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Does tertiarisation slow down productivity growth? A Kaldorian–Baumolian analysis across 10 developed economies

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Abstract

This study examines the impact of the expansion of the service sector on labour productivity growth in 10 developed economies, reaching back to the late 1970s. The main research novelty is that it combines both Kaldorian and Baumolian insights to develop a new shift-share decomposition that, consistent with Kaldorian theory, endogenises productivity growth at the industry level with respect to structural change, and, consistent with the Baumolian framework, includes the impact that arises from the cumulative reallocation of nominal output and employment. Our results show that tertiarisation leads to a gradual decrease in productivity growth in most of these economies.

KEYWORDS

Baumol's disease, Kaldor–Verdoorn law, labour productivity growth, shift-share analysis, structural change

JEL CLASSIFICATION

E24, L16, L60, L80, O47

1 | INTRODUCTION

The relative expansion of the service sector in employment and nominal value added (tertiarisation) with income per capita is one of the most salient aspects of structural change[1] and economic development (Fisher, 1939; Jorgenson & Timmer, 2011; Kuznets, 1957, 1966). Given the significance of this process, a growing amount of literature has sought to understand both the factors that drive this reallocation of employment and nominal value added and its impact on long-term economic growth. Concerning the latter, the key issue is how (and how much) structural change might affect the main determinant of long-term economic growth (that is, productivity growth).

This paper aims to provide a better assessment of this impact, by endogenising productivity growth at the industry level with respect to structural change. The empirical literature has tried to estimate in many ways the impact of structural change on productivity growth using either shift-share analysis or econometric techniques,[2] but these estimations are usually run following the canonical Baumolian framework, which considers productivity growth at the industry level as exogenous with respect to structural change.

According to Baumol (1967), since aggregate productivity growth is just a weighted average of the sectoral productivity growth rates (where the weights are the nominal value added shares), the gradual reallocation of nominal value added to the technologically stagnant sector that accompanies tertiarisation increasingly undermines aggregate productivity growth. However, Baumol never views productivity growth within each sector as a variable which could be endogenously affected by the factors that drive structural change. It is our opinion that the consideration of productivity growth as exogenous at the industry level seriously constrains the acknowledgement of the relationship between growth and structural change, as well as the scope of most empirical studies.

To overcome this limitation, we have extended the canonical Baumolian framework to incorporate Kaldorian assumptions. According to Kaldor's Third Law, productivity growth depends on demand due to the existence of increasing returns. Since returns to scale are usually greater in manufacturing, the expansion of the service sector in terms of employment at the expense of manufacturing limits the productivity gains that could be generated due to the existence of higher increasing returns in manufacturing, thereby slowing down aggregate productivity growth.

The combination of both Kaldorian and Baumolian insights leads to a change in the conventional shift-share analysis that results in a better estimation of the impact of structural change. Even though there have already been a few attempts to develop shift-share analyses considering the Kaldorian theory, to the best of our knowledge, this is the first empirical study that applies a shift-share analysis to evaluate the impact of structural change on productivity growth from this Kaldorian–Baumolian perspective. This first evaluation studies the relationship between structural change and productivity growth on 10 advanced economies during the period 1978–2007.

Moreover, while most of the shift-share literature only assesses the average impact of structural change over a period, our analysis also addresses the long-term implications of structural change on productivity growth that comes with the Baumolian asymptotic effects. This allows us to determine, on the one hand, whether the tertiarisation process has had a negative impact on productivity growth on average for the whole period, and, on the other hand, whether it leads to a gradual fall in the productivity growth rate that brings the economy closer to the Baumolian asymptotic result.

[1]Throughout this paper, structural change is understood as the reallocation of employment or nominal value added that takes place across industries.

[2]Certain shift-share analyses can be found in Deleidi et al., 2020; Di Meglio et al., 2018; Fagerberg, 2000; Maroto-Sánchez & Cuadrado-Roura, 2009; McMillan & Rodrik, 2011. For econometric techniques see Dasgupta & Singh, 2005; Dutt & Lee, 1993; Pariboni & Tridico, 2019; Peneder, 2003.

