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DEMAND AND SUPPLY-SIDE DRIVERS OF LABOUR PRODUCTIVITY GROWTH: AN EMPIRICAL ASSESSMENT FOR G7 COUNTRIES

Fabrizio Antenucci   Matteo Deleidi   Walter Paternesi Meloni

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ASTRIL
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Via Silvio D'Amico, 77 - 00145 Roma
Tel. 0039-06-57335751; 06-57335723
E-mail: astril@uniroma3.it
http://host.uniroma3.it/associazioni/astril

Demand- and Supply-side Drivers of Labour Productivity Growth: an empirical assessment for G7 countries ♣

Fabrizio Antenucci * Matteo Deleidi ** Walter Paternesi Meloni ***

Abstract

The recent slowdown in labour productivity growth experienced in advanced economies is generally considered one of the main causes of the current phase of economic stagnation. This has led scholars to carry out a number of theoretical and empirical studies to identify the long-run determinants of productivity growth. The present work aims to fall within this debate, with a peculiar focus on the relevance of the Kaldor-Verdoorn law. To this purpose, we empirically investigate on the determinants of labour productivity growth both for the total economy and for the manufacturing sector, comparing the role played by demand- and supply-side factors. A Structural Vector Autoregressive (SVAR) model is estimated for G7 countries from 1970 to 2017. Although the analyses confirm the positive role of supply-side factors in fostering productivity growth, our findings generally validate also the relevance of demand-side factors. Additionally, the positive effect generated by demand factors on labour productivity growth suggests that supply-side measures would be not sufficient to enhance productivity. Our findings suggest that demand-side policies are likely to foster productivity by also stimulating supply-side factors, particularly in the manufacturing sector of the economy.

JEL classification: O47; D24; E22.

Keywords: Labour Productivity; Kaldor-Verdoorn Law; Capital Deepening; SVAR.

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* Department of Economics, Roma Tre University; e-mail: fabrizio.antenucci@uniroma3.it.

** Department of Economics, Roma Tre University; e-mail: matteo.deleidi@uniroma3.it;
Institute for Innovation and Public Purpose, University College London; e-mail: m.deleidi@ucl.ac.uk.

*** Department of Economics, Roma Tre University; e-mail: walter.paternesi@uniroma3.it.

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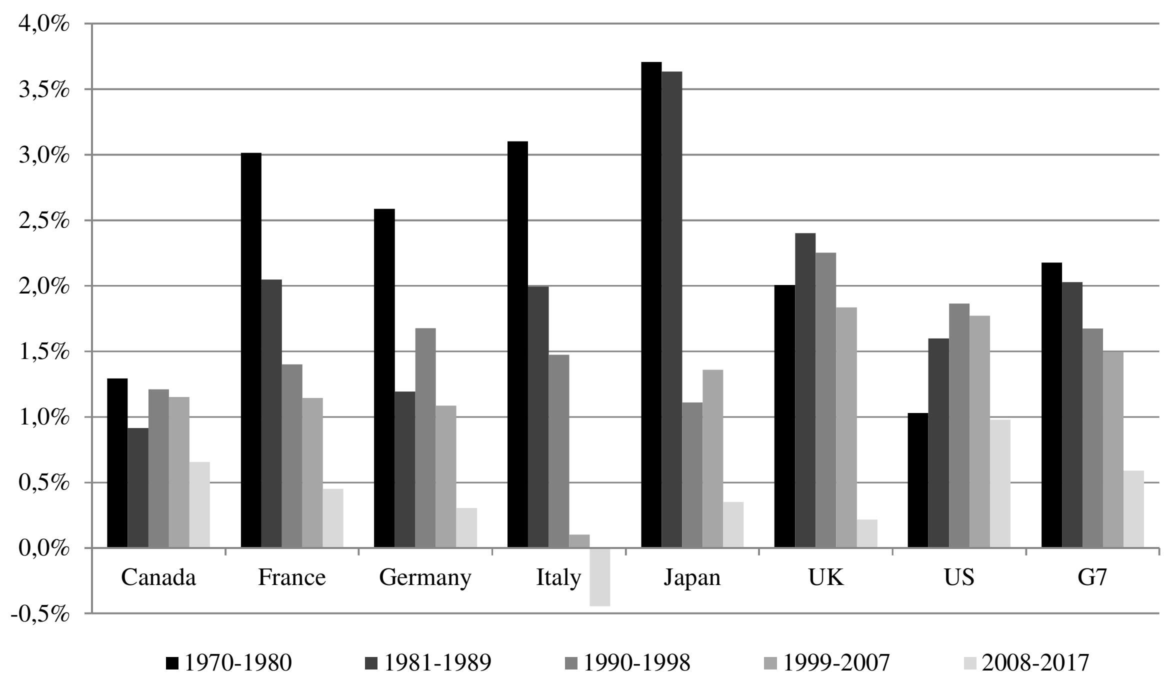
1. Introduction

The recent slowdown in labour productivity growth experienced in most developed economies in the last decades is generally regarded as one of the main causes of the current phase of economic stagnation. As shown in Figure 1, where G7 countries have been considered, labour productivity growth 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). The slackening has been particularly strong in Japan, where labour productivity grew over 3.5% per year until the beginning of the 1990s, and dramatic in Italy, where a negative productivity growth has been experienced during the last years. Similarly, a labour productivity slowdown is observed in United Kingdom, Germany and France, whereas the United States and Canada have shown the better performances.

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.

The causal relationship between labour 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 determined by supply-side factors. According to this view, the rate of growth of productivity, especially in the long run, is generally determined by technical progress, which is treated as an exogenous factor with respect to output dynamics and affected, particularly in 'new growth' models, by endogenous factors, operating from the supply side, such as investment in human capital, innovation stemming from R&D expenditure and knowledge diffusion. However, the slowdown in labour productivity dynamics has led economists to investigate the long-run determinants of productivity growth, both from a theoretical and an empirical standpoint. Interestingly, and in parallel to the standard perspective, an alternative strand of research, grounded on the Keynesian principle of effective demand and its extension to the long run,[1] considers also demand-side factors among the determinants of labour productivity growth. Basically, this perspective is analytically and empirically rooted on the so-called Kaldor-Verdoorn law,[2] which postulates that GDP growth, determined by aggregate demand dynamics, stimulates positive changes of labour productivity through economies of scale and technical progress embodied in new capital goods.

In the light of the aforementioned perspectives, the aim of this paper is to empirically assess the role played by both supply- and demand-side factors in stimulating labour productivity growth. Particularly, by making use of structural vector autoregressive models (SVAR), our research tests the Kaldor-Verdoon law as well as the effect of technical progress on productivity. To do this, we focus on G7 countries for the 1970-2017 period. In the spirit of the analysis developed by Forges Davanzati et al. (2017), this paper presents several innovations in terms of data, methods and findings compared to the existing literature. Particularly, the paper will: (i) use a SVAR model based on a suitable identification strategy; (ii) consider an innovative variable for identifying

[1] See Cesaratto (2015) and Lavoie (2016) for surveys of this literature.
[2] More precisely, scholars usually term Kaldor-Verdoorn law what was originally knew as Verdoorn's law or, alternatively, the Kaldor's second law of economic growth.

technological shocks; (iii) show the relevance of both supply and demand factors in shaping labour productivity dynamics; and (iv) provide elements suggesting the independence of output dynamics from labour productivity shocks.

The remainder of this paper is structured as follows. In section 2, an overview of the theoretical and empirical literature on the drivers of labour productivity growth is presented, with a particular focus on the Kaldor-Verdoorn law. Section 3 is aimed at identifying the dataset and the methodology. Section 4 presents and discusses the main findings by confirming the relevance of demand-side factors, particularly for the manufacturing sector, and the significant role played by supply-side factors, with the latter influenced by the former and not the other way round. Finally, section 5 concludes and derives some policy implications to deal with the current phase of stagnating productivity in advanced countries.

2. The two faces of labour productivity growth

The slowdown in labour productivity dynamics has led economists to carry out several theoretical and empirical studies to identify the long-run determinants of productivity growth rate. In this regard, the economic literature shows two main strands of thought on this topic. The former follows the traditional neoclassical approach to the analysis of growth and considers productivity as mainly determined by supply-side factors. The latter – though admitting a role played by technical progress – also considers the existence of a stable and positive effects of output dynamics on productivity growth. This second approach mainly refers to the so-called Kaldor-Verdoon law (Verdoorn 1949, 1956; Kaldor 1957, 1966) and its recent reappraisal within a theoretical framework that considers output growth as determined by aggregate demand.

According to the neoclassical approach, the relationship between output growth and the productivity of each factor is seen in only one direction. Particularly, it is the growth of factor productivity which determines the growth of output, rather than be the opposite. This mainly depends on the fact that canonical growth models (e.g., the Solow's model) 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. Consistently with this perspective, the slowdown in labour productivity growth has often been seen as one of the main causes of the lack of economic growth of the last decades. In this perspective, labour productivity is viewed as mainly determined by supply-side factors which are assumed to increase – directly or indirectly – the ability and the productivity of the workers in the production. Such a view can be traced both in the old Solow's model and in the more recent neoclassical growth models (which contributed to the advent of the so-called 'new growth theory') where, however, the role of endogenous factors is recognised (see among others, Arrow 1962; Romer 1994; Barro and Sala-i-Martin 2004). Following this approach, a weak growth of productivity is usually associated to deficiencies of supply-side factors, such as: human and social capital endowments (Baumol 1990; Becker et al. 1990; Barro 2001); private R&D (Romer 1990);[3] information and communication technology (ICT) investment able to foster innovation (Aghion et al. 2001; Preenen et al. 2017); inefficient institutions (Acemoglu 2006) and strong regulation (Nicoletti and Scarpetta 2003). These factors are assumed to negatively affect labour productivity dynamics and therefore GDP growth, with the causality link supposed to move from productivity to output and not on the other way round. Definitely, in such models there is no place for the role played by aggregate demand in affecting labour productivity growth.

By contrast, an alternative approach considers the existence of persistent and direct effects of demand-side factors on labour productivity growth. Particularly, the Kaldor-Verdoorn law (Verdoorn 1949; 1956; Kaldor 1957; 1966) provides both empirical support and theoretical explanation for labour productivity dynamics to be influenced also by output dynamics. By making use of the insight of the Keynesian principle of effective demand (Keynes 1936) and the idea of an economic growth driven by demand (Kaldor 1975), the Kaldor-Verdoorn law has gain momentum

[3] 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.

in the theoretical framework which considers output growth as determined by aggregate demand.[4] Kaldor (1966), by focusing on the manufacturing sector, found a positive long-run relationship between the growth rate of output and the labour productivity growth, with the former affecting the latter.[5] Following Kaldor (1966, p. 106), 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". 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)".[6] Therefore, the Kaldor-Verdoorn law is to be treated as a long-run relationship determined by static and dynamic increasing returns to scale (Bianchi 2002). On the one hand, the static or 'reversible' increasing returns to scale 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 learning-by-doing, specialisation and embodied technical progress – which, differently from the static increasing returns, are not reversible (McCombie

[4] However, it should be underlined that Verdoorn (1949; 1956) did not regard the output as determined by demand as instead advocated by supporters of the Keynesian tradition.

[5] Kaldor (1966, p. 104) 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". Similarly, Verdoorn (1949, p. 28) found that "the average value of the elasticity of productivity with respect to output is approximately 0.45 (with extreme values of 0.41 and 0.57). This means that over the long period a change in the volume of production, say of about 10 per cent, tends to be associated with an average increase in labour productivity of 4.5 per cent. […] one could have expected a priori to find a correlation between labour productivity and output, given that the division of labour only comes about through increases in the volume of production".

[6] 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 Erber (1994) and Jeon and Vernengo (2007).

2002).[7] As a consequence, a 'dynamic' version of the Kaldor-Verdoorn law is to be considered rather than a 'static' one, where output and labour productivity growth rates are analysed instead of their levels (McCombie 1982; Ofria 2009; Castiglione 2011).[8] The simplest version of the dynamic Kaldor-Verdoorn law can be represented as in Equation (1):

$$\dot{p} = \alpha + \eta\dot{y} \tag{1}$$

where $\dot{p}$ is the rate of growth of labour productivity, $\dot{y}$ is the rate of growth of output, and α is the rate of growth of the 'exogenous' technical progress. Accordingly, 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. As widely recognised, Kaldor (1966) showed that the estimation of the Verdoorn coefficient (η) was of about 0.5 in the manufacturing sector in a panel of industrial countries from 1953 to 1964. Furthermore, being labour productivity growth equal to output growth less employment growth (Kaldor 1966, p. 128; Bianchi 2002), Equation (1) can be rearranged as stated in Equation (2):

$$\dot{e} = -\alpha + (1 - \eta)\dot{y} \tag{2}$$

where $\dot{e}$ is the employment growth rate. Being Kaldor's estimate of η close to 0.5, it can be reasonably stated that 1% increase of the rate of growth of output would lead to a growth in employment of about 0.5%.

The evidence of a positive (and statistically significant) coefficient was explained by emphasising the presence of static and dynamic increasing returns to scale in the manufacturing sector, which are crucial in affecting productivity especially during the phase of economic

[7] 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.
[8] For a discussion concerning the static and the dynamic version of the Kaldor-Verdoorn law, see McCombie (1982) and McCombie and Roberts (2007).

development characterised by an increasing weight of the manufacturing sector. Inspired by Young (1928), Kaldor (1966; 1972) affirmed that the presence of dynamic economies of scale is due to specialisation processes both *between* and *within* firms, positive externalities *among* firms and industries (especially for the manufacturing sector) and, more importantly, because of technical progress embodied in new capital goods.[9] Differently from the original version of the Verdoorn's law, Kaldor (1966, p. 128) included in his estimations an additional term in order to take into consideration embodied and/or induced technical progress (Kaldor 1957; 1961; Kaldor and Mirrlees 1962), that is the investment-output ratio.[10] Yet, despite such a measure allows to capture the innovation embodied in new capital goods, investment in general does not represent exclusively technical progress as only represents the variation in the existing capacity. According to our perspective, in order to better identify technical progress, we prefer to focus on the technical conditions of production. Particularly, instead of the investment-output ratio, in our analyses we opt for the capital-labour ratio, not in the static version of the Kaldor-Verdoorn law but in a dynamic one. As we believe that technical progress principally materialises in new machines per unit on labour employed in the production, we make use of the rate of growth of capital per worker, i.e., a variable representing the dynamics of the capital deepening. This variable allows us to capture the effect of supply-side factors on labour productivity as the ratio between capital and labour can represent the technical conditions of production decided by firms. Indeed, it is plausible to argue that an increase in the capital endowment per worker will boost labour productivity. Surely, from a neoclassical point of view, assuming a production function with labour and capital, increasing capital endowment per worker increases the marginal productivity of labour. However, even in an

[9] 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 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).

