced by Kaldor himself in the investment-output ratio.

[15] As we will discuss below, econometric methodologies based on a single equation incorrectly deal with the portion of technical progress embodied in the investment-output ratio as a full exogenous variable, while Post-Keynesian economics, which is the perspective endorsed in this work, suggests the plausible endogeneity of investment.

[16] For the sake of completeness, it is worth noting at this stage that the original Kaldor technical progress function, which we refer in this paper, is traceable in Kaldor (1957; 1961), while in Kaldor and Mirrlees (1962) there is a different specification. However, McCombie and Spreafico (2015) argued that "the latter was not markedly different from the former" (p. 1119).

This relationship is motivated by the fact that "the use of more capital per worker inevitably entails the introduction of superior techniques" (Kaldor, 1957, p. 595), which in turn stimulates labour productivity growth. More specifically, this indicates that technical progress "depends on the rate of progress of knowledge" (captured by the parameter α) "as well as on the speed with which innovations are introduced, that is, with the pace of investment" (Lavoie, 2014, p. 429). Remarkably, the rational of this relation is that "innovations and improvements are more likely to be infused into the productive system when new investments are made and when entrepreneurs are more dynamic" (Lavoie, 2014, p. 429).

Anyway, also in Kaldor (1966) the process of capital accumulation is certainly supposed to positively affect productivity growth.[17] However, differently from what done in the original technical progress function, here the author concentrated predominantly on the presence of increasing returns to scale, just because capital accumulation was considered as an *endogenous* process. Indeed, as affirmed by McCombie (2002, p. 99), the use of the Verdoorn's law in Kaldor (1966) "would seem to be a linear Kaldorian technical progress function", which explicitly considered capital accumulation, "with an allowance for increasing returns". This represents, from our viewpoint, the most inspiring connection between Verdoorn and Kaldor contributions, since it allows to simultaneously consider the two effects. Such a perspective has been also shared by Michl (1985), who defined this cross-point as a 'marriage' between two interconnected effects on technical progress: one stemming from the increase in the scale of production, and the other arising from the process of capital accumulation.[18] In the author's

[17] The fact that in Kaldor (1966, p. 128) the investment to output ratio is used instead of the growth rate of the capital per worker (as in Kaldor, 1957) does not pollute, however, the overall reasoning on the determinants of technical progress: as suggested by Lavoie (2014, p. 428, emphasis added), "although Kaldor himself *nowhere* links this version of Verdoorn's law to his own previous work, it is clear that […] is close to Kaldor's technical progress function".

[18] Similarly, an increase in the capital-labour ratio may also represent a shift of the economy (that is, a structural change) towards high-tech branches, or symmetrically a change in the output composition. As these sectors are

own words, "in order to incorporate the effect that growth of output has *independently* of the rate of mechanization", the original technical progress function by Kaldor ought to be "*augmented* by the rate of output growth" (Michl, 1985, p. 474, emphasis added). Based on what suggested by Michl (1985), equation (3) is thus capable to combine the traditional 'scale effect' postulated by Verdoorn with the role of capital accumulation nested in Kaldor technical progress function:

$$\dot{p} = \dot{\alpha} + \eta\dot{y} + \lambda\dot{k} \quad (3)$$

where labour productivity growth ($\dot{p}$) is assumed to be shaped by both the rate of growth of the economy ($\dot{y}$) and by the rate of growth of the capital-labour ratio ($\dot{k}$). Therefore, in line with Michl (1985) our empirical analysis will be based on the estimation of equation (3), which we call the 'Verdoorn-augmented technical progress function' as it intuitively summarizes the effects on labour productivity already represented in equations (1) and (2). For the sake of simplicity, in our empirics these two effects will be called, respectively, the 'Verdoorn effect' (η) and the 'capital accumulation effect' (λ). Of course, a key challenge of our investigation will be endogeneity: to appropriately deal with this issue, which as we will see in the next section has already emerged from the literature, our empirics will use advanced time series techniques which allow us to overcome several empirical weaknesses of previous works which are based on single equation models (Michl, 1985; McCombie, 2002; Ofria, 2009; Millemaci and Ofria, 2014; Deleidi et al., 2018 among others).

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supposed to exhibit higher levels of value added per person employed, this would not undermine the whole reasoning behind Kaldor technical progress function.

3. Related empirical literature

Taking stock of what emerged so far, of particular interest for our purposes are those studies which have evaluated the effects on labour productivity growth stemming from a greater capital endowment per worker. Several works, largely grounded on the neoclassical theory of growth (Solow, 1956), demonstrated the positive role of capital accumulation in fostering productivity. In this perspective, the process of increasing capital per unit of labour is usually termed 'capital deepening'.[19] Yet, despite theoretical and methodological differences, this literature can be a suitable benchmark for our study since also from our perspective tangible investments allow workers to be provided for more (or more efficient) capital, thus improving their productivity.[20] For instance, Kumar and Russel (2002) found that the average contribution of capital deepening to the dynamics of output per worker is about 77% for a panel of 57 countries from 1965 to 1990 (e.g. 33% for Canada, 38% for Italy, 60% for France, 76% for Japan, 61% for United States). Moreover, Jorgenson et al. (2008) estimated a contribution of about 53% of the capital deepening to labour productivity growth (1.14% on 2.14% from 1959 to 2006, of which 0.43% stemming from ICT goods) in the US economy. With a similar approach, Foda (2017) founded that capital deepening's contribution to labour productivity growth was 0.5% on 1.1% in the US economy from 2005 to 2015.

Concerning the effect of the size (and the extension) of the market on labour productivity growth, after the initial estimations by Verdoorn (1949) and Kaldor (1966), several scholars

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[19] Notably, the neoclassical growth accounting typically decomposes labor productivity growth into the contributions of three components: capital deepening, labor quality and multifactor productivity. Then, labour productivity growth depends on i) the increase in capital per worker, ii) the substitution toward workers with higher marginal products, and iii) the impact of technical change and other factors that raise output growth beyond the measured contribution of inputs (Stiroh, 2001). An interesting comparison of the two approaches – namely, the total factor productivity and the Kaldorian technical progress function – which is focused on the empirical analysis of productivity growth has been provided by Paniccià et al. (2013).

[20] More recently, several authors extended the concepts of investment and capital beyond private investment in tangible assets, including human capital (Becker et al., 1990), R&D expenditures (Romer, 1990), and investment in public infrastructures (Aschauer, 1989). What may to same extent differ from this view can be the so-called 'new growth theory', which attributes greater significance to certain types of investment that create externalities and additional productivity increase through spillovers and/or technology diffusion (see among others Arrow, 1962; Grossman and Helpman, 1993).

contributed to validate the Verdoorn law. An all-embracing review of the first empirical investigations can be found in McCombie (1983), Thirlwall (1983), and McCombie et al. (2002). Among recent contributions, this approach has been applied to two broad classes of studies: the first one regards country-specific studies, while the second is based on panel explorations.[21] With respect to the first class of works, Bianchi (2002), Ofria (2009) and Forges Davanzati et al. (2017) estimated the Verdoorn coefficient for the Italian economy between 0.5 and 0.7; analogously, Apergis and Zikos (2003) verified the Verdoorn law for Greece for the period 1960–1995; Castiglione (2011) estimated the Verdoorn coefficient for the manufacturing sector through a cointegration analysis applied to US data; while Millemaci and Ofria (2014) and Deleidi et al. (2018) validated the long-run dynamic Verdoorn law for the manufacturing sector in several developed economies. For what regards panel analyses, Knell (2004) estimated a Verdoorn coefficient of 0.53 with respect to the manufacturing sectors of twelve industrial countries during the 1990s; Tridico and Pariboni (2018) estimated what they term 'Smith-Kaldor effect' – analogous to the Verdoorn effect – to be 0.36 for a panel of OECD countries; similarly, Magacho and McCombie (2017) found the existence of pervasive increasing returns to scale on a panel of manufacturing industries for 70 countries at different stages of development for the period 1963–2009.