Lastly, our analysis requires the previous econometric estimation of Verdoorn's Law for the various industries of the economy, since the Kaldorian impact depends on the existence of heterogeneous returns to scale, and we do not take for granted the Kaldorian assumption that, contrary to what occurs in the manufacturing sector, the other sectors of the economy exhibit constant (or even decreasing) returns to scale given their limited ability to benefit from induced technological change and 'learning by doing'. This estimation, which is necessary in order to obtain a more precise result of the impact of tertiarisation on productivity growth, might also be considered a valuable contribution to the still scarce literature on estimating returns to scale for manufacturing-sector or service-sector disaggregations.

The paper is organised as follows. Section 2 deals with the theoretical background of the Kaldorian–Baumolian framework. Section 3 addresses methodological considerations regarding the data sources, the econometric estimation of Verdoorn's Law, and the modification introduced into shift-share analysis. Section 4 discusses the results obtained from the estimation of Verdoorn's Law and the application of the modified shift-share analysis to assess both the average and asymptotic impact of structural change on productivity growth. Lastly, Section 5 summarises the main conclusions drawn from this study.

2 | THEORETICAL BACKGROUND: A KALDORIAN–BAUMOLIAN FRAMEWORK

Since the formulation of Kaldor's Growth Laws (1966, 1968, 1975) and Baumol's model (1967), these two theories have spurred a pessimistic view of the impact of tertiarisation on economic growth. Building on a sector-specific understanding of economic growth (Palma, 2005; Tregenna, 2009) based on the superior technological characteristics of the manufacturing sector, both theories emphasise that the expansion of the service sector at the expense of manufacturing slows down labour productivity growth. However, when it comes to substantiating the negative impact of the tertiarisation process, Kaldorian theory and Baumol's model do not underscore the same effects.

In Baumol's model, the gradual expansion of the service sector leads to an asymptotic result for aggregate labour productivity growth, which declines monotonically and approaches within the limit the productivity growth rate of the service sector. To achieve this asymptotic result, three conditions must be met. First, there must be a substantial productivity growth differential between the progressive sector of the economy (that is, the one with higher-than-average productivity growth in the economy) and the stagnant sector (that is, the one with below-average productivity growth). The model considers that the progressive sector exhibits significant productivity increases and resembles the manufacturing sector, while the stagnant sector has stagnant productivity and is more akin to the service sector. Second, the productivity gains of the progressive sector have to be passed on to consumers in lower relative prices, so '[t]he growth of […] productivity in manufacturing becomes a sort of fund in which […] both manufacturing and the services share equally' (Baumol & Wolff, 1984, p. 1031). Therefore, 'by means of declining relative prices, […] the productivity growth in manufacturing rapidly dissipates into the consumers' rent instead of raising the nominal value added earned by the industry' (Peneder & Streicher, 2016, p. 7). Third, despite this increase in their unit cost and relative price, services must present 'persistent demand' (Ten Raa & Schettkat, 2001), which means that their real output grows at about the same pace as that of manufacturing. As a consequence of the joint fulfilment of these three conditions, the service sector gradually increases its share in the nominal value added and employment and aggregate labour productivity growth is increasingly determined by the productivity growth rate of the service sector. Therefore, according to Baumol's model, the tertiarisation process leads to the gradual slowdown of aggregate labour productivity growth, which asymptotically tends to mirror the productivity growth in the service sector. This negative impact is known in the literature as Baumol's Growth Disease (BGD) (Nordhaus, 2008).

Unlike Baumol's model, Kaldorian theory does not stress the asymptotic result but rather the negative impact that takes place in every period in which the shift to services implies a relative decline in employment in industries with increasing returns to scale. Hence, to substantiate this Kaldorian effect, increasing returns to scale in certain industries of the economy must exist. According to Kaldor, productivity growth in manufacturing depends positively on the rate of growth of its demand; that is, manufacturing exhibits increasing returns to scale. This relationship is known in the literature as the Kaldor–Verdoorn Law. Even though this law constitutes a sort of black box (Blecker & Setterfield, 2020, ch. 8; McCombie & Spreafico, 2016), it is essentially a dynamic relationship in which the growth of demand stimulates the incorporation of new technologies into investment goods (induced technological change) and leads to a learning-by-doing process (Arrow, 1962; Kaldor, 1966; McCombie & Roberts, 2007; McCombie & Spreafico, 2016). Contrary to the manufacturing sector, the other sectors of the economy exhibit constant (or even decreasing) returns to scale given their limited ability to benefit from induced technological change and learning by doing.