[10] Algebraically, the growth rate of capital is equal to the investment-capital ratio. As Kaldor's stylized facts provided for a constant relationship between output and capital stock, a proxy for capital accumulation (therefore, for technical progress) has been traced by Kaldor himself in the investment-output ratio.

alternative approach, the idea that a worker would be able to produce more in the same work-time with a greater capital endowment (being qualitative or quantitative) is commonly accepted.

On the basis the abovementioned theoretical framework, the empirical part of the paper aims at analysing the determinants of labour productivity dynamics, comparing the role played by the demand- and the supply-side factors. Starting from some relevant contributions, and particularly from the recent work by Forges Davanzati et al. (2017), we take a few steps forward on the causal relationship between labour productivity and output, as well as on the effects of both supply and demand on the labour productivity.[11] Intuitively, in our framework labour productivity growth is then shaped on the demand side by the rate of growth of the economy ($\dot{y}$) as suggested by the Kaldor-Verdoorn law, and on the supply side by the rate of growth of the capital-labour ratio ($\dot{k}$) which captures the change in technical conditions of production. Therefore, our model can be theoretically represented by Equation (3):

$$\dot{p} = \alpha + \eta\dot{y} + \beta\dot{k} \qquad (3).$$

One of the novelties with respect to Kaldor (1966) and the empirical literature which aims at analysing the labour productivity dynamics (see among others, Forges Davanzati et al. 2017; Deleidi et al. 2018) is to consider technical progress as determined by rate of growth of the capital-labour ratio ($\dot{k}$) rather than the investment-output ratio.[12] According to our perspective, the rate of growth of capital can be considered a spurious approximation of technical progress as the technical conditions depend also on the quantity of labour employed in the production. For instance, in case labour and capital grew at the same rate, the technical conditions of production would not be

[11] A similar approach aimed at investigating different explanations of labour productivity slowdown in peripheral European countries, although with a peculiar focus on the role of international trade and finance, has been developed by Bagnai and Mongeau Ospina (2017), who also referred to the Kaldor-Verdoorn law for what concerns demand-side factors.

[12] For a review of the two versions of the Kaldorian technical progress function, see Kaldor (1957; 1961), Kaldor and Mirrlees (1962) and McCombie and Spreafico (2015). Furthermore, in 1957 Kaldor relates the growth of labour productivity to the growth of the capital-labour ratio. However, such a specification changes in Kaldor and Mirrlees (1962).

modified. As a consequence, no certain changes in labour productivity would be realized. For this reason, the rate of growth of the capital-labour ratio can be considered a better metric then the investment-output ratio for capturing the effect of supply-side factors on the rate of growth of labour productivity: particularly, positive shocks to the rate of growth of the capital-labour ratio (i.e., an increase in the capital deepening) are likely to better represent technical progress as they can be considered as a change of technical condition, and specifically a greater capital endowment per worker.[13] In fact, since we have specified the dynamics of productivity in the model, a positive change in the rate of growth of capital per worker must not be seen as a shift along a given production function.

From an empirical standpoint, several works – grounded on the neoclassical perspective – demonstrated the positive role of supply-side factors in fostering productivity. For what concerns the supply-side effects on labour productivity stemming from a greater capital endowment, which is generally represented by the role of private investment, there is plenty of theoretical and empirical literature. In this framework, which is grounded on the neoclassical theory of growth (Solow 1956), tangible investment allows workers to be provided for more capital, thus improving labour productivity.[14] One of the most influent works was the one by Kumar and Russel (2002), according to which 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, by decomposing labour productivity growth according to neoclassical growth accounting, Jorgenson et al. (2008) estimated a contribution of about 53% of 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 similar

[13] Similarly, an increase in the capital-labour ratio can represent a structural change of the economy towards high-tech branches, or more generally towards higher value added sectors. This would have the same implications with respect to our argument.

[14] 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).

techniques, Foda (2017) founded that capital deepening contribution to labour productivity growth was 0.5% on 1.1% in the US economy from 2005 to 2015.

On the contrary, after the initial estimations of Verdoorn (1949) and Kaldor (1966), some authors contributed to validate the Kaldor-Verdoorn law. In particular, this approach has been applied by Knell (2004), who estimated a Kaldor-Verdoorn coefficient of 0.53 with respect to the manufacturing sectors of twelve industrial countries during the 1990s. Moreover, McCombie and De Ridder (1984) and McCombie (1985) validated the Kaldor-Verdoorn law also at regional level. Bianchi (2002), Ofria (2009) and Forges Davanzati et al. (2017) estimated the Kaldor-Verdoorn coefficient for the Italian economy between 0.5 and 0.7. McCombie and Roberts (2007) discussed and verified both a static and dynamic Kaldor-Verdoorn law by using cross-regional data. Castiglione (2011) estimated the Kaldor-Verdoorn coefficient for the manufacturing sector through a cointegration analysis applied to US data. Similarly, Millemaci and Ofria (2014) and Deleidi et al. (2018) validated the long-run dynamic Kaldor-Verdoorn law for the manufacturing industry sector in several developed economies. Finally, Magacho and McCombie (2017) found that a faster output growth increases the growth of labour productivity in a panel of manufacturing industries.[15]

In accordance with this theoretical and empirical review, the paper will now proceed with an econometric analysis aimed at investigating on the determinants of labour productivity growth, comparing the role of its demand- and supply-side drivers.

3. Data and methodology

3.1. Data

For our estimations we make use of the STAN database with respect to G7 countries from 1970 to 2016. Specifically, labour productivity growth ($\dot{p}$) is calculated as the growth rate of real value added per person employed. In our specifications, demand-side factors are proxied by the growth rate of real output ($\dot{y}$). In parallel, supply-side factors are represented by means of capital

[15] For a deepened review on the empirical estimations of the Kaldor-Verdoorn law, please see the introduction in McCombie et al. (2002) and Castiglione (2011).

stock (at constant prices) per person employed, the so-called capital-labour ratio (k), whose rate of growth ($\dot{k}$) would capture the dynamics of capital deepening (and then it can indicate a 'capital using' technical progress). 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. Additional details about variable descriptions, time spans and data sources are accurately reported in Appendix A.

3.2. Methodology

In this paper, SVAR methodology is used 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 person employed ($\dot{k}_t$). 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.

Firstly, by making use of an Augmented Dickey-Fuller test we can affirm that all considered variables are stationary or I(0). Then, in each selected model, we choose one as the optimal lag as enables us to fully remove serial correlation.[16] As our variable are I(0) and the selected lag is one, we estimate a reduced-form VAR(1), as shown in Equation (4):

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

where y_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. Additionally, 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):

[16] Serial correlation is detected by using the Lagrange multiplier serial correlation test (Breusch 1978; Godfrey 1978). In this case, as well as for what concern stationarity tests, results are available upon request.

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

where B_0 represents the matrix of contemporaneous relationships between the k variables in y_t, B_i is the kxk 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 recursively model based on a Cholesky decomposition. The identification schemes used for Model 1 and 2 are summarised in the system of Equation (6):

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

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. Findings of accumulated responses to structural shocks will be reported with two-standard error bound, namely a 95% confidence interval.[17]

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). Additionally, the use of this class of models, and therefore the imposition of a suitable identification strategy, enables us to consider and solve one of the thorny and debatable issues raised by the empirical literature on the Kaldor-Verdoon law, namely the endogeneity of investment and employment (Millemaci and Ofria 2014; Deleidi et al.

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

2018).[18] Specifically, by following the identification set in system of Equation (6), we assume – in line with Forges Davanzati et al. (2017) – that $\dot{y}_t$ is exogenous and can influence $\dot{k}_t$ in the second equation. Finally, we assume that the demand- and supply- shocks determined by $\dot{y}_t$ and $\dot{k}_t$ affect the rate of growth of labour productivity ($\dot{p}_t$), respectively.[19]

4. Empirical findings

In this section, we report the results of IRF estimated both for the manufacturing and the total economy for each G7 country. In the following figures, we report the dynamic effect of what we identify as the Kaldor-Verdoorn coefficient measured by the rate of growth of sectoral and total output ($\dot{y}$), as well as the effect of supply-side factors proxied by the exogenous shock to the rate of growth of the capital stock per person employed ($\dot{k}_t$). We report both the response of GDP growth to labour productivity shocks and the response of labour productivity growth to demand-side and supply –side shocks. Yet, despite additional findings will be discussed below, IRFs are reported in Appendix B.

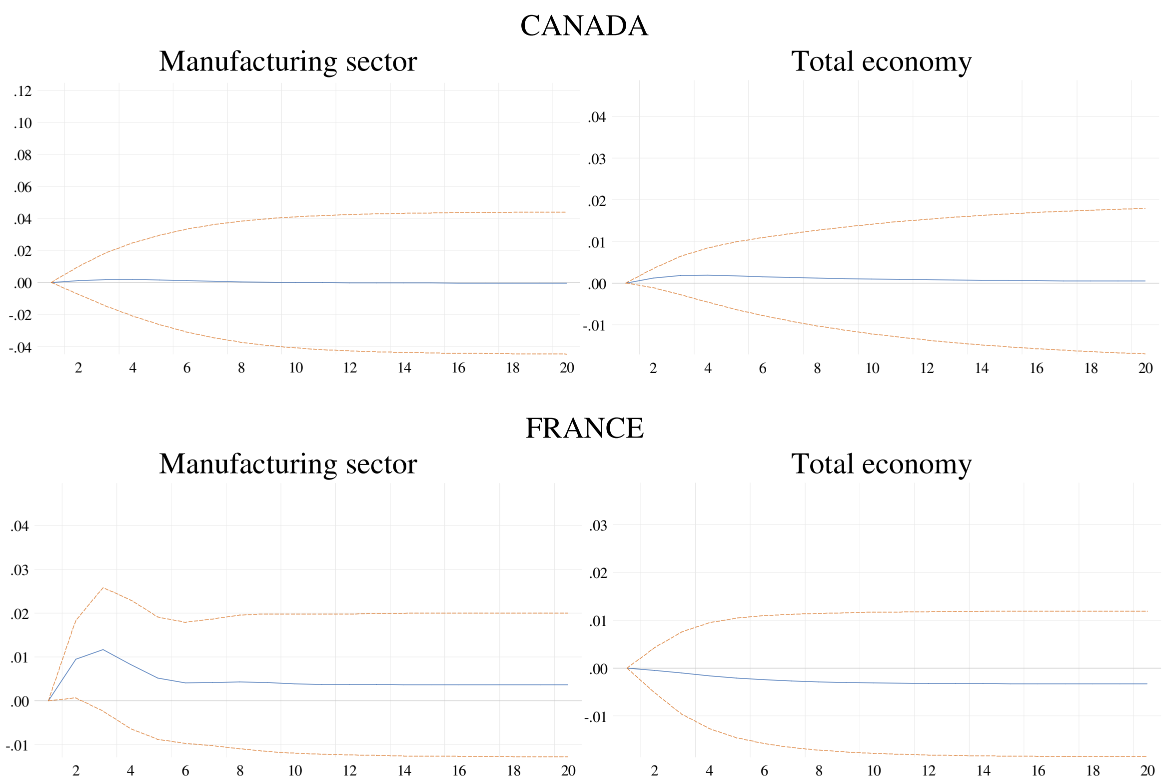
The first issue here addressed is the possible relationship that moves from the productivity of labour to output, obviously in dynamic terms: basically, we test the hypothesis whereby a shock in the growth rate of labour productivity could generate an increase in the growth rate of output. As can be seen in Figure 2, there is a *null* effect of a 1% positive shock of the rate of growth of labour productivity on the growth rate of the output for all G7 economies (despite a positive but very moderate effect in the manufacturing sector for Germany and Japan). A plausible explanation of this result could lie in the original specification of our model, where, compared to that proposed in

[18] Particularly, the canonical implemented methodology based on a single equation (Millemaci and Ofria 2014; Deleidi et al. 2018) is estimated where the technical progress embodied in the investment-output ratio is usually found not significant, probably because it is treated as a full exogenous variable. However, the means of productions could be endogenously determined and dependent on the level of current and expected demand, consistently with the well-known accelerator principle (Kaldor 1972; Garegnani 1962 [2015]). For a survey on this point, see Cesaratto (2015). Moreover, Girardi and Pariboni (2017) documented that changes in the rate of growth of autonomous demand tend to be followed by changes of the same sign in the share of business investment in GDP.

[19] Yet, despite we assume an identification strategy based on the empirical and theoretical works aimed at studying the Kaldor-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 will be provided upon request.

other studies, a variable related to the technical conditions is expressly specified. Particularly, it is possible that in our empirics the effect on output growth is captured exclusively on the supply side by a positive shock of the capital-labour ratio, differently to what occurs, for instance, in Forges Davanzati et al. (2017) model, which then might suffer from omitted variables bias.[20] However, as shown in Appendix B, we have verified whether a shock in the growth rate of the capital-labour ratio can have a permanent effect on the growth rate of output. Even in this case the effect is null, except for the United States. Therefore, according to our findings an increase in the rate of growth capital-labour ratio is not able to determine a rise in the rate of growth of output.

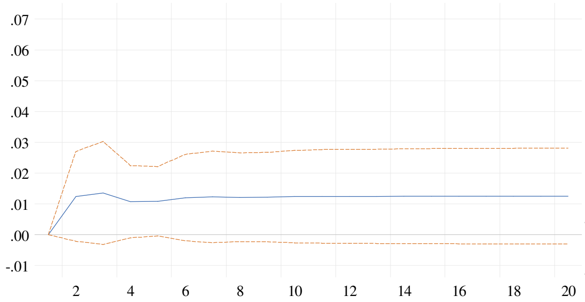
Figure 2. Cumulated response of output to labour productivity shocks



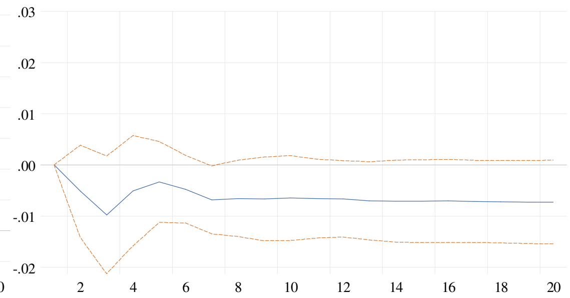
[20] It is noteworthy to specify that in Forges Davanzati et al. (2017) model, technical progress shocks are identified by means of labour productivity shocks, while in our specification they are directly identified by changes in the conditions of productions, i.e. by shocks of capital deepening. Such a shock can be interpreted as a 'labour saving' and 'capital using' technical progress.