Closely related to the purposes of this paper are the results obtained by Michl (1985), who was the first to estimate the augmented technical progress function. Focusing on eight advanced countries for the period 1950–1983, he found a Verdoorn coefficient of 0.54 and a capital accumulation (per worker) coefficient of 0.40, both statistically significant. More specifically, he initially estimated, as in equation (1), a simple Verdoorn law which generated a coefficient of 0.63. Then, he added the term related to the capital accumulation per worker

[21] Notably, while the Verdoon's coefficient is usually estimated by using macroeconomic data, McCombie and De Ridder (1984), McCombie (1985) and McCombie and Roberts (2007) discussed and validated this law also at regional level.

which, in addition to produce the aforementioned estimates, improved the overall goodness of fit.[22] Nevertheless, such empirics could reveal some weaknesses. To this regard, Michl (1985, p. 478) himself indicated that the estimation of "the Verdoorn Law may be a statistical artifact", namely that it can be affected by statistical endogeneity and simultaneity issues, especially whether the capital accumulation process is likely to be endogenously determined.[23] Consequently, such an investigation would require the use of econometric techniques able to consider and solve the most thorny and debatable concern raised by the empirical literature inspired by the works of Verdoorn and Kaldor, namely the endogenous nature of investment. Furthermore, another general criticism materialises from the empirical exercises aimed at estimating the Verdoorn effect. In particular, as postulated by the neoclassical theory, causality may actually run on the other way-round, namely from labour productivity to output growth.

Summing up, the following three considerations emerge from this review. First, there is a large consensus on the positive relationship between capital endowment per worker and productivity growth. Second, on empirical grounds the Verdoorn effect too is broadly verified. Finally, the existing works, aimed at jointly estimating the effect of capital accumulation and the Verdoorn law on labour productivity growth, do not appear fully persuasive in terms of econometric soundness.

As a consequence, the paper will then proceed by assessing the determinants of labour productivity growth through the estimation of the Verdoorn-augmented technical progress function, which simultaneously considers both the role played by the scale of production and the process of capital accumulation per worker. Specifically, by making use of structural vector autoregression (SVAR) models, we provide a methodological innovation which completely

[22] Importantly, a lower magnitude of the Verdoorn coefficient is due to the introduction of a variable capturing the effect of investment.

[23] Arguably, in the Post-Keynesian framework the process of capital accumulation is supposed to be endogenously determined – consistently with the accelerator principle (Kaldor, 1972) – and dependent on current and expected demand.

overcomes some of the weaknesses raised – but not solved – so far by Michl (1985), Deleidi et al. (2018), Ofria (2009), McCombie (2002) and Millemaci and Ofria (2014), such as endogeneity and simultaneity issues. Additionally, we will also be able to detect the causality among the considered variables by thus showing whether it moves from output growth to labour productivity dynamics or in the other way-round.

4. Data and methodology

4.1. Data

For our estimations of the Verdoorn-augmented technical progress function, which has been already sketched in equation (3), we use data from the STAN database with respect to G7 countries from 1970 to 2017. Specifically, we calculate labour productivity growth ($\dot{p}$) as the growth rate of real value added per person employed. In our specifications, the pace of the scale of production is proxied, as in Verdoorn (1949) and Kaldor (1966), by the growth rate of real output ($\dot{y}$). In parallel, the process of capital accumulation (per worker) is represented by the dynamics of capital stock (at constant prices) per person employed: following Kaldor (1957), we then make use of the growth rate of the capital-labour ratio ($\dot{k}$). For the sake of robustness, as well as with a view to recognize the original insights by Kaldor (1966), for each country we analyse both the total economy and the manufacturing sector, alternatively. Further details on variable descriptions and data sources are reported in Appendix A (Tables A.1 and A.2).

4.2. Methodology

As anticipated, we use a SVAR methodology to investigate the relationship among the rate of growth of labour productivity ($\dot{p}_t$), the rate of growth of output ($\dot{y}_t$) and the rate of growth of the capital stock per worker ($\dot{k}_t$). Such an analysis will be carried out both for the total economy as well as for the manufacturing sector for G7 countries for the 1970–2017 period.

Some remarks on the methodology used for our explorations are needed. Firstly, by making use of the augmented Dickey-Fuller test, we verified that all considered variables are stationary or I(0). Then, we choose one period as the optimal lag.[24] As our variables are I(0) and the selected lag is one, we estimate a reduced-form VAR(1), as shown in equation (4):

$$x_t = c + \sum_{i=1}^{p} A_i\, x_{t-p} + u_t \ (4)$$

where x_t is the $kx1$ vector of considered variables, c is the constant term, A_i is the kxk matrix of reduced-form coefficients and u_t is a $kx1$ vector composed by the error terms.

Secondly, an identification strategy has to be imposed to the reduced-form VAR(1), which in turn makes it possible to obtain a structural model, namely a SVAR. More precisely, a SVAR(1) can be represented as follows in equation (5):

$$B_0 x_t = c + \sum_{i=1}^{p} B_i\, x_{t-p} + w_t \ (5)$$

where B_0 represents the matrix of contemporaneous relationships between the k variables in x_t, B_i is the "$k\ x\ k$" matrix of autoregressive slope coefficients, and w_t is the vector of serially uncorrelated structural shocks (Kilian and Lütkepohl, 2017). The covariance matrix of structural errors is normalised: $\mathbb{E}(w_t w_t') = \sum_w = I_K$ (Lütkepohl, 2005). Furthermore, we set a

[24] The optimal lag has been chosen by minimizing the Schwarz information criterion.

recursively model based on a Cholesky decomposition. The identification scheme used for our model is summarised in the system of equation (6):

$$B_0 x_t = \begin{bmatrix} - & 0 & 0 \\ - & - & 0 \\ - & - & - \end{bmatrix} \begin{bmatrix} \dot{y}_t \\ \dot{k}_t \\ \dot{p}_t \end{bmatrix} \quad (6)$$

where '$-$' indicates an unrestricted parameter and a '0' represents a zero restriction. Once restrictions are imposed and the estimation of the B_0 matrix is implemented by means of maximum likelihood method, an accumulated Impulse Response Function (IRF) is estimated and standard errors will be estimated through the asymptotic distribution. IRFs will be reported with two-standard error bound, namely a 95% confidence interval.[25]

The econometric methodology used in our empirics offers several suitable properties compared to the remaining empirical methods. Particularly, SVAR models allow us to estimate the existing dynamic causal relationship among considered variables by ensuring the removal of any endogeneity issues (Kilian and Lütkepohl, 2017). With respect to the purposes of this paper, the use of this class of models, and therefore the imposition of a suitable identification strategy, enables us to assess and solve some of the most debated issues raised by the empirical literature on the Verdoon's law, namely the bidirectionality effect between labour productivity and output as well as the feasible effect of economic activity on the capital accumulation. Specifically, by following the identification set in the system of equation (6), we assume that $\dot{y}_t$ is not affected in the contemporaneous relationship by variables included in the model, but it can influence $\dot{k}_t$ in the second row. Finally, in line with our theoretical framework we assume

[25] Concerning the choice of standard-errors bands, see Sims and Zha (1999) and Kilian and Lütkepohl (2017, p. 334).

that the shocks of output growth and the accumulation process ($\dot{y}_t$ and $\dot{k}_t$, respectively) affect the rate of growth of labour productivity ($\dot{p}_t$).[26]

Putting it simply, the last row represented in equation (6) depicts the Verdoorn-augmented technical progress function, as suggested by Mitch (1985) and Lavoie (2014). Moreover, IRFs will enable us to assess and quantify the causal relationship moving from $\dot{y}_t$ and $\dot{k}_t$ to $\dot{p}_t$, as well as to evaluate whether a productivity shocks affect output dynamics.

5. Empirical findings

In this section, we report and discuss the results of IRFs estimated both for the manufacturing and the total economy for each G7 country. The following figures depict the dynamic effect of what we identify as the Verdoorn's effect, measured by the rate of growth of output ($\dot{y}$), as well as the capital accumulation effect, measured by the rate of growth of the capital stock per worker ($\dot{k}$). We report both the response of output growth to labour productivity shocks and the response of labour productivity growth to output and capital accumulation shocks.