Because there are differential returns to scale, and since Kaldor claimed that structural change is demand-driven (that is, tertiarisation happens due to an insufficient expansion of demand in the manufacturing sector), the expansion of the service sector in terms of employment at the expense of manufacturing limits the productivity gains that could be generated due to the existence of increasing returns in manufacturing and, as a consequence, constrains aggregate productivity growth. This is precisely the effect that is underscored in Kaldor's so-called Third Law, which specifically addresses the impact of structural change in a Kaldorian framework. According to Kaldor's Third Law, aggregate labour productivity growth depends positively on the growth of manufacturing demand and negatively on the growth of employment outside the manufacturing sector.[3]

However, the dichotomy between services and manufacturing on which both Baumol's model and Kaldorian theory are based has been questioned in the empirical literature. On the one hand, certain market services exhibit productivity gains comparable to those of the manufacturing sector, so the impact of BGD will depend on which services account for the expansion of the service sector.[4] On the other hand, both industries within the manufacturing sector and industries within the service sector show substantial heterogeneity in their returns to scale. Although the Kaldorian literature has traditionally estimated Verdoorn's Law for the manufacturing sector as a whole, confirming the existence of increasing returns to scale,[5] it has recently conducted estimations for the service sector and different disaggregations of both sectors. Even though the evidence remains limited, some studies have pointed to the existence of increasing returns to scale for different service industries in developing economies, as well as for the aggregate service sector in both developed and developing economies. Within the manufacturing sector, in the countries with the highest level of development, the returns to scale appear to be higher in high- and medium-high-technological industries (Magacho & McCombie, 2018; Romero & McCombie, 2016a) and in capital goods-producing industries (Magacho & McCombie, 2017, 2018).[6] In light of this heterogeneity in the returns to scale at the industry level, the Kaldorian impact of the tertiarisation process will be negative only if labour reallocates to industries with lower returns to scale.

[3]Kaldor's Third Law modifies some of Kaldor's early ideas on economic growth, such as his stylised facts (see Kaldor, 1957). In particular, by acknowledging that tertiarisation slows down aggregate productivity growth, he changed his early assumption that output per worker grows at a constant rate over long periods of time.

[4]See Baumol et al., 1985; Duarte & Restuccia, 2020; Fernández & Palazuelos, 2012; IMF, 2018; Inklaar & Timmer, 2014; Jorgenson & Timmer, 2011; Maroto-Sánchez & Cuadrado-Roura, 2009.

[5]See Angeriz et al., 2009; Kaldor, 1966; McCombie, 1982; McCombie and Rider, 1984; Millemaci & Ofria, 2014.

[6]See also Basu & Foley, 2013; Crespi & Pianta, 2008; Di Meglio et al., 2018; Felipe et al., 2009; León-Ledesma, 2000; Pieper, 2003.

Therefore, although both Baumol's model and Kaldorian theory provide relevant partial views of the impact of the tertiarisation process, it is more appealing to combine the two frameworks to obtain a more complete picture of this impact. This combination improves the quantitative evaluation of the impact, making it necessary to consider, on the one hand, that productivity growth at the industry level is endogenous and depends on the expansion of demand and, on the other hand, that the cumulative change in the nominal value added shares may affect aggregate productivity growth.

3 | METHOD

3.1 | Data sources

The main data source used in this study is EU KLEMS (March 2011 version) (O'Mahony & Timmer, 2009), which allows analysis of the period 1978–2007. To the extent that the analysis of the asymptotic impact of structural change plays a crucial role in this work, the period under study must be as long as possible, making it appropriate to use the March 2011 release. However, we also use the 2021 release of EU KLEMS (Lab of European Economics, 2021) to check the robustness of our results for the period 1996–2018.

Ten economies are the subject of the present paper: the United States, the United Kingdom, Japan, Spain, Italy, Germany, the Netherlands, Finland, Denmark, and Austria. This work makes use of the following variables for each economy: real value added, nominal value added, employment in hours worked (persons engaged in production), price index, and real capital stock. Data on these variables are employed at a disaggregated level of 31 industries (NACE rev. 1), as reported in Appendix A (Table A1).