GERMANY

Manufacturing sector

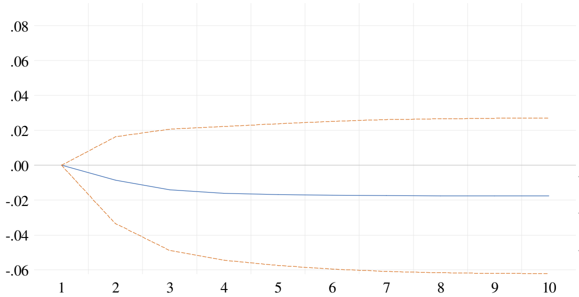


Total economy

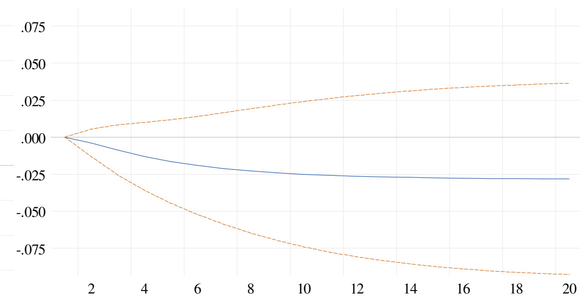


ITALY

Manufacturing sector

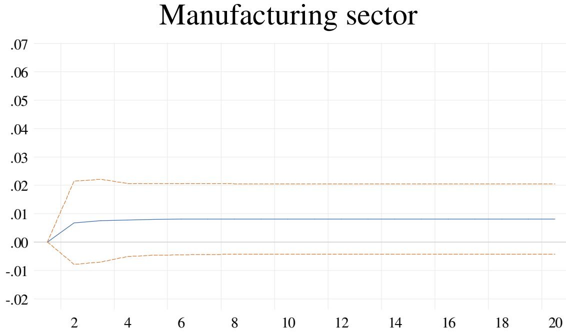


Total economy

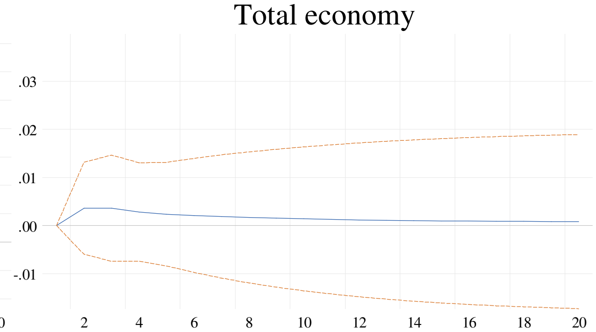


JAPAN

Manufacturing sector

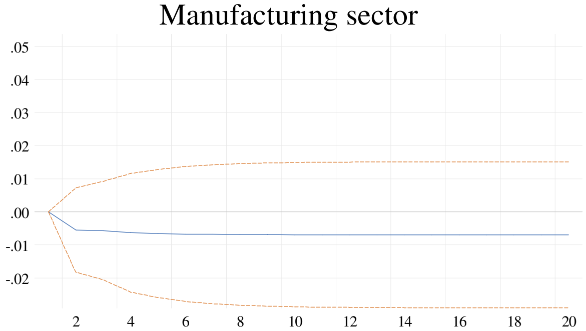


Total economy

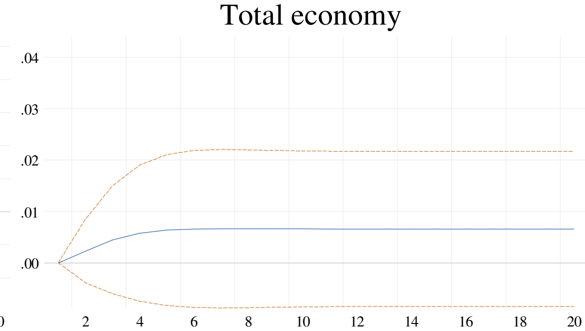


UNITED KINGDOM

Manufacturing sector

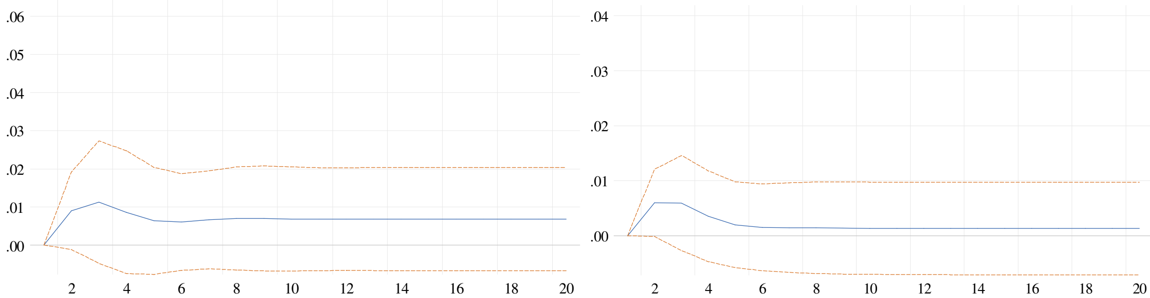


Total economy



UNITED STATES

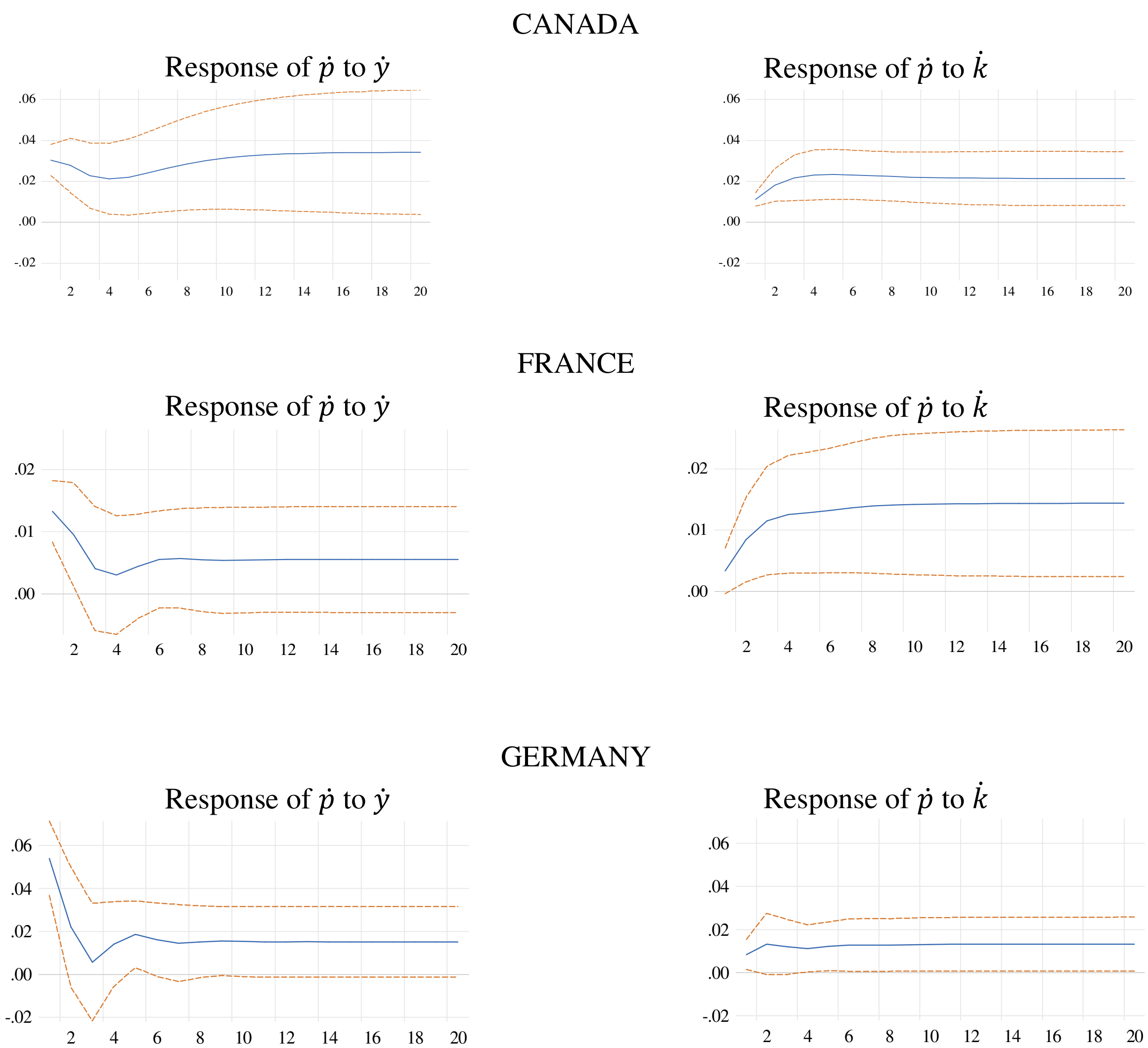
Manufacturing sector | Total economy



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

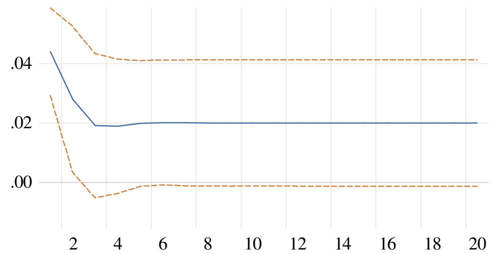
Furthermore, we found that both demand and supply factors generate positive effects on the rate of growth of labour productivity in the manufacturing sector (see Figure 3). In particular, in six out of seven major countries, our findings indicate that a stable and persistent relationship moving from the rate of growth of output to the growth rate of labour productivity holds. These results confirm the 'dynamic' version of the Kaldor-Verdoorn law, namely dynamic increasing returns related to learning-by-doing and knowledge diffusion mechanisms, specialisation processes and embodied technical progress (Kaldor 1961; 1966; McCombie 2002; Ofria 2009; Millemaci and Ofria 2014). Similarly, we have shown that an increase in the rate of growth capital-labour ratio ($\dot{k}$) generates a positive and strong effect on labour productivity, confirming the relevance of supply-side factors in shaping productivity growth. However, as shown in the IRFs reported in Appendix B, the rate of growth of capital-labour ratio ($\dot{k}$) is strongly affected by the rate of growth of output ($\dot{y}$): in other words, the supply side is affected by the demand side of the economy. Nevertheless, these results (which, for easier interpretation, we discuss below on the basis of the cumulative coefficients reported in Table 1 and Table 2) are not confirmed in the US manufacturing sector where only an increase in the rate of growth of capital stock per person employed generates a positive effect on labour productivity dynamics. A possible explanation lies in the fact that the US manufacturing sector has undergone profound changes in the production structure due to the increasing off-shoring (e.g., Mexican *Maquiladoras*, South-East Asian countries) and imports of intermediate goods (Borjas et al. 1992; Feenstra and Hanson 1999; Antenucci 2018). This led to an increase in labour productivity as the phases with the highest added value remained in the United States, despite a decline in investments in this sector and the consequent slowdown in capital accumulation per worker. This means that in the United States, more than other countries, the manufacturing sector would need an industrial policy aimed at increasing labour productivity by technical progress rather than by international division of labour.