The first issue here addressed is the possible relationship that moves from labour productivity to output, obviously in dynamic terms. We test the hypothesis whereby a positive shock in the growth rate of labour productivity could generate an increase in the growth rate of output. As can be seen in Figure 2, there is a null effect of a one percentage point increase of the rate of growth of labour productivity on the growth rate of output in all G7 economies. The only exceptions are the manufacturing sectors of Germany and Japan, where positive productivity shocks have modest effects on output. This finding is in sharp contrast to what postulated by the neoclassical growth theory, according to which increasing factor productivity

[26] Yet, despite we assume an identification strategy based on the empirical and theoretical works aimed at studying the Verdoorn law – see among others, Millemaci and Ofria (2014), Forges Davanzati et al. (2017) and Deleidi et al. (2018) – we estimate SVAR models with a different identification strategy based on the following ordering: $[\dot{k}_t, \dot{p}_t, \dot{y}_t]$. Findings, which we do not include here for reasons of space, will be provided upon request.

decisively stimulates output growth. A plausible explanation of this result could lie in the specification of our model, where a variable related to the process of capital accumulation is expressly specified in a system of equation rather in a single equation model. Particularly, it is possible that in our empirics the effect on output growth is captured almost exclusively by an increase $\dot{k}$, differently to what occurs, for instance, in other works (see among others, Forges Davanzati et al., 2017) which then might suffer from omitted variables bias.

[Figure 2 about here]

Then, looking at the effect of the output growth and the capital accumulation on labour productivity dynamics, we find that both $\dot{y}$ and $\dot{k}$ exert a positive effect on $\dot{p}$ in the manufacturing sector (see Figure 3), in line with the results of Verdoorn (1949) and Kaldor (1957; 1966). In particular, for six out of seven countries, our IRFs reveal the existence of a stable and persistent relationship moving from the rate of growth of output to the growth rate of labour productivity. Similarly, we find that an increase in the rate of growth capital-labour ratio ($\dot{k}$) generates a positive effect on labour productivity growth, thus endorsing the intuitions of Kaldor (1957) original technical progress function. This combination of results clearly confirms the validity of the Verdoorn-augmented technical progress function. Nevertheless, this evidence is not confirmed in the US manufacturing sector, where only positive shocks of the rate of growth of capital per worker exert a positive effect on productivity dynamics. A possible explanation of such a finding lies in the fact that the US manufacturing sector has undergone profound changes in its production structure due to the increase of off-shoring practices (e.g. Mexican *Maquiladoras*, South-East Asian countries) and imports of intermediate goods (Borjas et al., 1992; Feenstra and Hanson, 1999; Antenucci, 2018). To this regard, it has been shown that, in several branches of the US manufacturing sector, the increase of the output-labour ratio was not due to a greater capital-labour ratio, and then labour productivity growth was not the result of growing investment.[27] Indeed, the output-labour ratio has increased because employment has fallen more than the output did (Acemoglu et al., 2014; Antenucci, 2018).

[Figure 3 about here]

Even when our analysis is extended to the total economy, as reported in Figure 4, we can generally confirm the validity of the Verdoorn-augmented technical progress function. Both the rate of growth of the capital-labour ratio and the total output produce a positive effect on productivity growth. Also in this case, results are not completely validated for the United States, where an increase in the growth rate of output affects productivity only on impact, while an increase in the rate of growth of capital-labour ratio upsurges the labour productivity dynamics also in the long run, similarly to what occurs in the manufacturing sector.

[Figure 4 about here]

In order to quantify the magnitude of the two effects, in Tables 1 and 2 we report the response of labour productivity per unit increase in the rate of growth of output and of capital stock per worker. Following Spilimbergo et al. (2009), such effects are estimated by dividing the cumulative variation of the labour productivity ($\dot{p}$) for the cumulative change in rate of growth of output ($\dot{y}$) and in capital stock per worker ($\dot{k}$), respectively. Accordingly, the cumulative dynamic Verdoorn coefficient (ε_V) is computed as follows in equation (7):

[27] Interestingly, in a recent work of the European Central Bank (2016, p. 34) it is reported that, for the period 2011–2014, the contribution of capital deepening to US labour productivity growth is negative.

$$\varepsilon_V = \frac{\sum_{j=0}^{n} \Delta\dot{p}_{(t+j)}}{\sum_{j=0}^{n} \Delta\dot{y}_{(t+j)}} \quad (7)$$

and the cumulative dynamic coefficient related to capital accumulation per worker (ε_C) is calculated as in equation (8):

$$\varepsilon_C = \frac{\sum_{j=0}^{n} \Delta\dot{p}_{(t+j)}}{\sum_{j=0}^{n} \Delta\dot{k}_{(t+j)}} \quad (8)$$

Intuitively, ε_V and ε_C represent the 'Verdoorn effect' and the 'capital accumulation effect' reported in equation (3), respectively. The cumulative effects estimated for the manufacturing sector are reported in Table 1, whereas those calculated for the total economy are displayed in Table 2. The reliability of the Verdoorn-augmented technical progress function is generally confirmed also when cumulated effects are considered: specifically, we find positive and persistent effects over time of output growth (ε_V) and capital accumulation per worker (ε_C) on labour productivity.

[Table 1 and Table 2 about here]

Concerning the manufacturing sector (Table 1), our findings show that in all countries the greatest effect on labour productivity derives from the intensification of the capital-labour ratio. The sole exception is Japan, where the capital accumulation coefficient is lower than the Verdoorn effect at all time horizons. Notably, Japan exhibits the highest long-run Verdoor effect (0.899 on impact and 0.594 after 20 years). The size and the persistence of the Verdoorn effect is also relevant in Germany (virtually 1 on impact, while 0.4 on average in the medium-to-long run), Italy (0.75 on impact, and then approximatively 0.37), and Canada (0.546 in the very short run, then about 0.4). France and United Kingdom present positive and significant short-run Verdoorn coefficients (0.5 on average), while a lower effect is traceable in the longer run. Differently, Unites States exhibits a lower Verdoorn coefficient (0.221 on impact), which becomes virtually zero in the medium-to-long run. In parallel, the manufacturing sector of United States shows the highest long-run capital accumulation coefficient, which remarkably passes from 0.710 on impact to 2.525 at a 20-year window. Similarly, a strong long-run impact of capital accumulation is founded for Italy (1.874), Canada (1.438) and United Kingdom (0.824). Although to a lower extent, positive capital accumulation coefficients are estimated for Japan and Germany which are equal – on average – to 1 on impact and 0.6 in the medium-to-long run. Finally, the lowest capital accumulation coefficient emerges in France, which assumes a value of 0.274 on impact and 0.446 in the long run.

When we look at the total economy (Table 2), a striking finding is the Verdoorn coefficient in Japan, which takes a long-run value of 0.779. Similarly, United Kingdom (0.501) and Germany (0.543) exhibit high and statistically significant Verdoorn coefficients even at a 20-year time horizon. France represents a milder case in the spectrum of our exploration, with a Verdoorn coefficient of about 0.3 at all time horizons. Italy and Canada present sizeable Verdoorn coefficients only in the short-medium run, equal to 0.434 and 0.417, respectively. The only country showing a negative long-run Verdoorn coefficient is the United States, albeit a modest positive response of 0.231 on impact. As previously argued, the singularity of this result could be justified by the remarkable process of structural change, mainly related to increasing off-shoring, experienced by the US economy in the last decades. When the process of capital accumulation per worker is analysed, the higher effect at aggregate level is detected for Canada (from 0.890 on impact to 2.280 in the long run). Albeit with a lower magnitude, the relevance of the capital accumulation coefficient is also confirmed for Japan (about 0.6 at all time horizons) and Germany (0.874 on impact and 0.568 in the very long run). United States and Italy are two interesting cases since they exhibit high capital accumulation coefficients in the long run (1.518 and 1.355), while such an effect is lower in the short run (0.584 and 0.521, respectively). Finally, attention should be paid to France, which represents a remarkable exception: notably, the process of capital accumulation, which was proved to be positive but modest in size for the manufacturing sector, seems to be not so relevant for aggregate productivity growth in the medium-to-long run at aggregate level.[28]

When comparing the manufacturing sector and the total economy, the former generally shows greater capital accumulation coefficients, further confirming the relevance of capital-labour ratio in shaping labour productivity in manufacturing branches. Even when we look at the Verdoorn coefficient, our results tend to confirm a higher effect in the manufacturing sector than in the total economy on impact. However, when this comparison is extended to the medium-long run, our findings are more mixed. For example, while in the United Kingdom, France and Germany such effects are found to be stronger in the total economy, in Canada and Italy the greater Verdoorn effect is detectable in the manufacturing sector.