Besides EU KLEMS, we also use data on purchasing power parity for value added at the industry level provided by the GGDC Productivity Level Database (1997 benchmark) (Inklaar & Timmer, 2009) to calculate the technological gap for each industry. This variable will be used as an explanatory variable in the estimation of Verdoorn's Law. The technological gap is defined as the natural logarithm of the productivity differential in levels and purchasing power parity with respect to the frontier economy, which in this study is considered to be the United States (Romero & Britto, 2017; Romero & McCombie, 2016a).

$$G_{ijt} = \ln\left(\frac{LP_{PPPijt}}{LP_{iUSt}}\right) \tag{1}$$

where LP is the productivity level, the subscript PPP denotes that the variable is in purchasing power parity, and the subscript US denotes the US economy.

Given that purchasing power parities at the industry level are available in the GGDC Productivity Level Database for the year 1997, we apply the following formula to approximate the current purchasing power parities method, which updates purchasing power parities on a year-to-year basis (Inklaar & Timmer, 2008):

$$PPP_{ijt} = \left(\frac{P_{ijt}}{P_{iUSt}}\right) \times PPP_{ij1997} \tag{2}$$

where PPP denotes purchasing power parity and P is the price index with 1997 as the reference year. The purchasing power parities are normalised with respect to the US economy (which takes one as its value).

3.2 | Econometric estimation of Verdoorn's law

The specification of Verdoorn's Law to be estimated econometrically is the following:

$$q_{ijt} = \beta_0 + \beta_1 y_{ijt} + \beta_2 \left(k_{ijt} - y_{ijt}\right) + \beta_3 G_{ijt-1} + z_t + \varepsilon_{ijt} \quad (3)$$

where q is productivity growth, y refers to real value added growth, k is the real capital stock growth, G is the technological gap, z denotes time dummies, ε is the error term, the subscript i refers to industry i, the subscript j denotes country j, and the subscript t refers to the time period. Therefore, the Verdoorn coefficient corresponds to β_1. If $\beta_1 > 0$, then there are increasing returns to scale, whereas if $\beta_1 = 0$, there are constant returns to scale.

In addition to the growth of the real value added, the equation includes as explanatory variables the growth of the capital-output ratio and the technological gap. On the one hand, since the capital-output ratio is not constant,[7] the omission of this variable would lead to a biased estimation of Verdoorn's Law (McCombie, 1982).[8] On the other hand, the inclusion of the technological gap captures how the distance from the frontier economy might boost technological diffusion and productivity growth (Cornwall & Cornwall, 2002; León-Ledesma, 2002).

One of the main econometric problems that arises when estimating Verdoorn's Law is the two-way causality between productivity growth and output growth. If output growth fosters productivity growth due to the Verdoorn relationship, productivity growth also fuels output growth through price and income effects (Dixon & Thirlwall, 1975; León-Ledesma, 2002; Setterfield, 2011). Consequently, output growth is not strictly exogenous. To deal with this endogeneity issue, the Kaldorian literature has recently started to use the system GMM method, which is useful even if the model is not dynamic (Arellano & Bover, 1995; Blundell & Bond, 1998). This method estimates the parameters through a system of equations in levels and in differences using the lags of the variables in differences and levels, respectively, as instruments.

Since Verdoorn's Law involves a long-term relationship between output growth and productivity growth, we apply 5-year non-overlapping moving averages to avoid capturing the short-term relationship between these two variables (Okun's Law). This reduces the influence of cyclical variables such as the variation in the degree of capacity utilisation or in the intensity of the use of labour, which have nothing to do with the existence of returns to scale.

This study uses cross-country–industry panels to estimate Verdoorn's Law, which allows increase in the number of observations. The 31 industries into which this version of EU KLEMS disaggregates the economy are classified into 5 different groups, so we estimate Verdoorn's Law for each group.[9] First, following Magacho and McCombie (2017, 2018), Romero and Britto (2017), and Romero and McCombie (2016a), we distinguish two groups within the manufacturing sector based on the

[7]While Kaldor assumed in one of his stylised facts that the capital-output ratio remains constant over long periods of time, we do not follow this assumption because short-term fluctuations in this variable affect the magnitude of the Verdoorn coefficient.

[8]Given that for Germany there is a consistent lack of capital stock data for most of the years of the period 1978–2007, we exclude Germany from the estimation of Verdoorn's Law and assume that the industries of this economy exhibit the same Verdoorn coefficients as in the other nine countries. Nevertheless, we check the robustness of our results for Germany by using the 2021 release of EU KLEMS. Using that release, we include the 10 economies in the estimation of Verdoorn's Law.