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

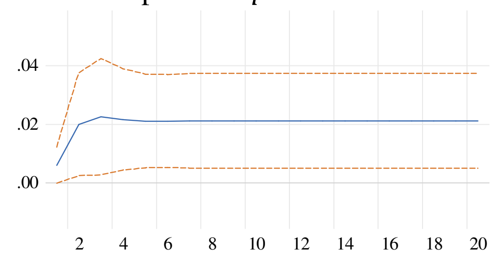


ITALY

Response of $\dot{p}$ to $\dot{y}$

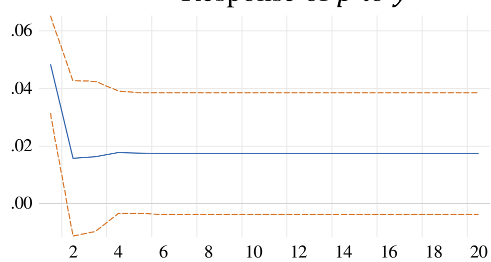


Response of $\dot{p}$ to $\dot{k}$

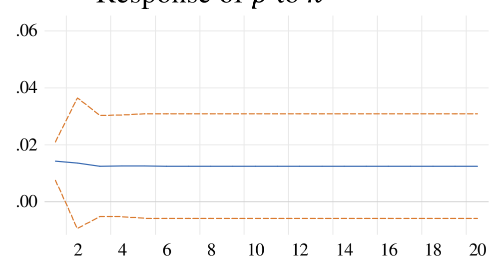


JAPAN

Response of $\dot{p}$ to $\dot{y}$

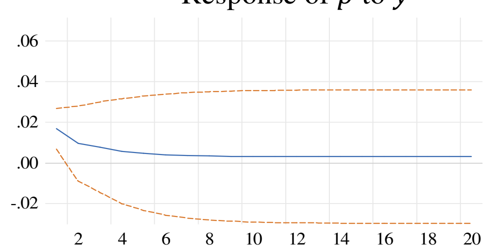


Response of $\dot{p}$ to $\dot{k}$

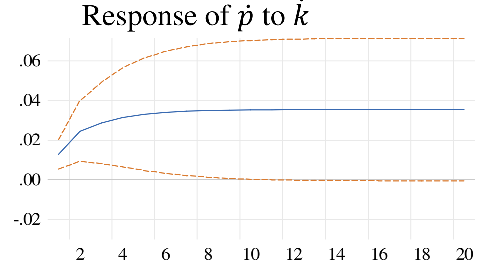


UNITED KINGDOM

Response of $\dot{p}$ to $\dot{y}$

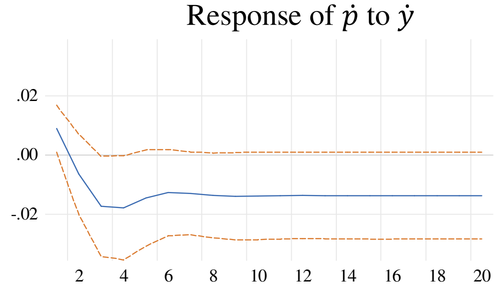


Response of $\dot{p}$ to $\dot{k}$

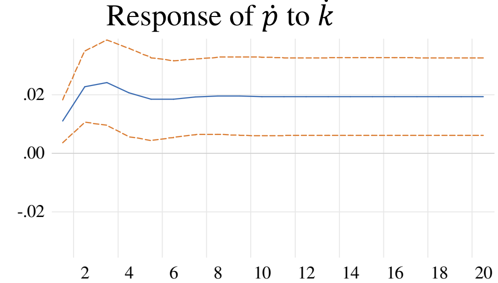


UNITED STATES

Response of $\dot{p}$ to $\dot{y}$



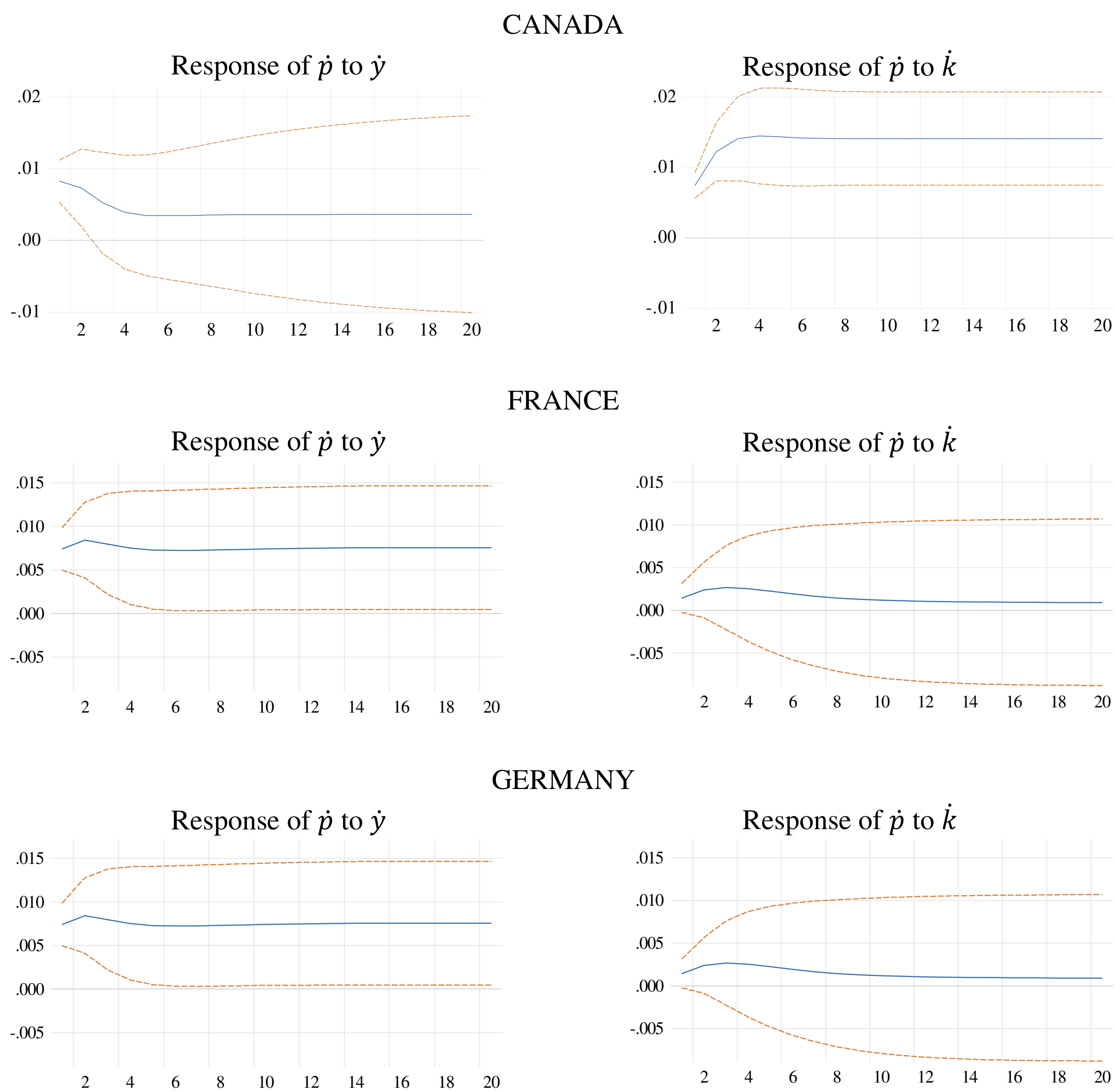
Response of $\dot{p}$ to $\dot{k}$



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 (a 95% confidence interval).*

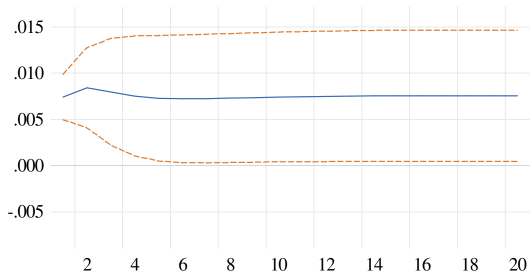
When we consider the total economy, as reported in Figure 4, we can confirm that both the rate of growth aggregate capital-labour ratio and the growth rate of total output engender a positive effect on labour productivity growth. Even in this case, results are not confirmed for the United States, where $\dot{y}$ affects total labour productivity only on impact. Conversely, an increase in the rate of growth of capital-labour ratio upsurges the dynamics of labour productivity.

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

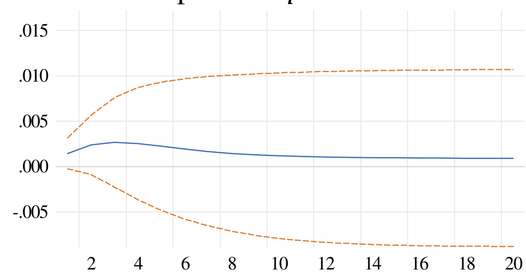


ITALY

Response of $\dot{p}$ to $\dot{y}$

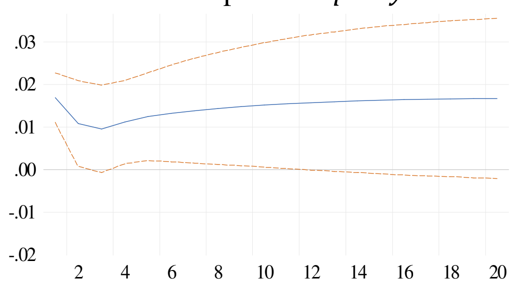


Response of $\dot{p}$ to $\dot{k}$

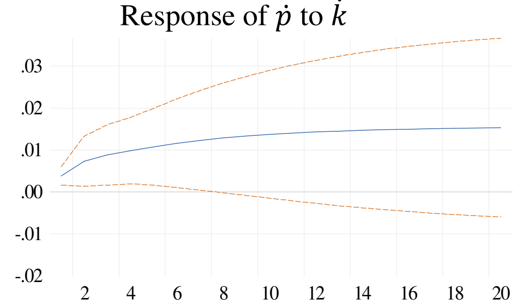


JAPAN

Response of $\dot{p}$ to $\dot{y}$

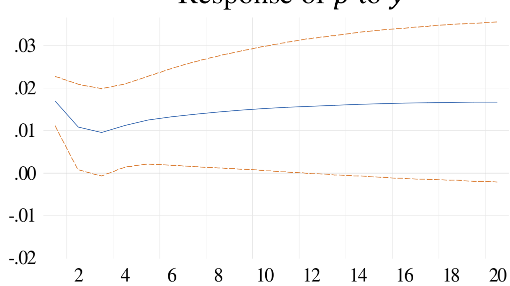


Response of $\dot{p}$ to $\dot{k}$

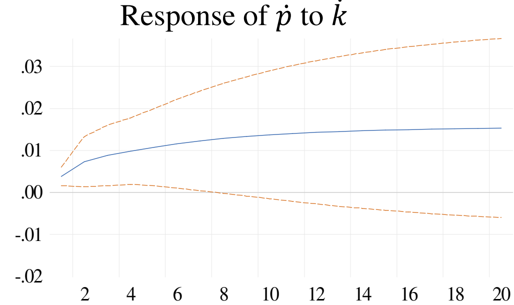


UNITED KINGDOM

Response of $\dot{p}$ to $\dot{y}$

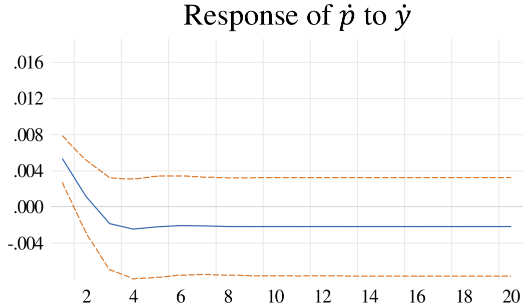


Response of $\dot{p}$ to $\dot{k}$

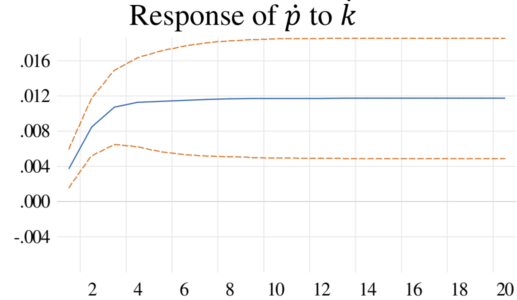


UNITED STATES

Response of $\dot{p}$ to $\dot{y}$



Response of $\dot{p}$ to $\dot{k}$



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 (a 95% confidence interval).*

While in Figure 2 and Figure 3 we represent the IRF, in Table 1 and Table 2 we show the cumulative effect which represents the response of labour productivity ($\dot{p}$) per unit increase in the rate of growth output ($\dot{y}$) and capital stock per person employed ($\dot{k}$). These estimations will be carried both at aggregate and manufacturing level in order to show the magnitude of the dynamic Kaldor-Verdoorn coefficients as well as the effect of one-unit percent increase in $\dot{k}$. As shown in Equation (6), such a cumulative effect is estimated by dividing the cumulative variation of the labour productivity ($\dot{p}$) for the cumulative change in rate of growth of output and ($\dot{y}$) and capital stock per person employed ($\dot{k}$), respectively.[21] Such ratios will be calculated both for the total economy and for manufacturing sector. Accordingly, the cumulative dynamic Kaldor-Verdoorn coefficient (ε_{KV}) is computed at the aggregate level as in Equation (7):

$$\varepsilon_{KV} = \frac{\sum_{j=0}^{n} \Delta\dot{p}_{(t+j)}}{\sum_{j=0}^{n} \Delta\dot{y}_{(t+j)}} \qquad (7);$$

and similarly, the cumulative dynamic coefficient related to the capital stock per person employed, i.e., to capital deepening (ε_{CD}), is computed as in Equation (8):

$$\varepsilon_{CD} = \frac{\sum_{j=0}^{n} \Delta\dot{p}_{(t+j)}}{\sum_{j=0}^{n} \Delta\dot{k}_{(t+j)}} \qquad (8).$$

As defined above, the cumulative effects of both demand-side ($\dot{y}$) and supply-side factors ($\dot{k}$) on labour productivity ($\dot{p}$) are represented in Table 1 and Table 2 for the manufacturing sector and the total economy, respectively. First, a positive impact on labour productivity growth can be observed from both demand- and supply-side factors: such effect should also be considered as

[21] For a comprehensive overview about the methodology, see Spilimbergo et al. (2009).

persistent over time due to the fact that they are generally positive also in the long run. The most striking case for what regards the relevance of demand-side factors is Japan, where the long-run Kaldor-Verdoorn coefficient, as defined in Equation (7), is 0.779 for total economy. Also United Kingdom (0.501) and Germany (0.543) exhibit high and statistically significant Kaldor-Verdoorn coefficients even at a 20-years time horizon, France represents a milder case in the spectrum, while for other countries (like Italy and Canada) demand-side factors conclude their effects in the short to medium run. The only country showing a negative cumulative effect of output growth is the United States, albeit the initial positive response to shocks (0.231 at year 1). As previously stated, however, the singularity of this result could be justified by the slowdown in the accumulation of capital per worker as a consequence of a structural change in the US economy, occurred through a shift in employment from the manufacturing to the services sector. Concerning the supply side, the higher elasticity of labour productivity to capital deepening, as defined in Equation (8), is detected for Canada (2.280 in the very long term), United States (1.518) and Italy (1.355), while a very low effect holds for France (also in the short term).

Table 1. Kaldor-Verdoorn and capital deepening coefficients in the manufacturing sector

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

Table 2. Kaldor-Verdoorn and capital deepening coefficients in total economy

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

When comparing the manufacturing sector and the total economy, the former generally shows a greater long-run supply-side effect on labour productivity (emblematic is the case of France, while Canada represents an interesting exception), while demand-side effects are more mixed. For instance, the long-run Kaldor-Verdoorn coefficient passes from 0.149 (total economy) to 0.376 (manufacturing) for Italy, while from 0.501 to 0.098 for United Kingdom. Finally, the results show that in all countries the greatest effect on labour productivity comes from the intensification of the capital-labour ratio, with the sole exception of Japan which, however, exhibits the highest elasticities to output. However, we would like to highlight that the accumulation process (remarkably, to be intended as capital endowment per worker) receives a positive impulse from an increase in output and not *vice versa*. The results obtained allow us, therefore, to validate the Kaldor-Verdoorn law in its initial intent to show the positive effects on labour productivity deriving from the extension of the market through a boost of aggregate demand.

Summing up, our results allow us to conclude that a higher rate of growth of output stimulates labour productivity dynamics both in the manufacturing sector and in the total economy. Findings show a positive Kaldor-Verdoorn coefficient estimated both for the total economy and for the manufacturing sector. However, these findings are not confirmed for the US economy for the reasons mentioned above, in particular deindustrialization and slowdown of investments. We also found that the dynamics of capital deepening – represented by the rate of growth of the capital stock per person employed – generates a positive and persistent effect on the rate of growth of labour productivity. However, as shown in Appendix B, capital accumulation per worker is strongly affected by the rate of growth of output, consistently with the accelerator principle (Deleidi et al. 2018), thus revealing us that the volume of workers employed in the production as well as the capital stock installed by firms is likely to be endogenously affected by the output growth. The same explanation is suggested by McCombie (2002, p. 97), who affirmed 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)".[22]

5. Conclusions and policy implications

The research question of this work was to empirically verify, through an econometric analysis based on a SVAR methodology, the determinants of labour productivity in the G7 countries from 1970 to 2016. To do this, we focus both on the total economy and the manufacturing sector by taking into account both demand- and supply-side factors. Regarding the demand side, we recall some insights from Kaldor-Verdoorn law which postulates a positive relationship between output and labour productivity, with the former affecting the latter. The dynamic version of the Kaldor-Verdoorn law is estimated by using the growth rates of variables rather than their levels. As supply-

[22] 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).

side factors are concerned, we introduced a variable which takes into considerations the technical progress. Particularly, unlike Kaldor's original work (Kaldor, 1966) and more recent empirical studies where the ratio between investments and output were used, we opted for the growth rate of the capital-labour ratio, whose growth rate (i.e., the dynamics of capital deepening) can approximate a 'capital using' technical progress.