Summing up, our results allow us to conclude that a higher growth rate of output generally stimulates labour productivity dynamics both in the total economy and in the manufacturing sector. This enables us also to validate the Verdoorn law in its initial intent, i.e. to show the positive effects of the extension of the market, along with learning by doing and positive externalities, on labour productivity. The Verdoorn effect is not confirmed for the US economy uniquely, which may probably suffer of a deindustrialization process started in the 80's which has led to slowdown of investment (Lawrence and Edwards, 2013; Rodrik, 2015). We also found that an increase in the rate of growth of the capital stock per person employed

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[28] Recently, the findings of a work by Cette et al. (2017) belied the idea that for France the decline in productivity was related to a faltering of the technological frontier. On the contrary, the slowdown in productivity may be ascribed to sustained misallocation phenomena.

exerts a positive and persistent effect on the rate of growth of labour productivity: this finding confirms the Kaldorian intuition of an embodied technical progress, infused into the economy through the introduction of new equipment and machineries. Therefore, our findings validate the Verdoorn-augmented technical progress function, by confirming both the original Kaldor (1957) idea, according to which the process of capital accumulation fosters labour productivity, as well as the existence of increasing returns to scale into the economy, and particularly in the manufacturing sector where they are likely to be more persuasive.

6. Conclusions and policy implications

The recent slowdown in productivity growth in advanced countries has been often regarded as the direct cause of economic stagnation. While this consideration is based on a theoretical approach that has a canonical representation in the neoclassical theory of growth, in this paper we adopt a different theoretical framework, whereby long-term growth depends on aggregate demand, and this in turn is able to affect also the pace of labour productivity. Specifically, we aim at empirically assessing the determinants of labour productivity growth by following the Post-Keynesian tradition: this approach is focused on the role played by both the output growth and the process of capital accumulation per worker in determining labour productivity growth. On the one side, the effect of a greater scale of production is considered by estimating the classical Verdoorn (1949) effect, which postulates a positive relationship between output and labour productivity growth rates, with the former affecting the latter (Kaldor, 1966). On the other side, the effect of capital accumulation is derived by the initial Kaldorian technical progress function (Kaldor, 1957) and it is measured by the growth rate of the capital-labour ratio. In the spirit of the initial contribution of Michl (1985), the combination of these two effects gives birth to a technical progress function which considers both the original Kaldorian technical progress function and the traditional Verdoorn's law.

Our empirics are aimed at jointly verifying these two effects. We focus on G7 countries for the 1970–2017 period, and we explore both the total economy and the manufacturing sector. To quantify the relationships among the variables included in our models, we make use of SVAR methods. We firstly investigated the causal relationship between labour productivity and output: in this respect, findings do not trace any statistically significant impact of the growth rate of labour productivity on the growth rate of output for all G7 economies (with the sole exceptions of Germany and Japan manufacturing sectors). This appears in sharp contrast with what one would have expected from a neoclassical perspective, where is the increase in the labour productivity to determine the output growth. On the contrary, this initial evidence led us to consider the Post-Keynesian approach (Lavoie, 2014) as the more promising framework for exploring the determinants of labour productivity growth. Therefore, we submitted to an empirical scrutiny our Verdoorn-augmented technical progress function.

According to our main findings, a positive shock of the rate of growth of output generates a positive and permanent effect on labour productivity dynamics (in all countries except in the United States), confirming the general validity of the Verdoorn law. Additionally, we found a persistent impact on labour productivity resulting from an increase in the growth rate of the capital-labour ratio (with the only exception of France in the total economy). Both effects are positive, persistent and statistically significant: specifically, the greater effect on labour productivity growth generally stems from the process of capital accumulation per worker, which is able to stimulate productivity also in the very long run. The comparison between the manufacturing sector and the total economy highlights that elasticities tend to be higher, particularly for what concerns capital accumulation, for the manufacturing sector, confirming the original intuitions by Kaldor.

In addition to confirm the relevance of investment in fostering productivity, our evidence indicates that a non-negligible fraction of the recent slowdown in labour productivity can be attributed to the stagnation of output, and then, according to the Post-Keynesian framework, to stagnating aggregate demand. Even though a faster process of capital accumulation per worker, as in the spirit of what originally postulated by the Kaldorian technical production function, has been proved to be crucial in shaping labour productivity, according to our findings the endogenous mechanism *à la* Verdoorn may also help in explaining the recent slowdown in productivity. In this context, the relevance of aggregate demand in stimulating productivity growth twofold. First, as it shapes output trajectories, a sustained dynamic of aggregate demand would stimulate productivity through the well-documented Verdoorn effect. Second, the positive role of aggregate demand in fostering productivity is also confirmed by a large body of empirical literature on the determinants of aggregate investment, which finds large accelerator effects.[29]

Consistently, the policy implications of our results are that the conventional wisdom in macroeconomic and industrial policies may have to be revised. Since aggregate demand is found to positively influence labour productivity growth, coordinated expansionary macroeconomic policies, which certainly involve an active role of policy makers in stimulating aggregate demand, would contribute to enhancing productivity growth also by stimulating the process of capital accumulation, particularly in large countries and in those with a higher weight of the manufacturing sector. Certainly, a positive Verdoorn coefficient implies that demand policies would stimulate productivity growth, but being lower than one, such measures would also have positive effects on employment dynamics and then contribute to break out of this prolonged phase of economic stagnation.

[29] See Chirinko (1993), Khotari *et al.* (2014), Schoder (2014), Girardi and Pariboni (2018) among others.

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APPENDIX

Appendix A. Data and sources

Table A.1. Variable descriptions

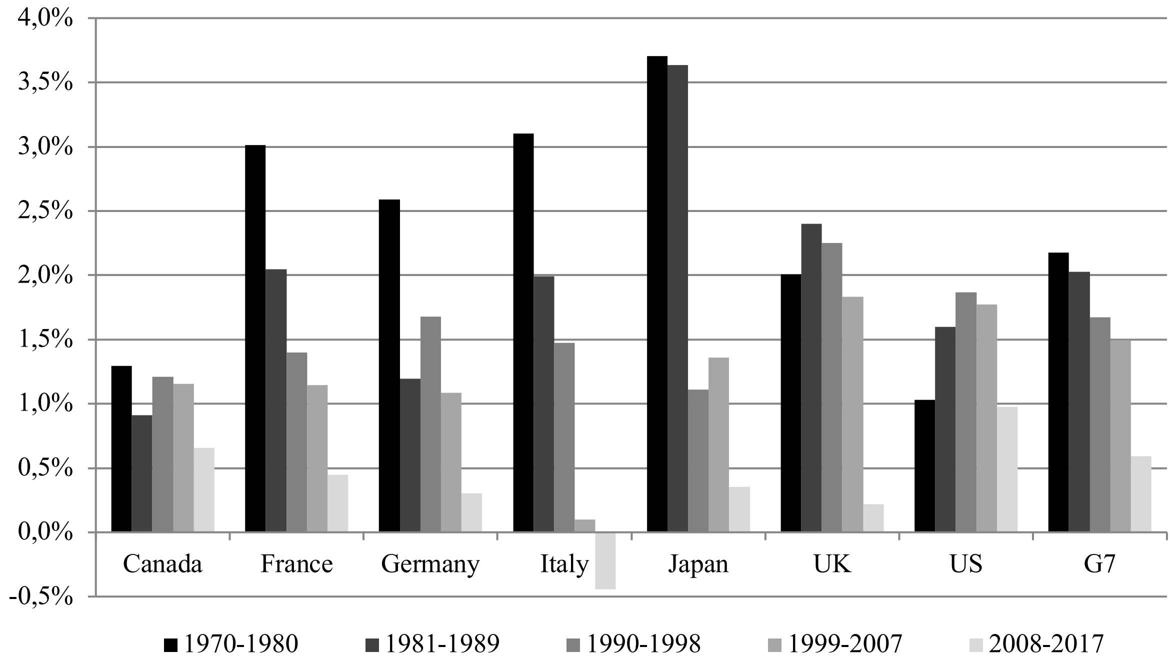
Labour productivity	Real labour productivity has been computed, for both total economy and the manufacturing sector, as the ratio of VALK (value added, volumes, local currency) on EMPN (number of total engaged). **Source:** STAN Database for Structural Analysis (ISIC Rev. 4) from OECD.Stat; https://stats.oecd.org/Index.aspx?DataSetCode=STANI4#.
Output	Production (gross output) by sector is PRDK (volumes, local currency). When PRDK is not available, we use VALK. **Source:** STAN Database for Structural Analysis (ISIC Rev. 4) from OECD.Stat; https://stats.oecd.org/Index.aspx?DataSetCode=STANI4#.
Capital stock	Gross capital stock is CPGK (volumes, local currency). When gross capitals stock is not available, we use net capital stock (CPNK). **Source:** STAN Database for Structural Analysis (ISIC Rev. 4) from OECD.Stat; https://stats.oecd.org/Index.aspx?DataSetCode=STANI4#.