[9]We exclude the fuel industry from the estimation of Verdoorn's Law because its productivity growth presents high spikes, which could be attributed to measurement errors or a strong volatility in oil prices (Herrero & Rial, 2022; Romero & McCombie, 2016a). However, we include this industry when we apply the shift-share analysis to decompose aggregate productivity growth, accepting for this industry the usual assumption of constant returns to scale.

technological content (or the research intensity) of the industries (Galindo-Rueda & Verger, 2016).[10] Besides being stressed as a key determinant for technical progress and productivity growth (e.g. Aghion & Howitt, 1992; Madsen, 2008; Romer, 1990), research intensity has been positively associated with the magnitude of returns to scale, so that higher research intensity generates faster knowledge accumulation and increases the response of technical progress to output growth (Romero & Britto, 2017). The two groups that we distinguish based on research intensity are the high- and medium-high-technological industries, of which there are four (chemicals and chemical products, machinery, electrical and optical equipment, and transport equipment), and the low- and medium-low-technological industries, of which there are eight (food, textiles, wood, paper, plastics, minerals, metals, and other manufacturing). Second, we distinguish two groups of industries within the service sector. The first of these groups consists of eight industries in total: three non-market service industries (public administration and defence, education, and health and social work), three personal service industries (hotels and restaurants, other community, social, and personal services, and private households with employed persons), and real estate and business services.[11] These industries are characterised by being labour intensive, subject to fewer competitive pressures, presenting obstacles to innovation or having companies with a smaller size (Fernández & Palazuelos, 2012; Maroto & Rubalcaba, 2008; Pariboni & Tridico, 2019; Wölfl, 2005). Conversely, the second of these groups is made up of those services that are less labour intensive and more akin to manufacturing. The following six market service industries belong to this group: distribution services (wholesale trade, retail trade and maintenance, and repair of motor vehicles and motorcycles, transport, and storage), post and telecommunications, and financial intermediation. Lastly, the fifth group is composed by the remaining four industries (agriculture, mining, utilities, and construction). Since we are aware that these industries constitute a heterogeneous group, we will perform a robustness test to check whether any of these industries present different returns to scale to the other three industries by introducing interaction terms between output growth and industry dummies.

3.3 | A modified shift-share analysis for a Kaldorian–Baumolian framework

3.3.1 | Decomposing aggregate labour productivity growth

In a chained Törnqvist index framework, aggregate labour productivity growth in real terms in period t can be approximated as follows[12]:

[10]There are many studies that classify manufacturing industries according to research intensity, finding that industries with higher research intensity exhibit stronger productivity growth (Romero & McCombie, 2016a), higher returns to scale (Magacho & McCombie, 2018; Romero & McCombie, 2016a), an export performance with lower sensitivity to unit labour costs (Gräbner et al., 2020) and higher income elasticity (Romero & McCombie, 2016b), and a positive impact of innovation on employment (Van Roy et al., 2018).

[11]Business services are included in this group because, even though the literature has stressed the ability of some business services (*e.g*. research and development, computer-related activities, and engineering) to generate positive externalities through the diffusion of technology and knowledge (Ciarli et al., 2012; Di Meglio et al., 2018; Gallouj & Savona, 2008; Kox & Rubalcaba, 2007), their labour-intensive nature leads to poor productivity gains or even declining productivity within the industry.

[12]Aggregate productivity growth is approximated here as a weighted average of the sectoral productivity growth rates, where the weights are the nominal value added shares. However, other studies use as weights the ratio of industry's gross output to aggregate value added, known as Domar weights (Domar, 1961; Hulten, 1978; Oulton, 2001).

$$\Delta \ln(\mathrm{LP}_t) = \sum w_{it-1} \Delta \ln(\mathrm{LP}_{it}) + \sum (w_{it-1} - h_{it-1}) \Delta \ln(H_{it}) \tag{4}$$

where $\Delta \ln(\mathrm{LP})$ stands for aggregate labour productivity growth based on logarithmic growth rates, $\Delta \ln(\mathrm{LP}_i)$ is the labour productivity growth of industry i based on logarithmic growth rates, $\Delta \ln(H_i)$ is the employment (hours worked) growth of industry i based on logarithmic growth rates, w_i is the nominal value added share of industry i, h_i is the employment share of industry i in hours worked, and the subscripts t and $t-1$ stand for the time period.