Concerning the empirics, we firstly investigated the causal relationship between labour productivity and output, findings do not trace any positive impact of the growth rate of labour productivity on the growth rate of output for all G7 economies (only a low effect in the manufacturing sector is estimated for Germany and Japan). This can be in sharp contrast with what can be expected from a neoclassical perspective. Furthermore, 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 validity of the Kaldor-Verdoorn law.

Additionally, we compared the impact on labour productivity resulting from a positive shock to output growth rate and to capital-labour ratio dynamics, alternatively. In both cases we found a positive, statistically significant and persistent effect on labour productivity dynamics and, specifically, the greatest increase derives from the capital deepening process with the only exception of Japan. The comparison between the manufacturing sector and the total economy highlighted a greater long-run supply-side effect on labour productivity, while demand-side effects are more mixed.

According to our findings, a non-negligible fraction of the recent slowdown in labour productivity can be attributed to demand-side factors. Even though supply-side shocks (i.e., tangible investment able to increase the capital-labour ratio) are crucial in shaping labour productivity, the endogenous mechanism *à la* Kaldor-Verdoorn also helps in explaining the slowdown in productivity growth. The relevance of demand-side factors is also confirmed by the fact that according to our results output growth played a significant role in affecting the dynamics of capital accumulation per worker, while not *vice versa*. Consistently, the policy implications of our results are that the conventional wisdom in macroeconomic and industrial policies may have to be revised: since demand factors are found to influence both capital deepening dynamics and labour productivity growth, the latter should not be seen as uniquely determined by supply-side factors, and then should not be pursued only by means of supply-side policies. Indeed, coordinated expansionary macroeconomic policies would contribute to enhancing productivity growth also from the supply side of the economy, particularly in large countries and in those with a higher weight of the manufacturing sector. Finally, as the Kaldor-Verdoorn coefficient is found positive but lower than one, demand policies would also have positive effects on employment growth.

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APPENDIX

Appendix A. Data and sources

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#.

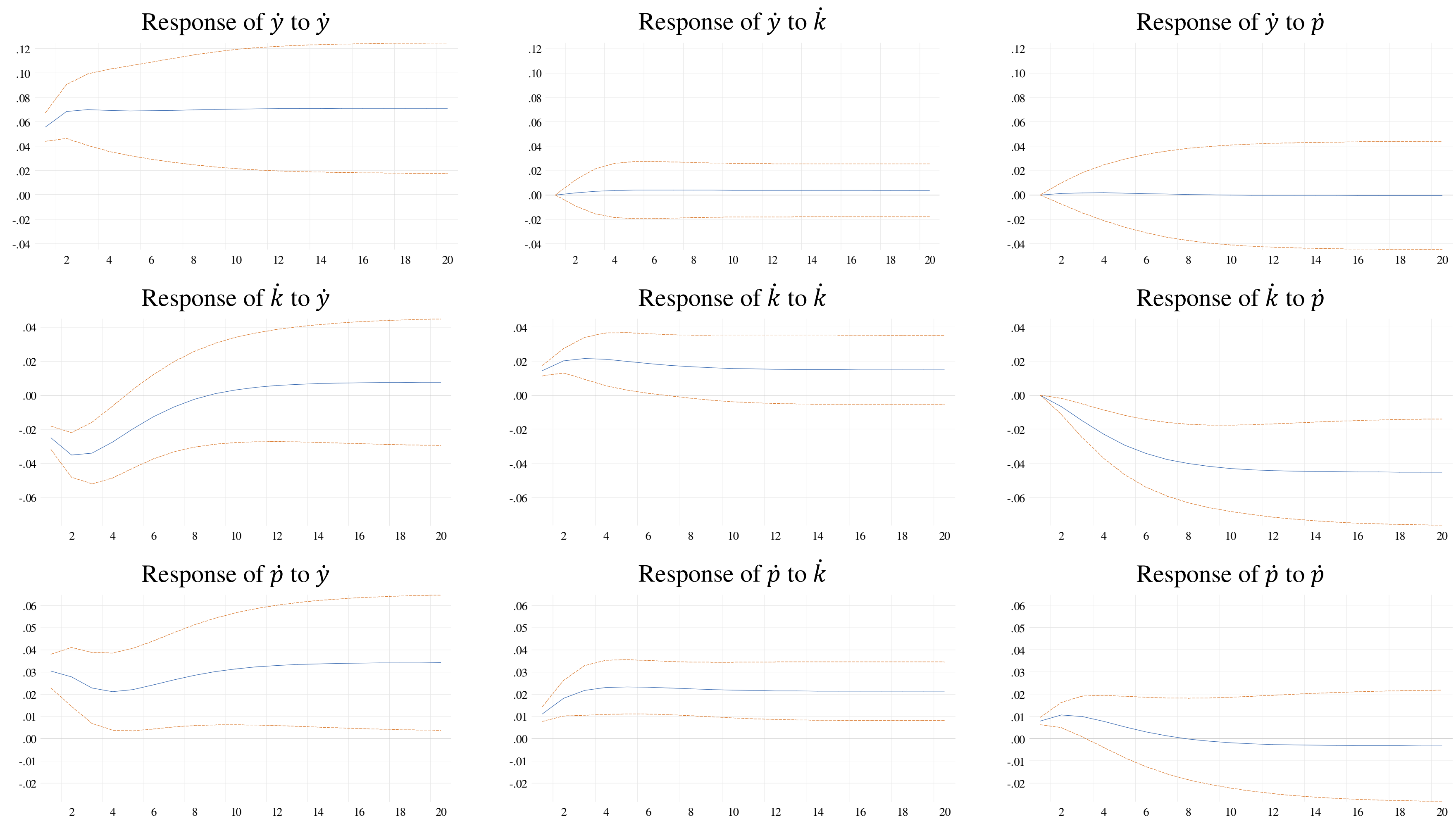
A.2 – Samples (G7 countries)

Country	**Timespan**	**Notes**
Canada	1970-2016	VALK instead of PRDK.
France	1970-2016	CPGK starts from 1978.
Germany	1991-2016	--
Italy	1970-2016	CPGK starts from 1992.
Japan	1970-2016	CPNK instead of CPGK; CPNK starts from 1994.
UK	1970-2016	VALK instead of PRDK; CPGK starts from 1995.
US	1970-2016	CPNK instead of CPGK.

Appendix B. Cumulated responses of variables to different shocks

B.1 – Manufacturing sector

CANADA



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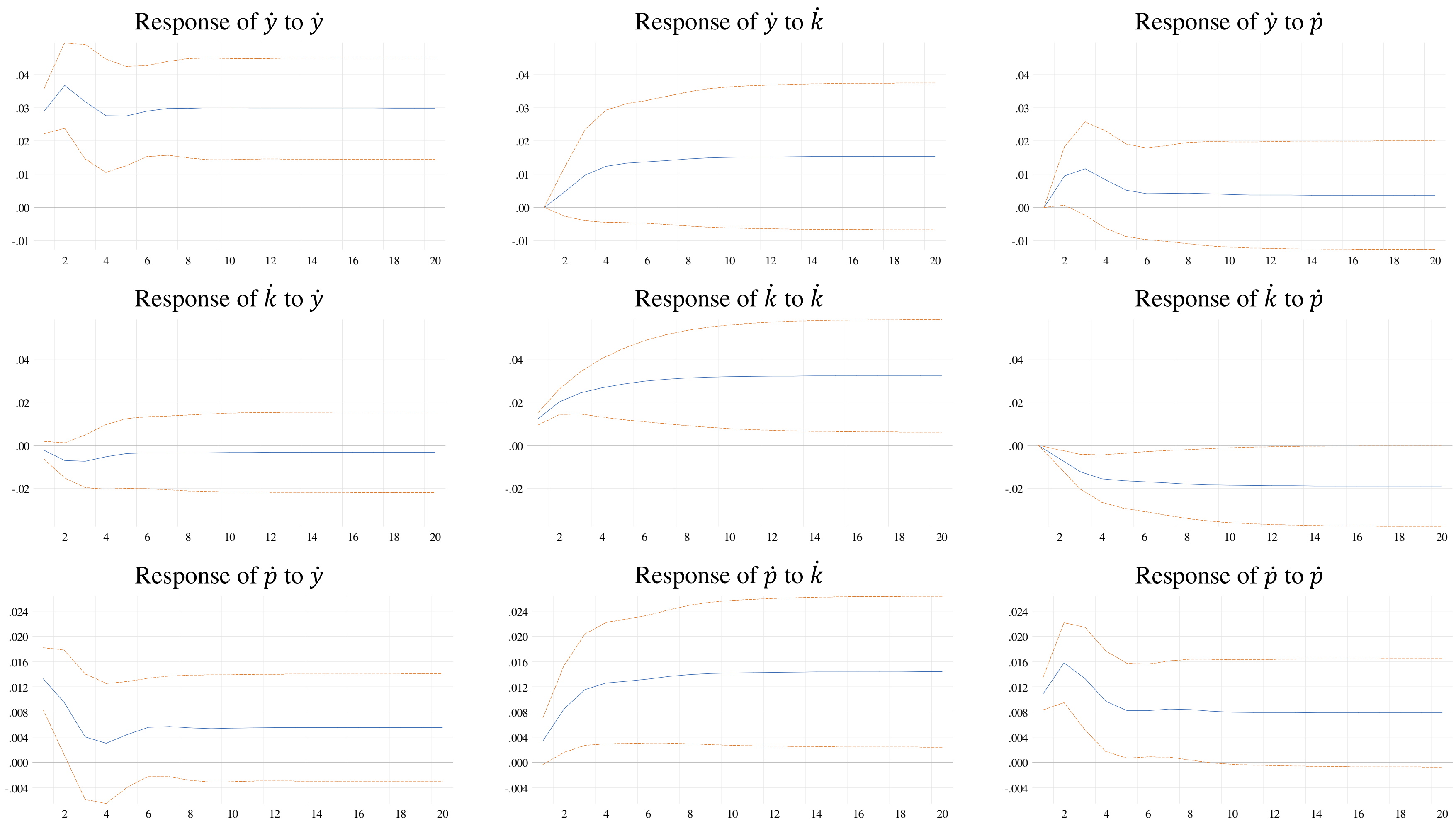

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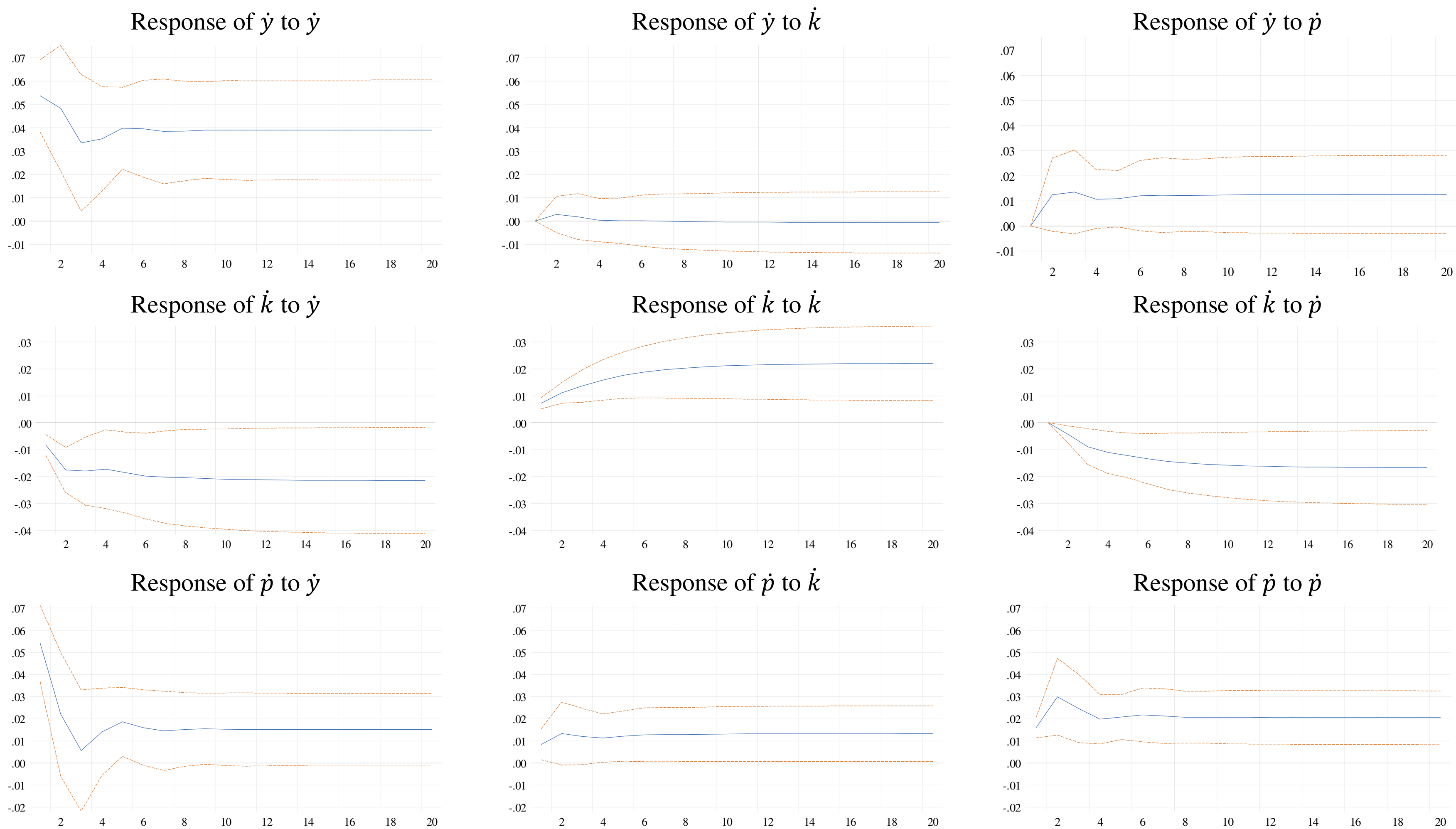
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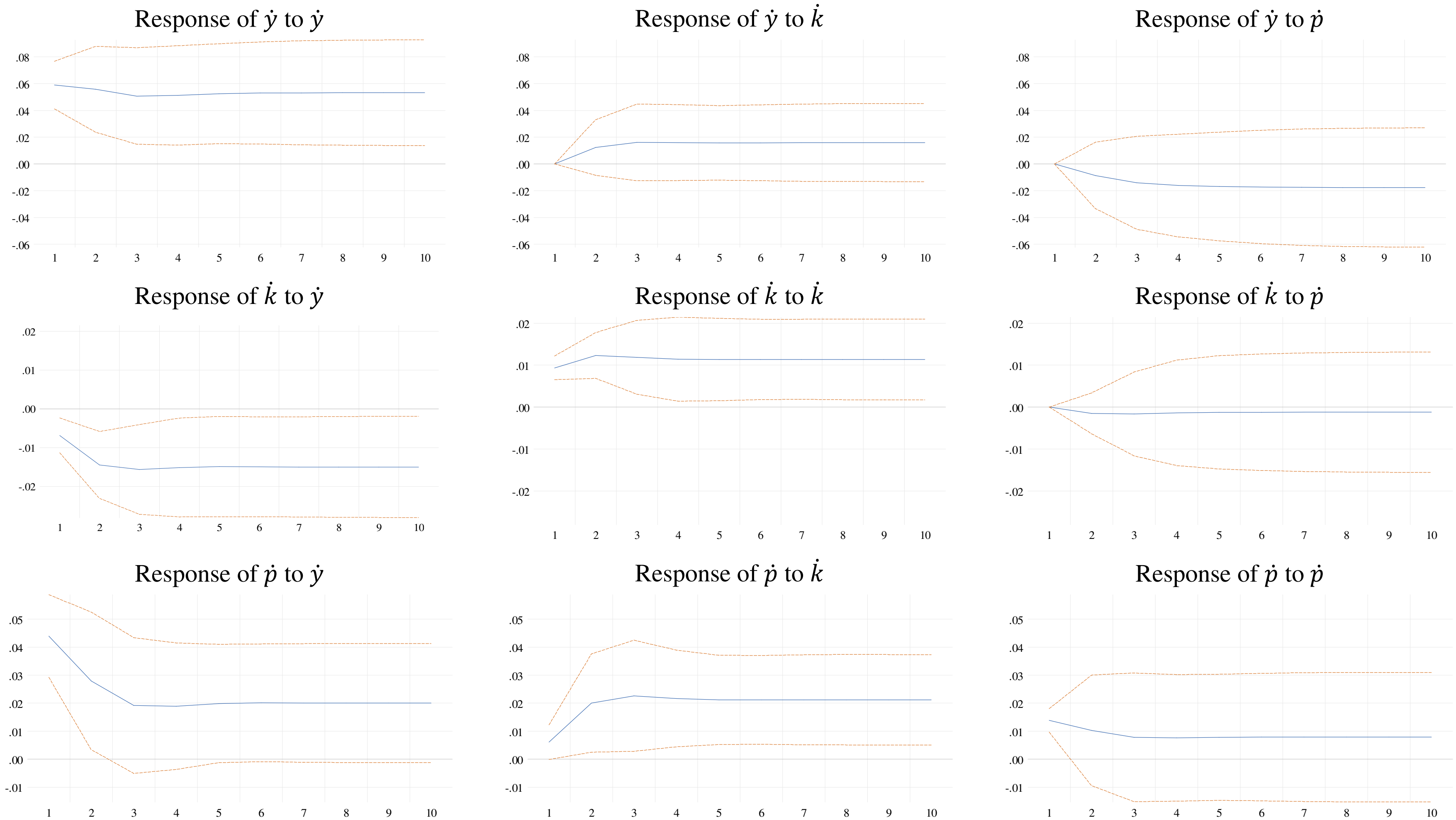