Table A.2. Samples (G7 countries)

Country	Timespan	Technical notes
Canada	1970-2017	VALK instead of PRDK.
France	1970-2017	CPGK starts from 1978.
Germany	1991-2017	--
Italy	1970-2017	CPGK starts from 1992.
Japan	1970-2017	CPNK instead of CPGK; CPNK starts from 1994.
UK	1970-2017	VALK instead of PRDK; CPGK starts from 1995.
US	1970-2017	CPNK instead of CPGK.

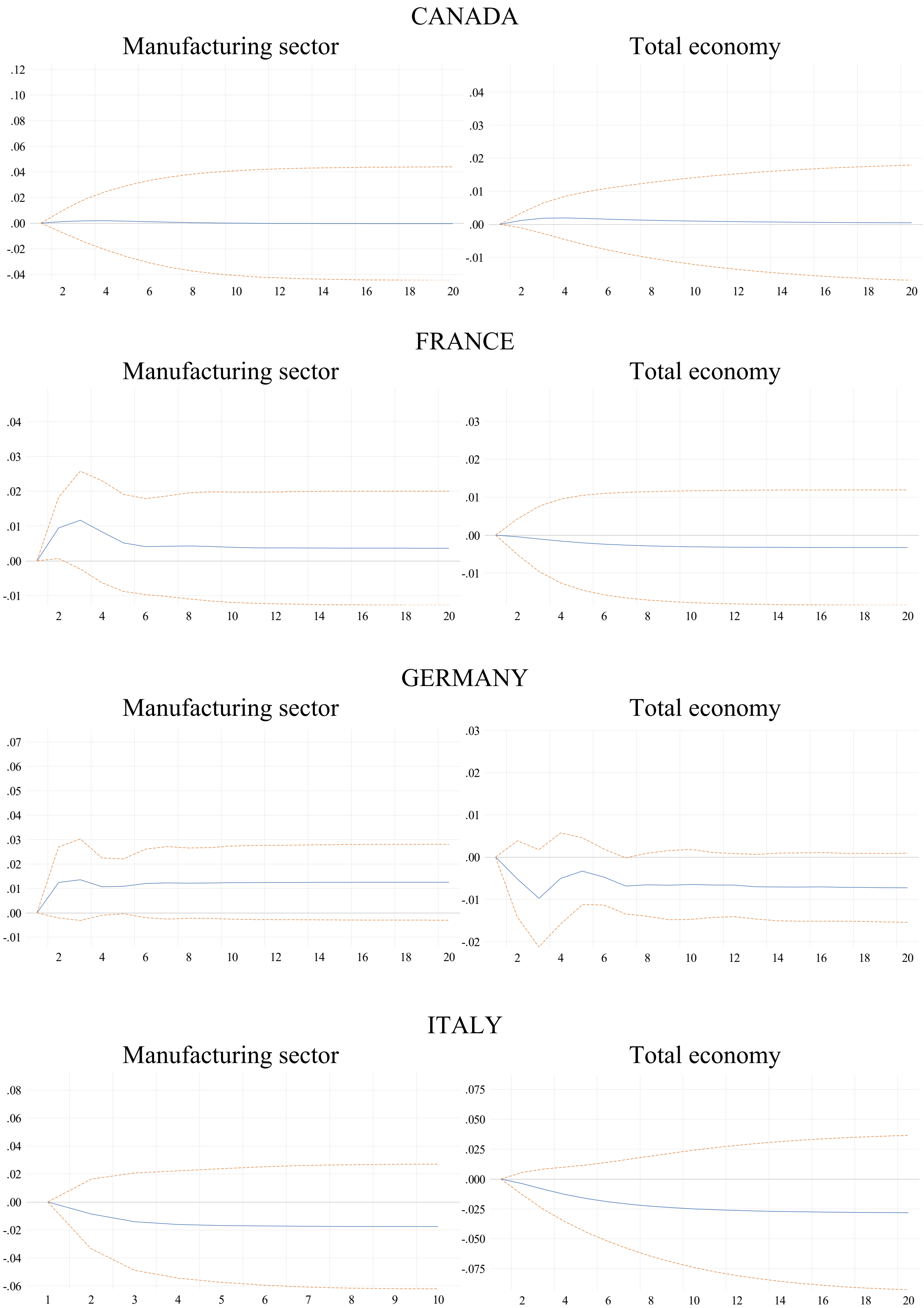
FIGURES

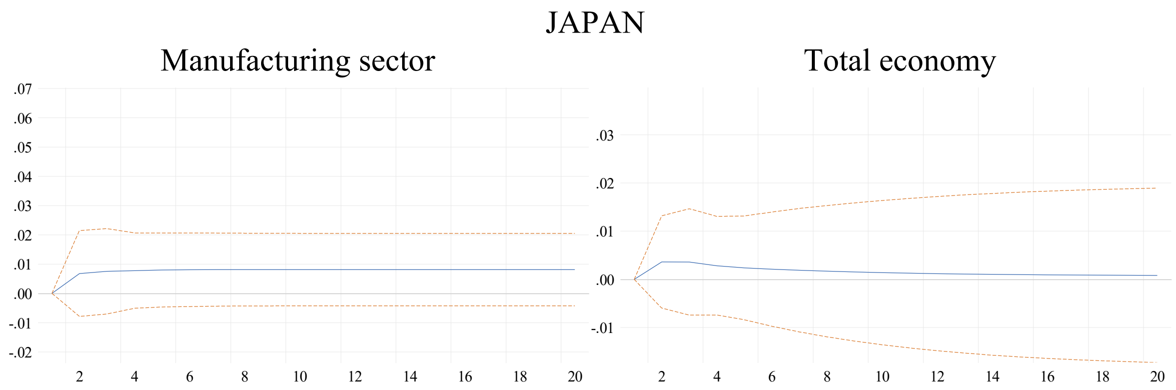
Figure 1. Labour productivity growth in G7 countries