Aggregate labour productivity growth is broken down into industry contributions characterised by two terms or effects. The first term, on the right side, is known in the literature as the 'within' effect and measures the contribution to aggregate labour productivity growth due to factors other than compositional change. The second term corresponds to the so-called Denison effect (Nordhaus, 2001, 2002) and estimates the impact that arises from the reallocation of labour that takes place between industries with heterogeneous nominal productivity levels. The Denison effect is positive (negative) if employment reallocates to industries with above (below)-average nominal productivity levels. Consequently, the only structural change effect taken into account in this decomposition is the Denison effect. To the extent that this formula does not identify the effects that arise from the reallocation of labour between industries with heterogeneous returns to scale and from the cumulative changes in terms of the nominal value added, these effects are implicitly considered in the within effect. It is therefore necessary to introduce different modifications into this formula to estimate satisfactorily the different effects stemming from structural change in a Kaldorian–Baumolian framework.

This decomposition assumes that productivity growth at the industry level is not affected by the reallocation of labour that takes place in each period t. This means that every industry in the economy is assumed to exhibit constant returns to scale, so the reallocation of labour across these industries does not yield any productivity gain or loss at either the industry or the aggregate level. However, if this assumption does not hold and industries show heterogeneous returns to scale, the reallocation of labour will affect the productivity growth of the industries that do not exhibit constant returns to scale, generating productivity gains or losses at the aggregate level. If industries with above (below)-average returns to scale gain weight in terms of employment, aggregate productivity growth will be boosted (undermined) by this reallocation of labour across industries with heterogeneous returns to scale. To incorporate this effect into the formula, the following modification is introduced into the decomposition:

$$\begin{aligned}\Delta \ln(\mathrm{LP}_t) = {} & \sum w_{it-1} \Delta \ln(\mathrm{LP}_{it}) - \sum w_{it-1} (\Delta \ln(H_{it}) - \Delta \ln(H_t)) \left(\frac{\beta_i}{1-\beta_i}\right) \\ & + \sum w_{it-1} (\Delta \ln(H_{it}) - \Delta \ln(H_t)) \left(\frac{\beta_i}{1-\beta_i}\right) + \sum (w_{it-1} - h_{it-1}) \Delta \ln(H_{it})\end{aligned} \tag{5}$$

where $\Delta \ln(H)$ is aggregate employment (hours worked) growth based on logarithmic growth rates and β_i is the Verdoorn coefficient for industry i.

The modification that has been introduced into the formula consists of adding an element that detracts from the within effect and is added to the Denison effect in the structural change term. The total structural change effect is now composed of the Denison effect and this new effect. This effect is defined as the addition of the product of the relative employment growth of industry i and the quotient

$\left(\frac{\beta_i}{1-\beta_i}\right)$,[13] which collects the productivity gains or losses exhibited by industry i due to this relative employment growth under the existence of non-constant returns to scale, weighted by the nominal value added share of industry i in period $t-1$. Given that Kaldor's Third Law emphasises the impact of the reallocation of labour that takes place across industries with heterogeneous returns to scale, we refer to this new term as the Kaldor effect.

Despite having introduced an additional effect of structural change, the decomposition formula continues to exhibit strong limitations to account for the impact of structural change in a Kaldorian–Baumolian framework. To the extent that the weight that conditions the within effect of industry i is defined by the nominal value added share of industry i in period $t-1$, the within effect is affected by the cumulative change that has taken place in terms of the nominal value added shares since the base period. To make sure that the within effect is not affected by this cumulative structural change, the decomposition formula is developed in a way whose result is (see Appendix B for the whole development):

$$\begin{aligned}\Delta \ln(\mathrm{LP}_t) = & \sum w_{i0}\left(\Delta \ln(\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln(H_{\mathrm{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right)\right) \\ & + \sum (w_{\mathrm{it}-1} - w_{i0})\Delta \ln(\mathrm{LP}_{\mathrm{it}}) + \sum w_{i0}(\Delta \ln(H_{\mathrm{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) \\ & + \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1})\Delta \ln(H_{\mathrm{it}})\end{aligned} \tag{6}$$

where the subscript 0 refers to the base period.