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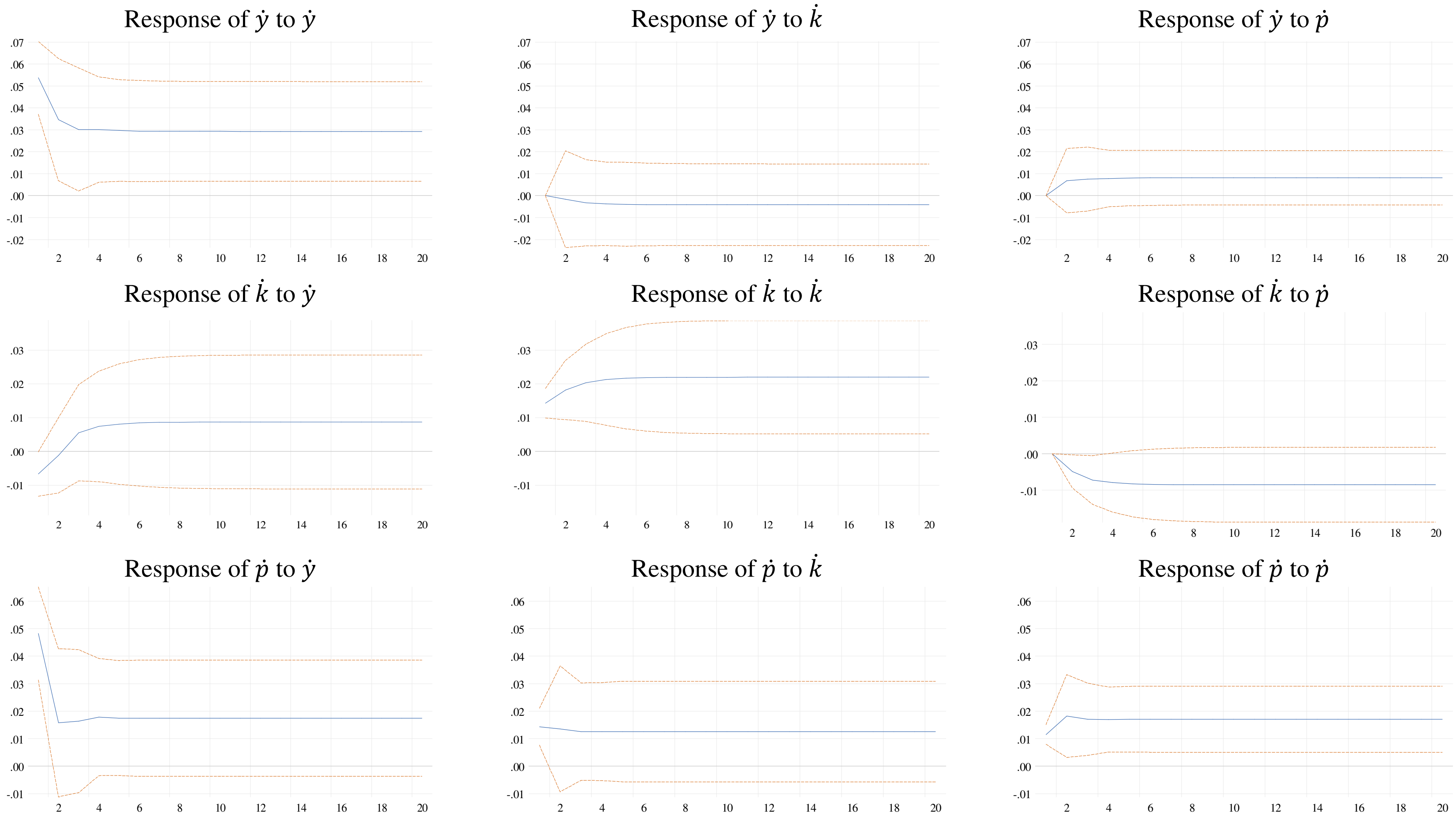
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UNITED KINGDOM

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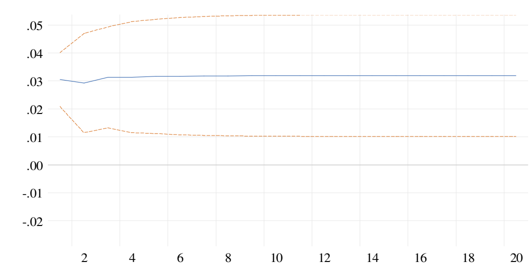

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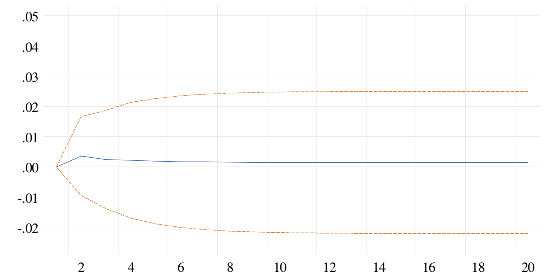

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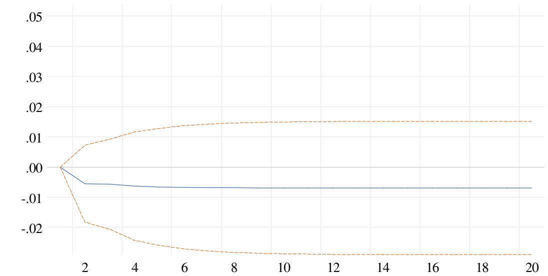

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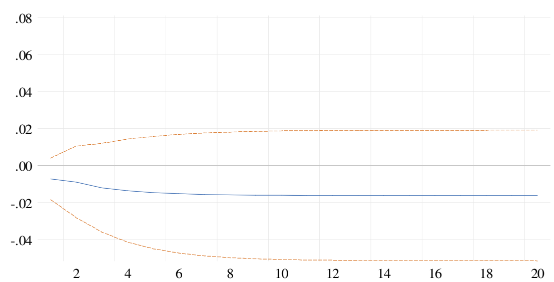

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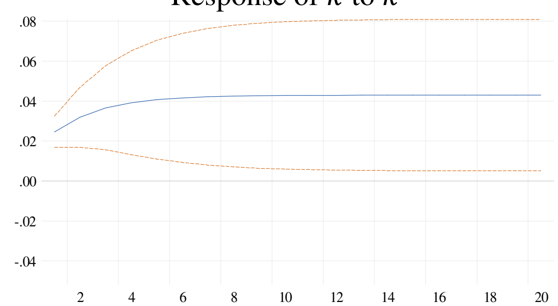

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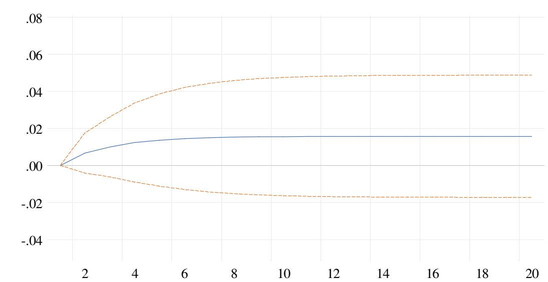

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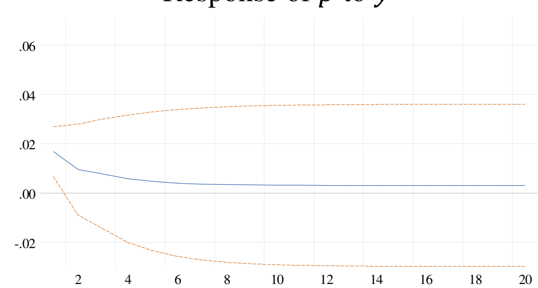

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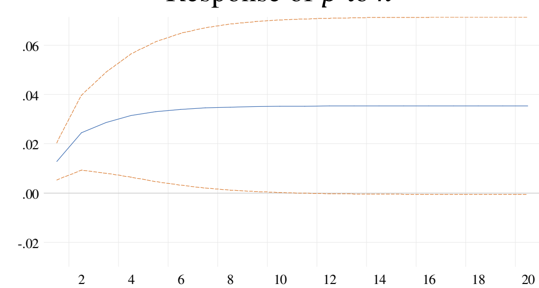

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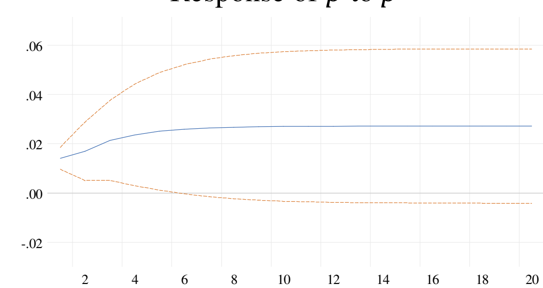