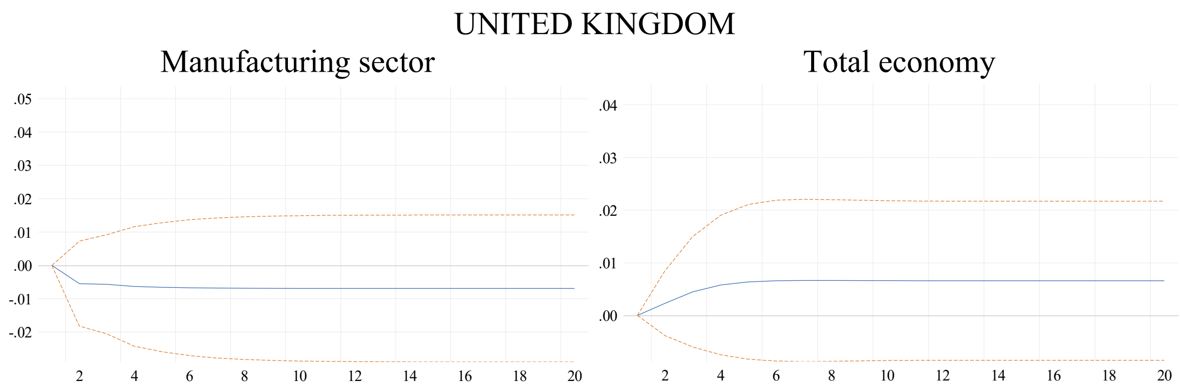


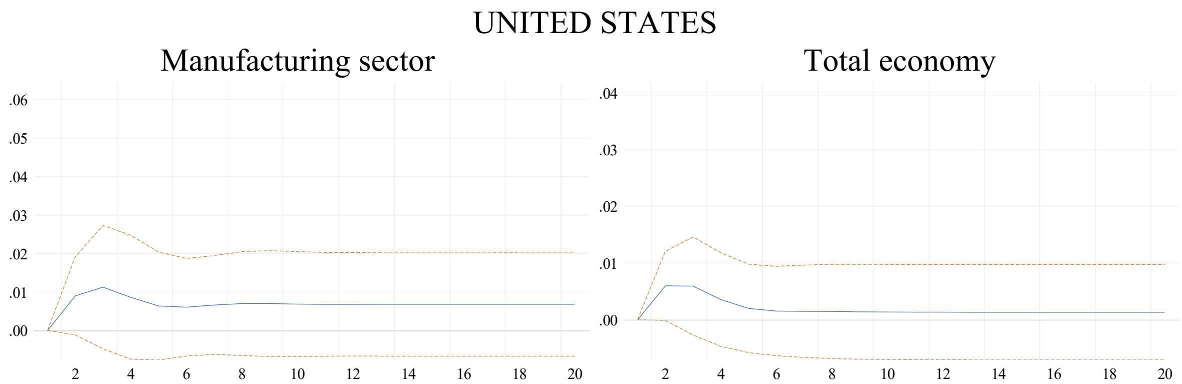
The graph depicts average labour productivity dynamics in G7 countries from 1970 to 2017. The analysis has been carried out on five sub-periods and is based on real labour productivity per person employed. Source: our elaboration on OECD.Stat.

Figure 2. Cumulated response of output to labour productivity shocks



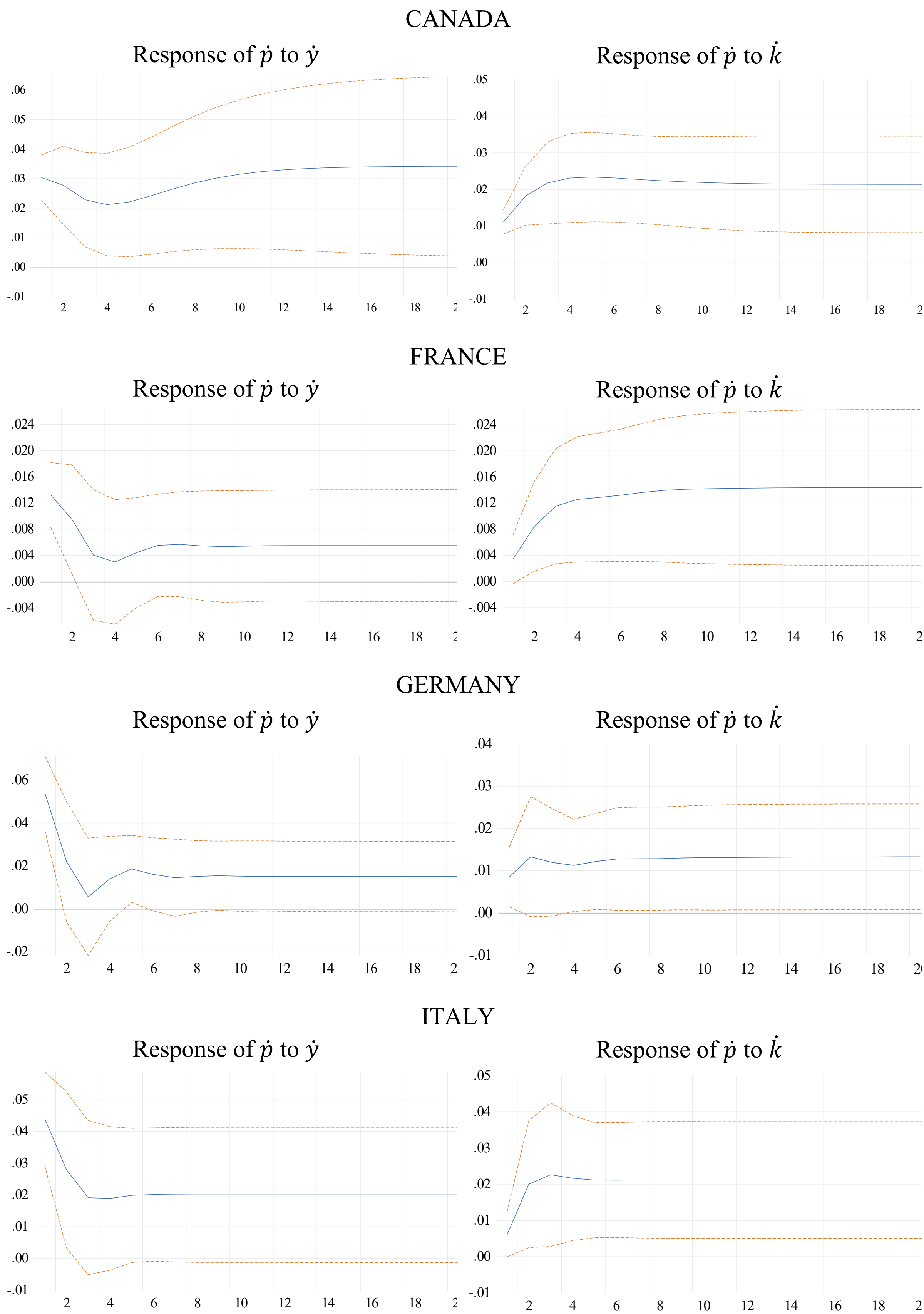




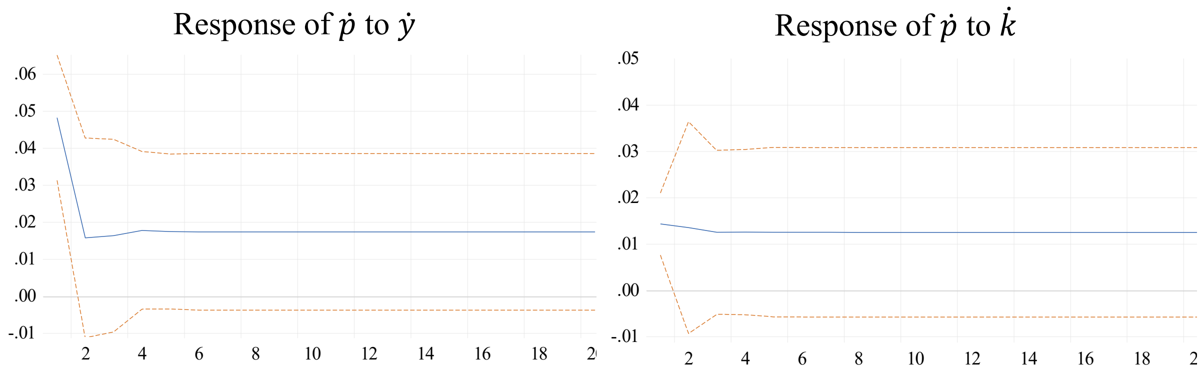


The figures depict the IRFs of output growth ($\dot{y}$) in the total economy and in the manufacturing to a 1% shock on labour productivity growth ($\dot{p}$). Cumulated responses to structural shocks are reported with two-standard error bound (95% confidence interval).