Consequently, in a Kaldorian–Baumolian framework, which takes into account both the impact of structural change that arises from the reallocation of labour across industries with heterogeneous returns to scale and the impact that arises from the cumulative change in terms of the nominal value added shares, aggregate labour productivity growth can be broken down into the following effects:

$$\Delta \ln(\mathrm{LP}_t) = \sum c_{\mathrm{it}}^{W} + \sum c_{\mathrm{it}}^{\mathrm{SCH}} \tag{7}$$

$$\sum c_{\mathrm{it}}^{W} = \sum w_{i0}\left(\Delta \ln(\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln(H_{\mathrm{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right)\right) \tag{8}$$

$$\sum c_{\mathrm{it}}^{\mathrm{SCH}} = \sum c_{\mathrm{it}}^{\mathrm{BGD}} + \sum c_{\mathrm{it}}^{\mathrm{RSE}} + \sum c_{\mathrm{it}}^{\mathrm{DE}} \tag{9}$$

$$\sum c_{\mathrm{it}}^{\mathrm{BGD}} = \sum (w_{\mathrm{it}-1} - w_{i0})\Delta \ln(\mathrm{LP}_{\mathrm{it}}) \tag{10}$$

$$\sum c_{\mathrm{it}}^{\mathrm{RSE}} = \sum w_{i0}(\Delta \ln(H_{\mathrm{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) = \sum c_{\mathrm{it}}^{\mathrm{KE}} - \sum c_{\mathrm{it}}^{\mathrm{KBE}} \tag{11}$$

$$\sum c_{\mathrm{it}}^{\mathrm{DE}} = \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1})\Delta \ln(H_{\mathrm{it}}) \tag{12}$$

$$\sum c_{\mathrm{it}}^{\mathrm{KE}} = \sum w_{\mathrm{it}-1}(\Delta \ln(H_{\mathrm{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) \tag{13}$$

[13]Considering that (1) $\Delta \ln(Y_{\mathrm{it}}) = \Delta \ln(\mathrm{LP}_{\mathrm{it}}) + \Delta \ln(H_{\mathrm{it}})$, where $\Delta \ln(Y_{\mathrm{it}})$ is the output growth of industry i based on logarithmic growth rates, and that (2) $\beta_i \Delta \ln(Y_{\mathrm{it}})$ yields the productivity gains or losses exhibited by industry i due to its output growth, then it follows that $\left(\frac{\beta_i}{1-\beta_i}\right)\Delta \ln(H_{\mathrm{it}})$ yields the productivity gains or losses exhibited by industry i due to its employment growth (Thirlwall, 2015, ch. 14).

$$\sum c_{\mathrm{it}}^{\mathrm{KBE}} = \sum \left(w_{\mathrm{it}-1} - w_{i0}\right)\left(\Delta \ln\left(H_{\mathrm{it}}\right) - \Delta \ln\left(H_t\right)\right)\left(\frac{\beta_i}{1-\beta_i}\right) \tag{14}$$

where $\sum c_{\mathrm{it}}^{W}$ is the within effect, $\sum c_{\mathrm{it}}^{\mathrm{SCH}}$ is the structural change effect, $\sum c_{\mathrm{it}}^{\mathrm{BGD}}$ stands for the BGD effect, $\sum c_{\mathrm{it}}^{\mathrm{RSE}}$ is the returns to scale effect, $\sum c_{\mathrm{it}}^{\mathrm{DE}}$ is the Denison effect, $\sum c_{\mathrm{it}}^{\mathrm{KE}}$ refers to the Kaldor effect, and $\sum c_{\mathrm{it}}^{\mathrm{KBE}}$ is the Kaldor–Baumol effect.

The *BGD effect* measures, consistent with Baumol's model, the impact that arises from the cumulative change in terms of the nominal value added shares that has taken place since the base period. This effect is positive (negative) if progressive industries have gained (lost) weight in the total nominal value added with respect to the base period.

The *returns to scale effect (RSE)* estimates the impact that stems from the reallocation of labour that takes place across industries with heterogeneous returns to scale. This effect is positive (negative) if labour reallocates to industries with above (below)-average returns to scale.

The *Denison effect* (DE) measures the impact that arises from the reallocation of labour across industries with heterogeneous nominal productivity levels. This effect is positive (negative) if industries with above (below)-average nominal productivity levels gain weight in total employment.