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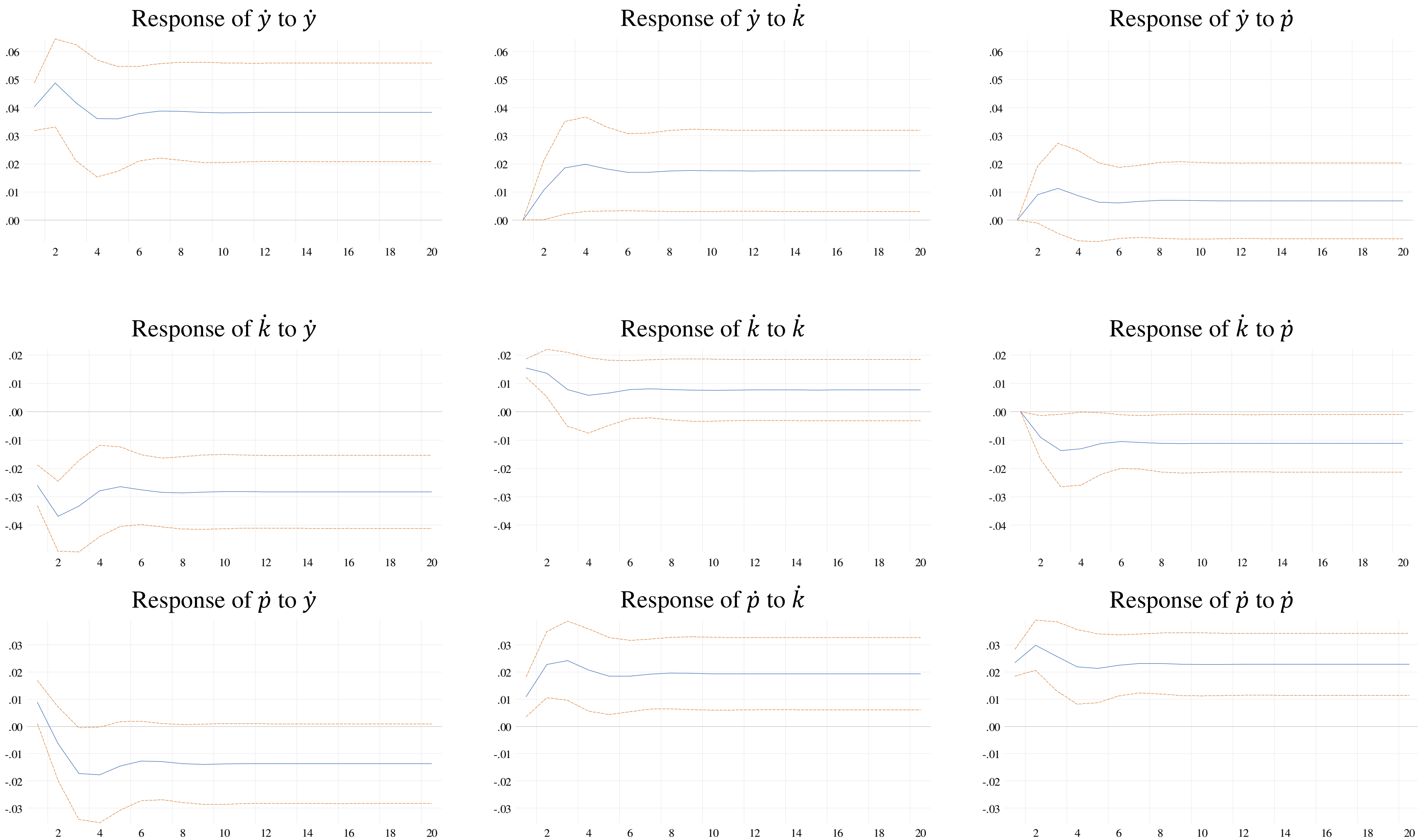
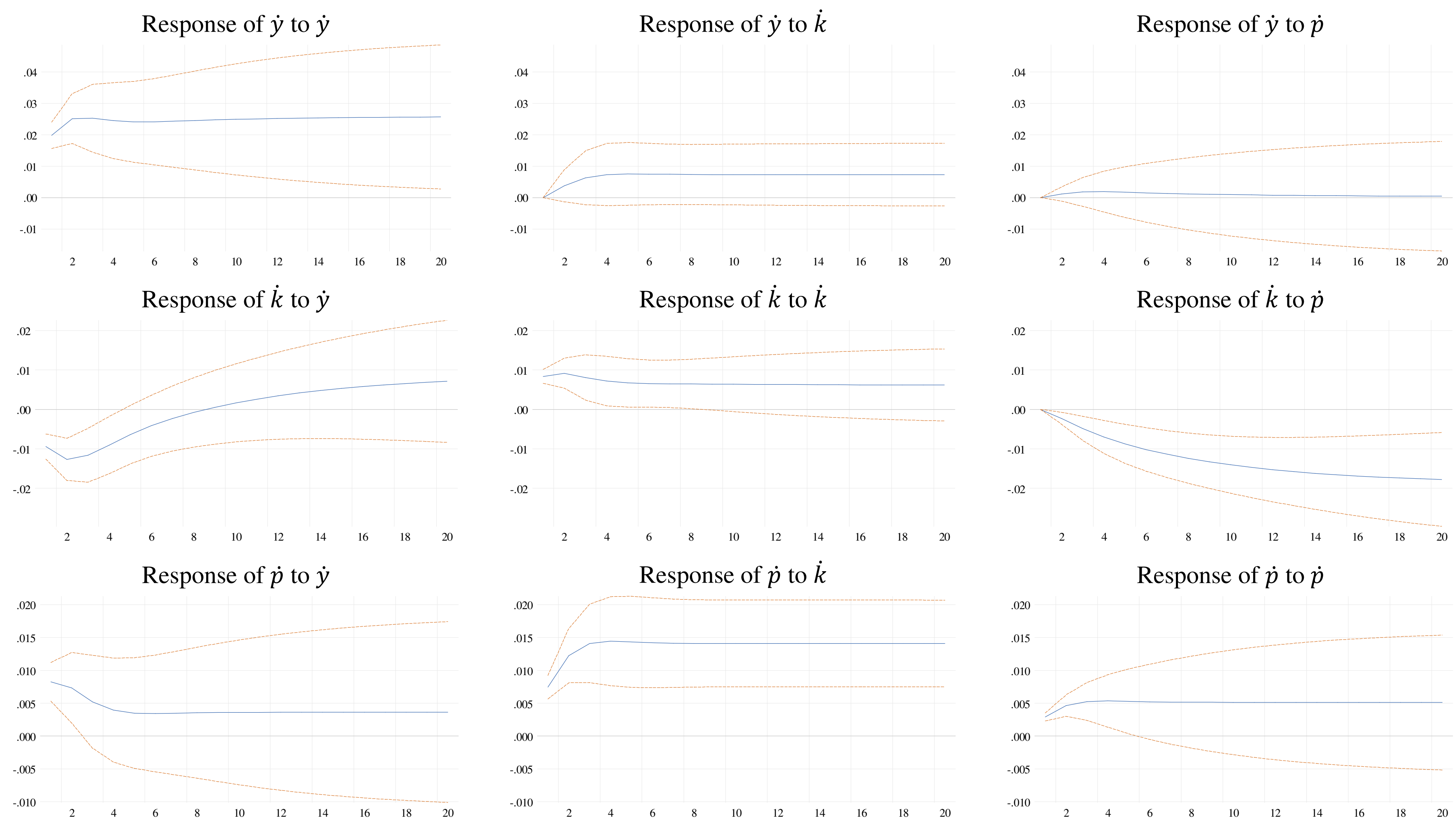


For each variable in the manufacturing sector of the economy, the figures depict the IRFs to a 1% shock on output growth ($\dot{y}$), capital-deepening dynamics ($\dot{k}$), or labour productivity growth ($\dot{p}$), alternatively. Cumulated responses to structural shocks are reported with two-standard error bound (a 95% confidence interval).

B.2 – Total economy

CANADA



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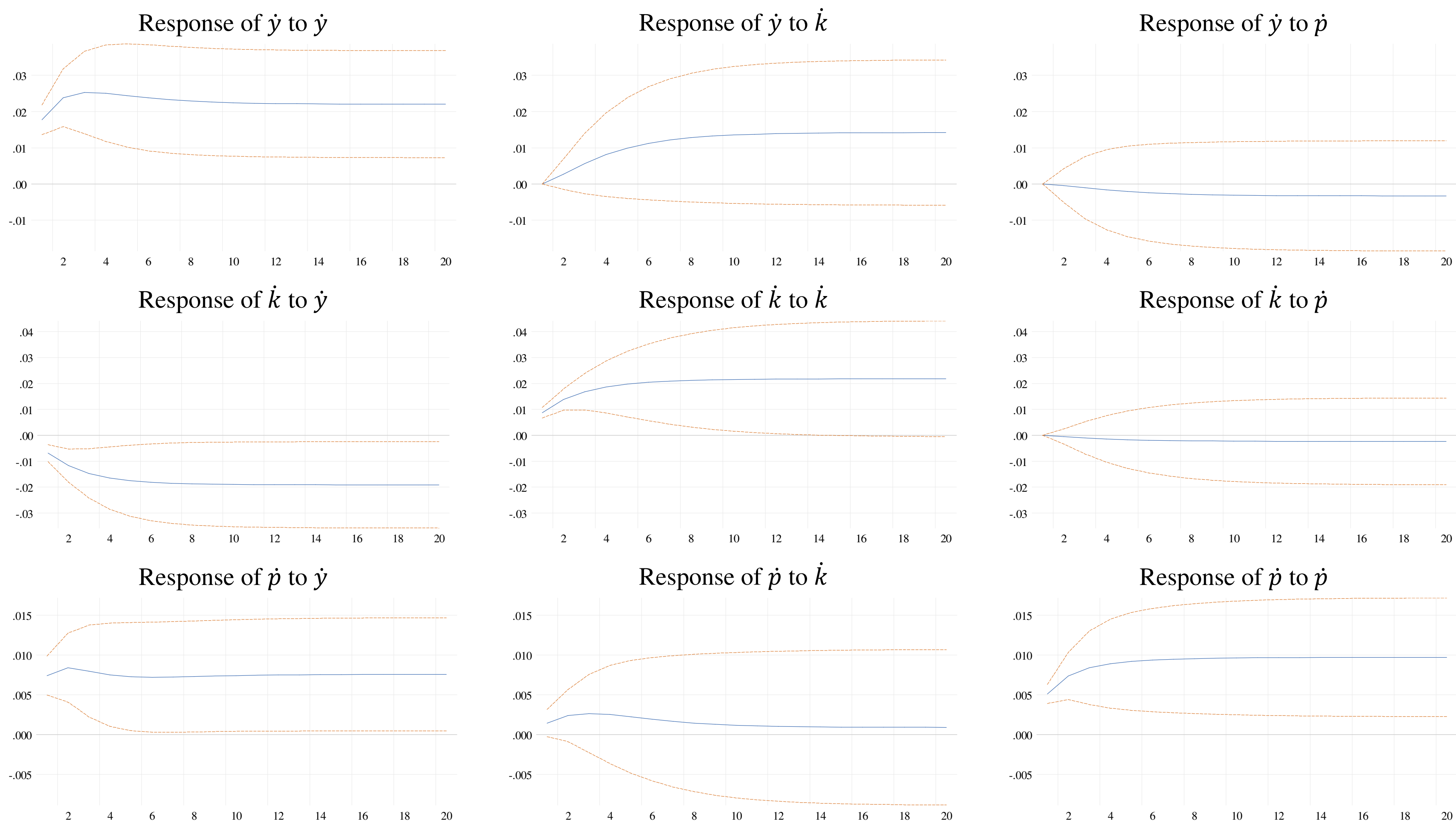
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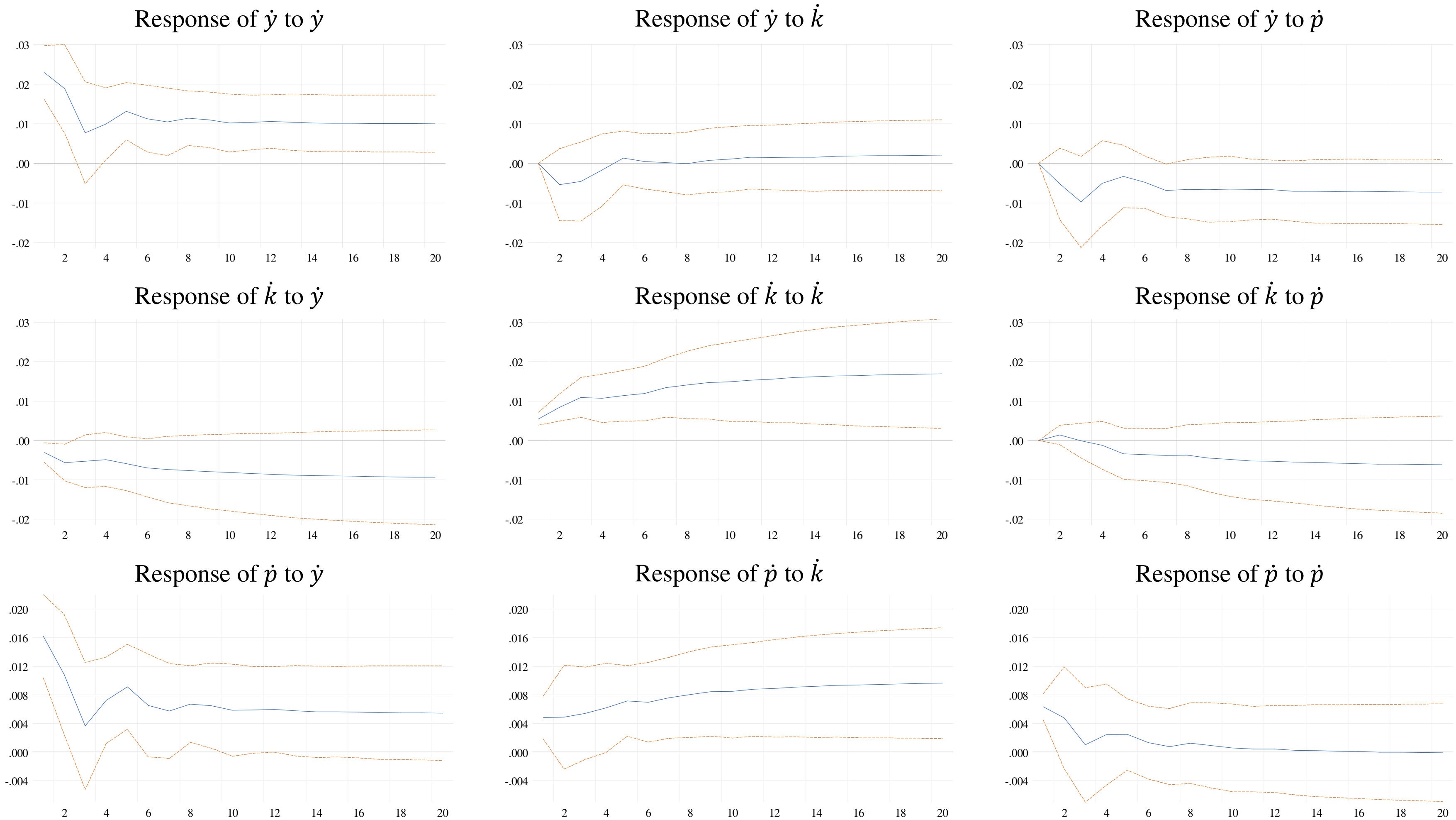
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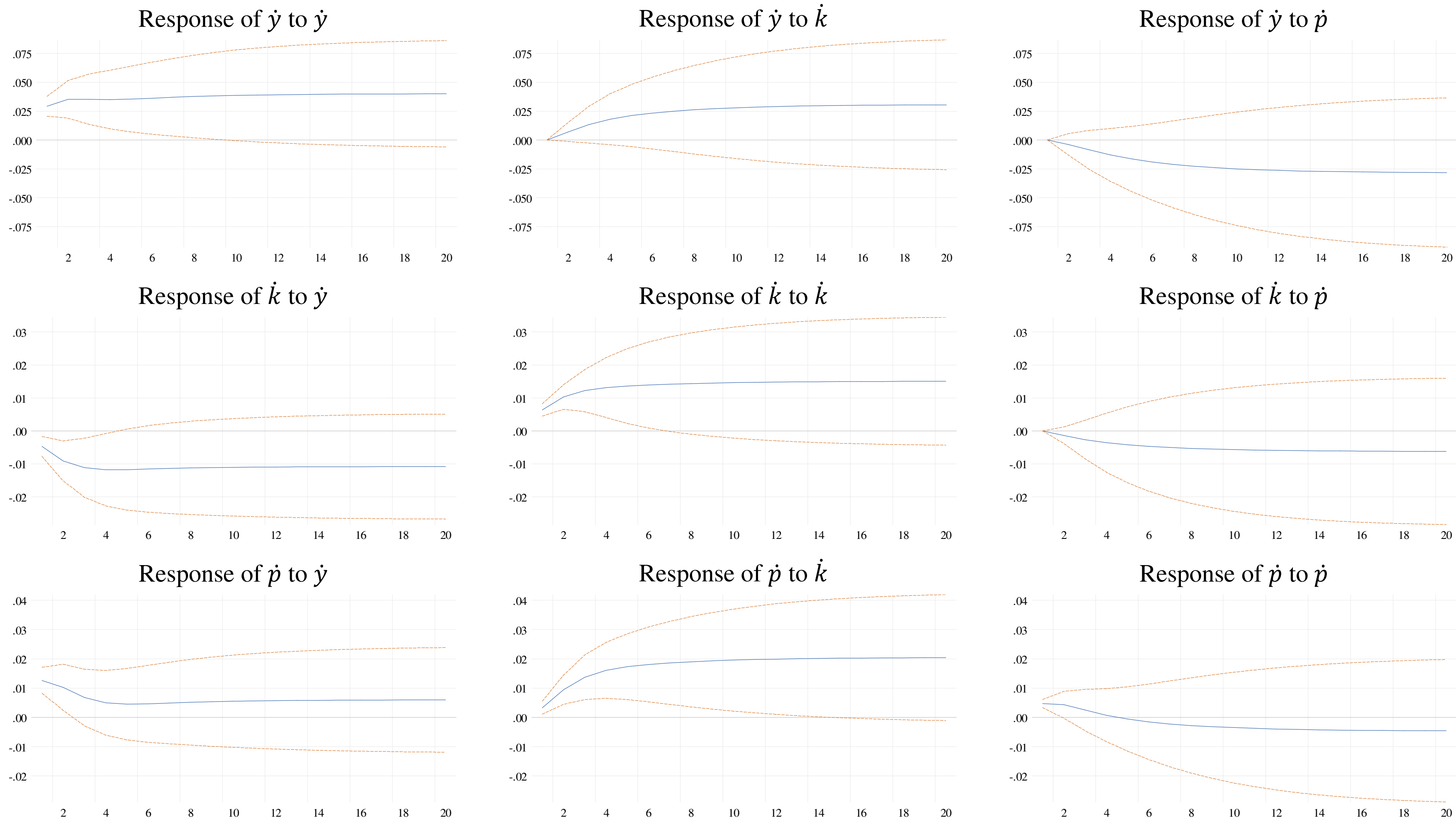