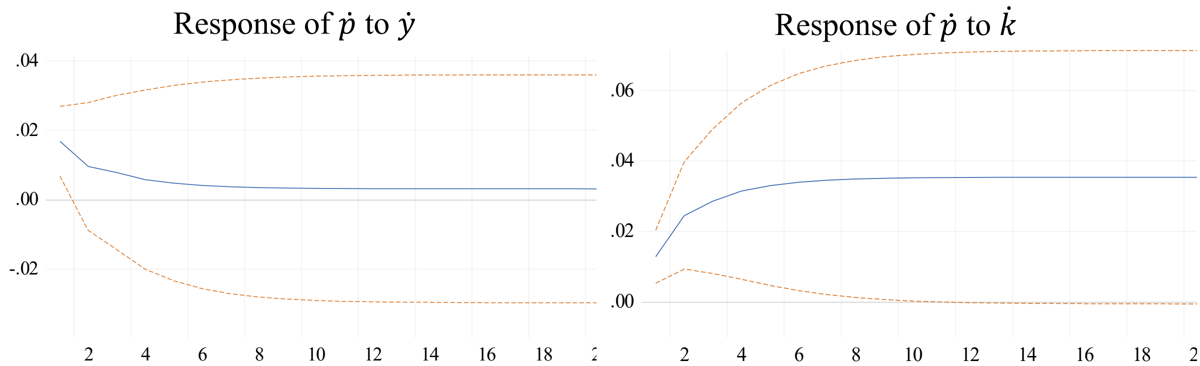
Figure 3. Cumulated response of labour productivity in the manufacturing sector



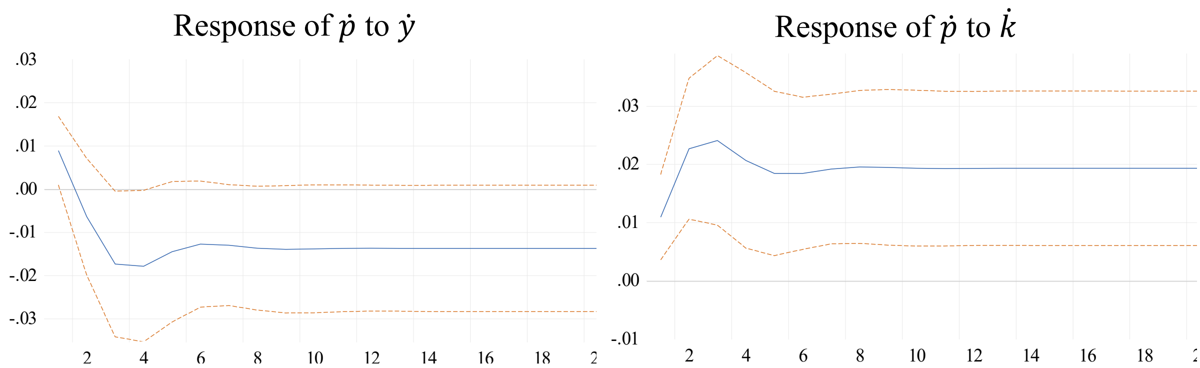
JAPAN



UNITED KINGDOM



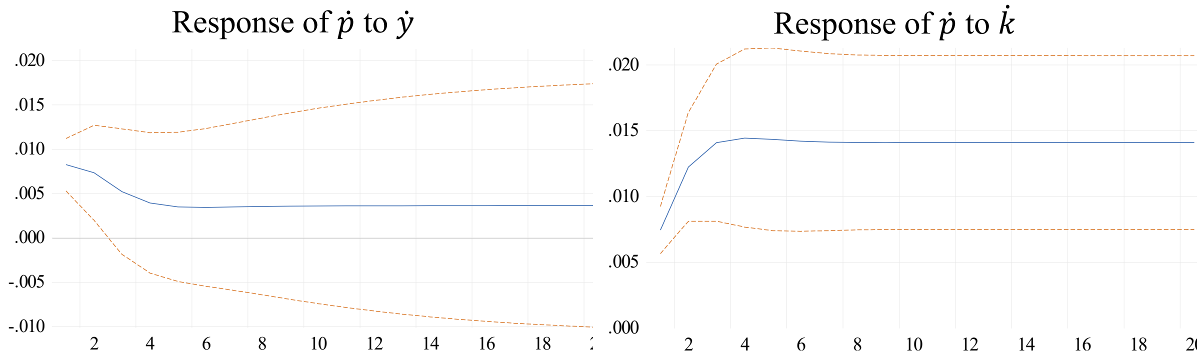
UNITED STATES



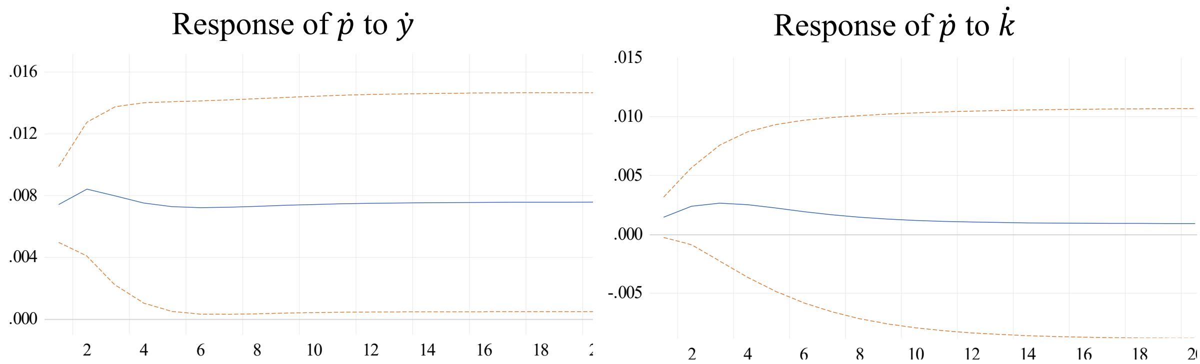
The figures depict the IRFs of labour productivity growth ($\dot{p}$) in the manufacturing sector to a 1% shock from the demand side, proxied by manufacturing output growth ($\dot{y}$), and from the supply side, proxied by capital-deepening dynamics ($\dot{k}$) in the manufacturing sector of the economy. Cumulated responses to structural shocks are reported with two-standard error bound (95% confidence interval).