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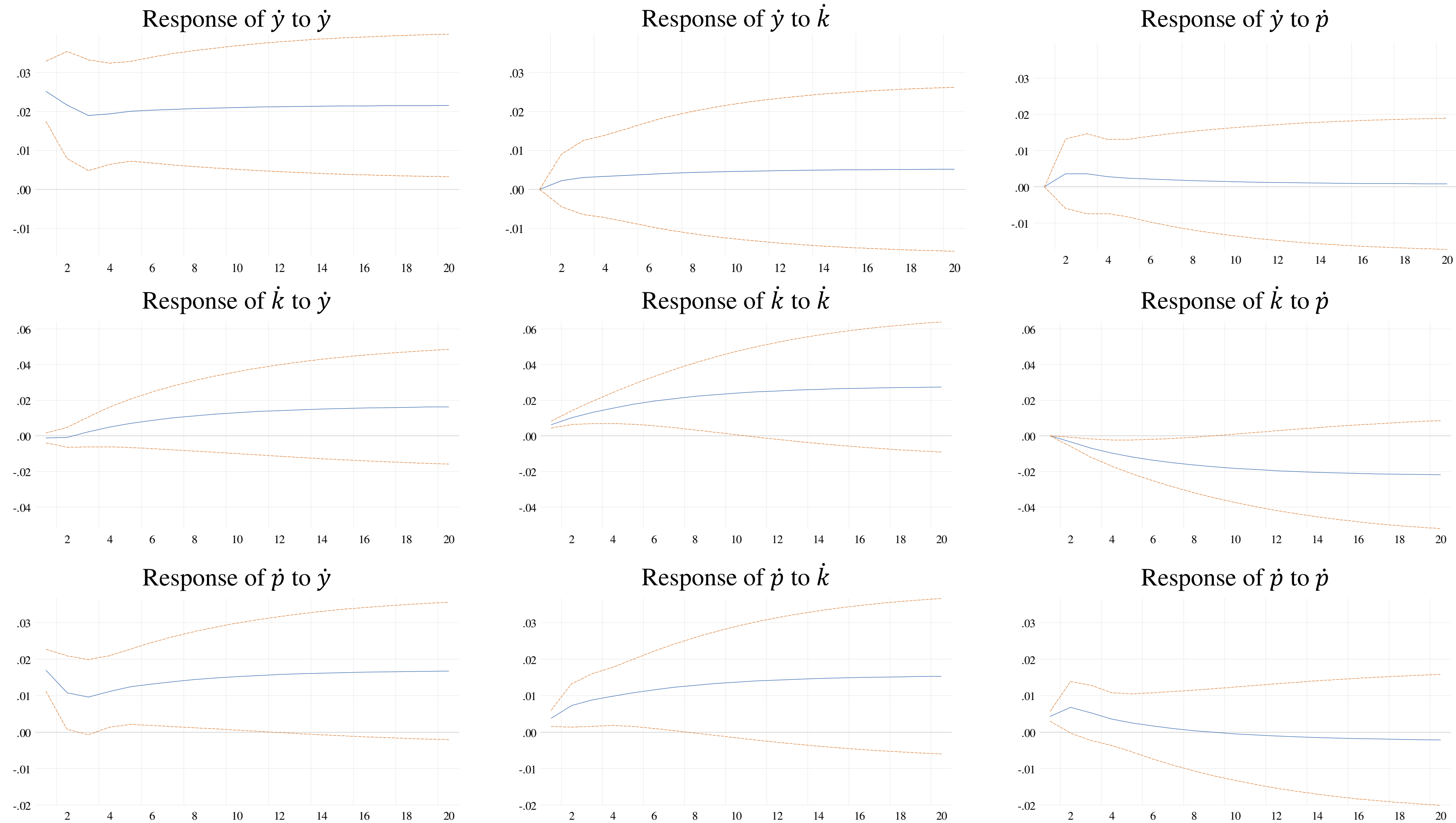

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UNITED KINGDOM

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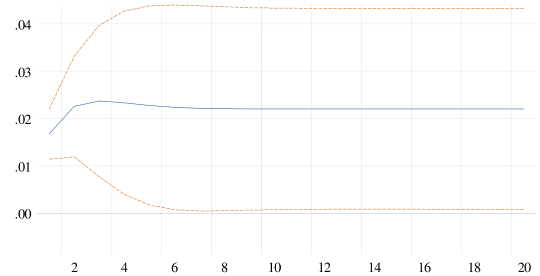

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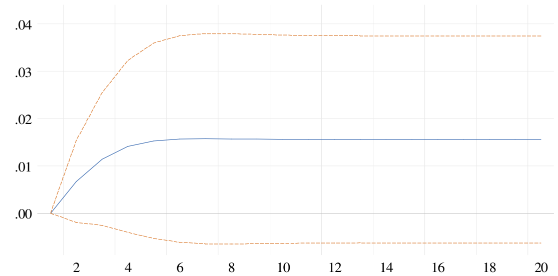

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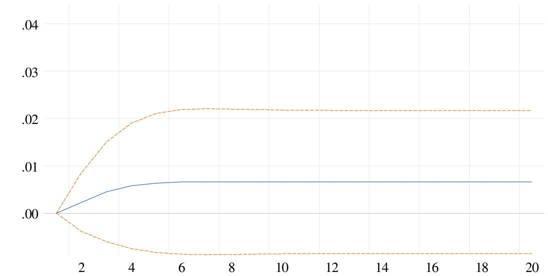

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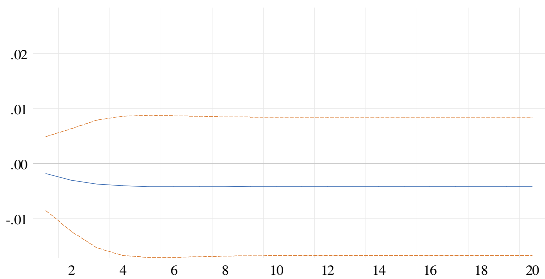

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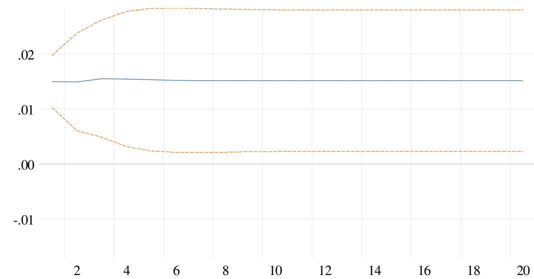

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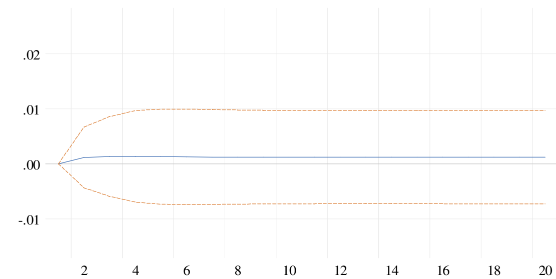

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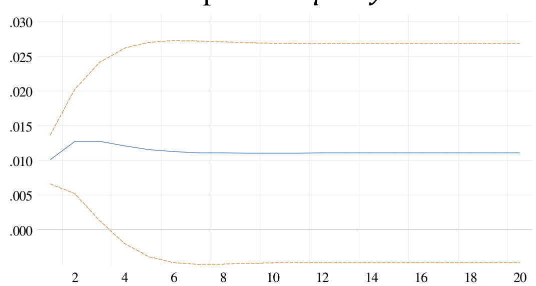

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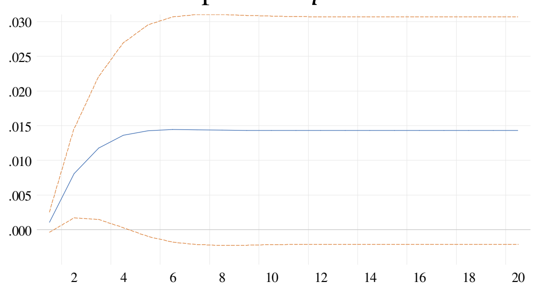

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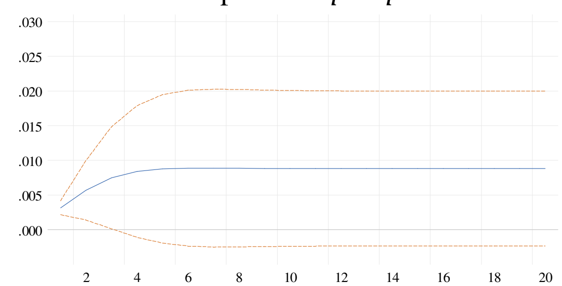

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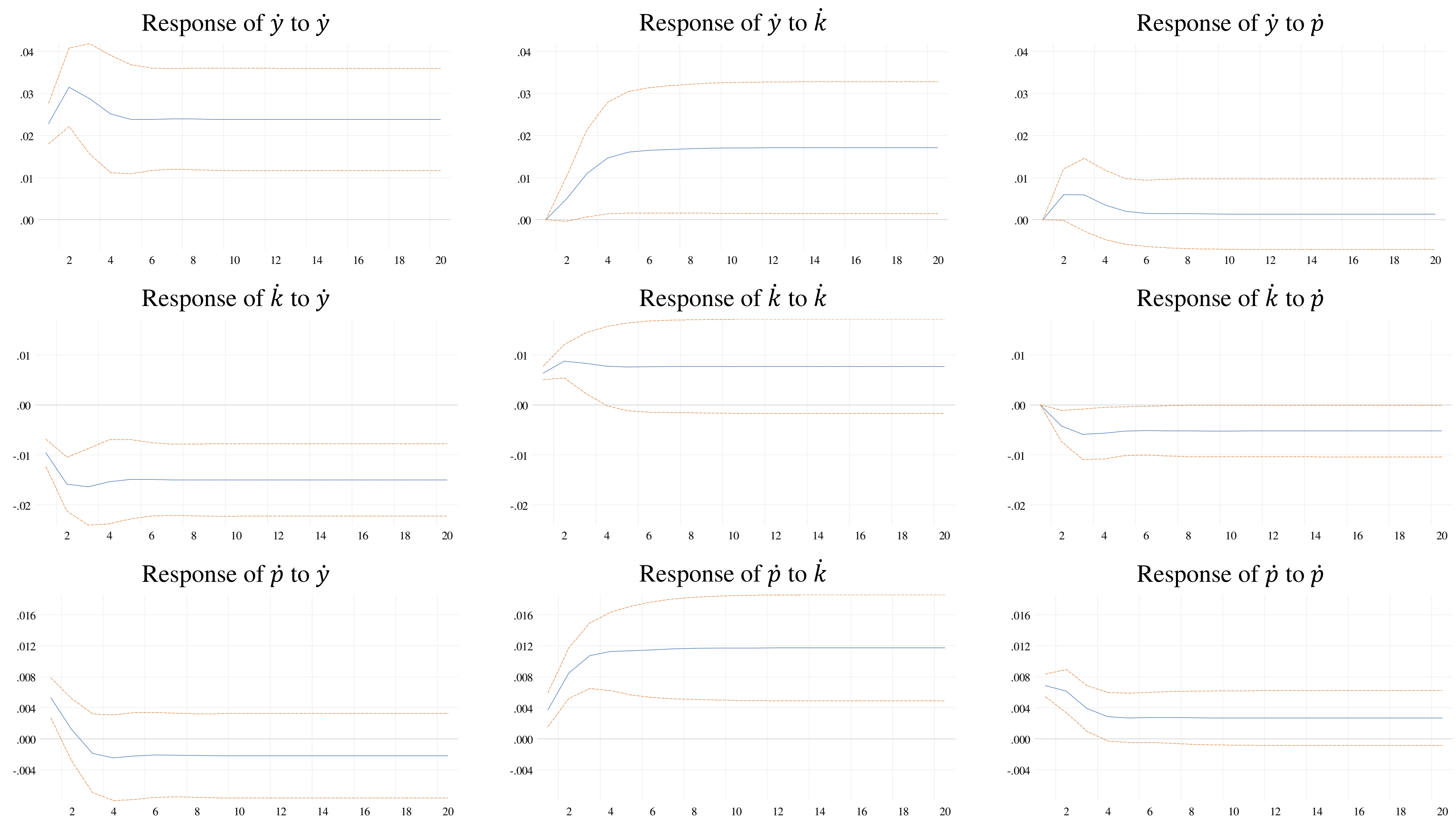

For each variable in the total economy, the figures depict the IRFs to a 1% shock on output growth ($\dot{y}$), capital-deepening dynamics ($\dot{k}$), or labour productivity growth ($\dot{p}$), alternatively. Cumulated responses to structural shocks are reported with two-standard error bound (a 95% confidence interval).