Figure 4. Cumulated response of labour productivity in the total economy

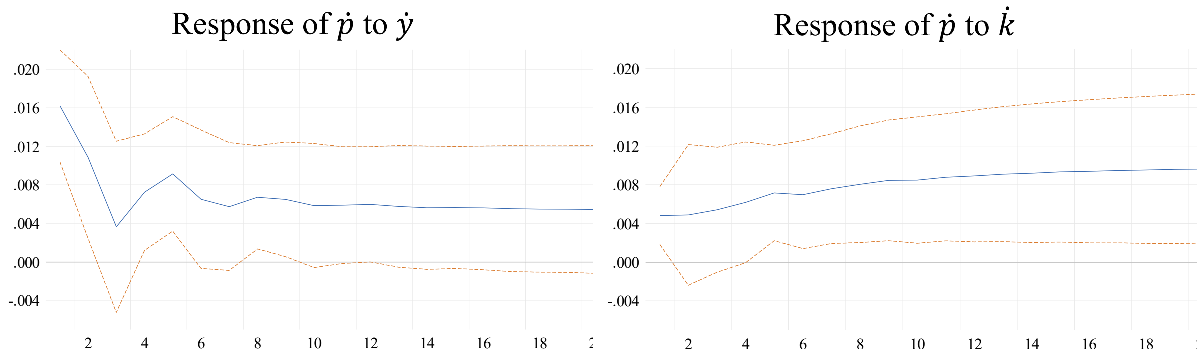
CANADA



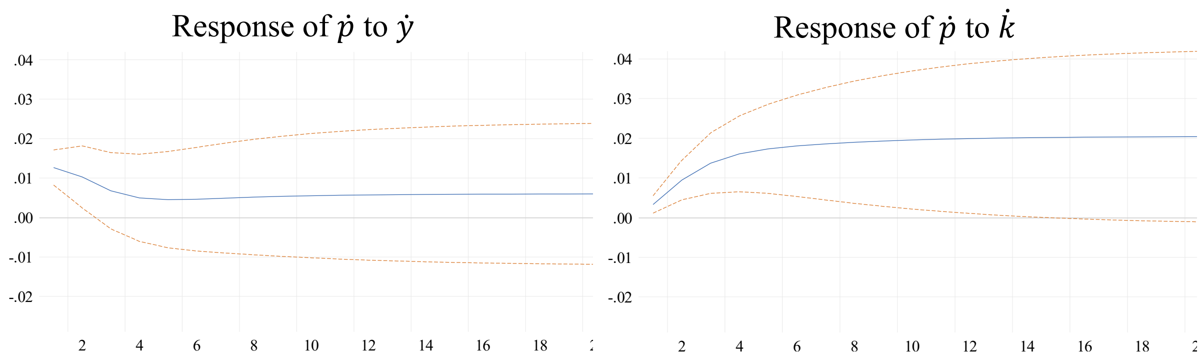
FRANCE

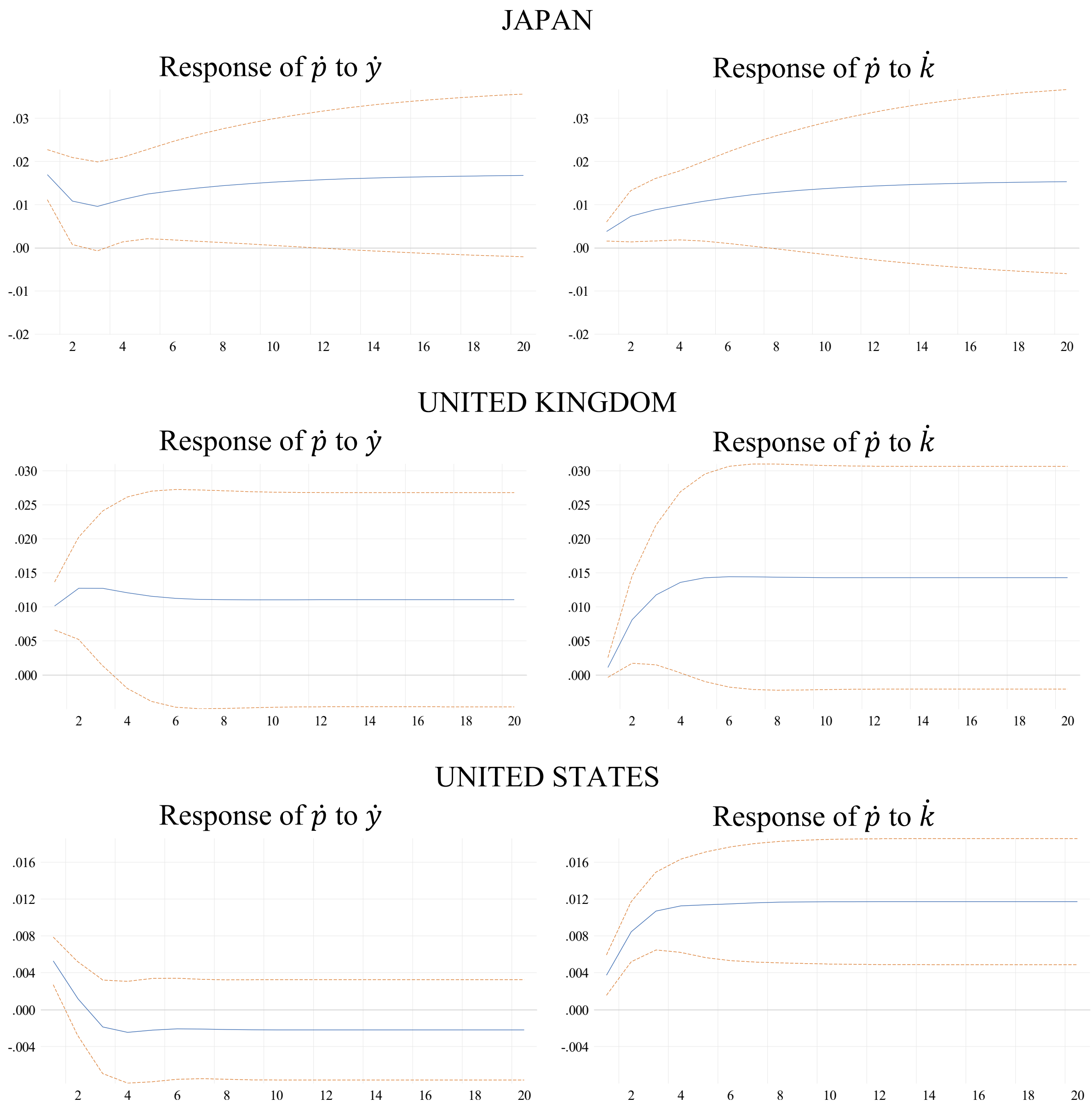


GERMANY



ITALY





The figures depict the IRFs of labour productivity growth ($\dot{p}$) in the total economy sector to a 1% shock from the demand side, proxied by total output growth ($\dot{y}$), and from the supply side, proxied by aggregate capital-deepening dynamics ($\dot{k}$). Cumulated responses to structural shocks are reported with two-standard error bound (95% confidence interval).

TABLES

Table 1. Verdoorn and capital accumulation (per worker) coefficients, manufacturing sector

Manufacturing	**Effect**	**1 year**	**5 year**	**10 year**	**15 year**	**20 year**
Canada	ε_V	**0.546**	**0.321**	**0.447**	**0.477**	**0.481**
	ε_C	**0.771**	**1.177**	**1.393**	**1.433**	**1.438**
France	ε_V	**0.457**	0.161	0.183	0.185	0.185
	ε_C	**0.274**	**0.453**	**0.446**	**0.446**	**0.446**
Germany	ε_V	**1.007**	**0.468**	**0.391**	**0.387**	**0.386**
	ε_C	**1.160**	**0.687**	**0.618**	**0.604**	**0.601**
Italy	ε_V	**0.746**	**0.378**	**0.376**	**0.376**	**0.376**
	ε_C	**0.648**	**1.865**	**1.864**	**1.864**	**1.864**
Japan	ε_V	**0.899**	**0.590**	**0.594**	**0.594**	**0.594**
	ε_C	**1.004**	0.579	0.570	0.570	0.570
United Kingdom	ε_V	**0.553**	0.150	0.102	0.098	0.098
	ε_C	**0.520**	**0.811**	**0.823**	0.824	0.824
United States	ε_V	**0.221**	-0.402	-0.362	-0.358	-0.357
	ε_C	**0.710**	**2.777**	**2.551**	**2.527**	**2.525**

Significant estimates (at 95% level) are indicated in bold.

Table 2. Verdoorn and capital accumulation (per worker) coefficients, total economy

Total Economy	**Effect**	**1 year**	**5 year**	**10 year**	**15 year**	**20 year**
Canada	ε_V	**0.417**	0.145	0.144	0.143	0.142
	ε_C	**0.890**	**2.138**	**2.211**	**2.258**	**2.280**
France	ε_V	**0.419**	**0.298**	**0.331**	**0.342**	**0.344**
	ε_C	**0.168**	0.114	0.055	0.044	0.043
Germany	ε_V	**0.705**	**0.693**	**0.573**	**0.554**	**0.543**
	ε_C	**0.874**	0.629	0.570	0.569	0.568
Italy	ε_V	**0.434**	**0.127**	**0.143**	**0.148**	**0.149**
	ε_C	**0.521**	1.275	1.336	1.351	1.355
Japan	ε_V	**0.673**	**0.621**	**0.725**	0.764	0.779
	ε_C	**0.604**	0.608	0.572	0.562	0.558
United Kingdom	ε_V	**0.604**	**0.507**	**0.501**	**0.501**	**0.501**
	ε_C	**0.073**	**0.932**	**0.945**	0.944	0.944
United States	ε_V	**0.231**	-0.093	-0.092	-0.092	-0.092
	ε_C	**0.584**	**1.493**	**1.516**	**1.518**	**1.518**

Significant estimates (at 95% level) are indicated in bold.