The *Kaldor effect* (KE) differs from the RSE in the nominal value added shares that are used as weights for the industry contributions. While in the latter those shares are taken from the base period, in the former shares are updated in every period. As a result, the Kaldor effect is affected by the cumulative change that takes place in terms of the nominal value added shares since the base period.

The *Kaldor–Baumol effect* (KBE) captures how the cumulative reallocation of nominal value added might lead to the divergence between the Kaldor effect and the returns to scale effect. Since the Kaldor–Baumol effect depends on the cumulative reallocation of nominal value added and the existence of heterogeneous returns to scale, it combines both Baumolian and Kaldorian insights. The Kaldor–Baumol effect will be positive if industries with above-average productivity losses (gains) as a result of a reallocation of labour to industries with below (above)-average returns to scale reduce (increase) their share in the total nominal value added with respect to the base period, and will be negative otherwise. Given the invariability of the returns to scale effect with respect to changes in the nominal value added shares, it follows that this cumulative reallocation of nominal value added implies a trade-off between the Kaldor–Baumol effect and the Kaldor effect.

By including the effects that arise from the reallocation of labour across industries with heterogeneous returns to scale and from the cumulative reallocation of nominal value added, our formula is able to provide a more complete picture on the impact of structural change with respect to the partial views provided by Kaldor's Third Law or the Baumolian framework.

On the one hand, since Kaldor's Third Law does not take into account the cumulative changes in terms of the nominal value added shares, this law estimates the impact of structural change as the sum of the Kaldor effect and the Denison effect. However, as we do not rule out a priori the relevance of the cumulative impact of structural change, our decomposition formula shows that both the BGD effect and the Kaldor–Baumol effect must also be taken into account.

On the other hand, by considering productivity growth at the industry level as exogenous and incorporating the impact of the cumulative reallocation of nominal value added, the Baumolian framework estimates the impact of structural change as the sum of the BGD effect and the Denison effect. However, as we do not assume that every industry in the economy exhibits constant returns to scale, our formula acknowledges that the returns to scale effect must also be considered to estimate the impact of structural change according to a Kaldorian-Baumolian framework.

Finally, it must be said that the formula we are proposing is obviously related to the previous attempts made by McCombie (1980, 1991) and Timmer and Szirmai (2000) to introduce the role of returns to scale into shift-share analysis. Nevertheless, this formula solves some of the significant shortcomings that characterised those previous attempts. First, to the extent that they assume that relative prices are constant, the decompositions proposed by McCombie and by Timmer and Szirmai are not valid for a framework in which real output is deflated with a chained index. Second, although both McCombie and Timmer and Szirmai identified a Kaldorian effect that arises from a reallocation that takes place across industries with heterogeneous returns to scale, none of these decompositions satisfactorily identify the cumulative impact of structural change and, therefore, they do not integrate the Baumolian and Kaldorian effects in a proper way. Third, the only Kaldorian effect identified by Timmer and Szirmai depends on the reallocation of real output that takes place across industries with heterogeneous returns to scale rather than on the reallocation of employment. As a result, their Kaldorian effect is positive as long as real output reallocates to industries with above-average returns to scale, notwithstanding the fact that employment might be shifting away from those industries.

3.3.2 | Asymptotic effects

Beyond using the formula to estimate the average impact of structural change over a period, we also want to know whether the cumulative structural change leads to a gradual slowdown of the total contribution of structural change. This would imply a progressive fall in the productivity growth rate that brings the economy closer to the asymptotic Baumolian result. To shed light on this subject, we use the method proposed by Nordhaus (2008) (also used by Duernecker et al., 2017; Hartwig, 2011; Nishi, 2019; and Oh & Kim, 2015). For each of the effects that are able to evolve asymptotically and that condition the impact of structural change, we use the corresponding expression in the formula, although instead of using annual data we use the average data for the whole period for all the variables except the shares in the nominal product and employment, which we update on a year-to-year basis. By eliminating the volatility of all the other variables, the results capture whether there has been a gradual change in the nominal value added or employment shares that has led to a decreasing contribution over time of the corresponding effect.

Consequently, the formulaes that we use to estimate the asymptotic effects of structural change and the asymptotic productivity growth are the following:

$$\sum c_{\mathrm{it}}^{\mathrm{SCH}_{\mathrm{ASYMP}}} = \sum c_{\mathrm{it}}^{\mathrm{BGD}_{\mathrm{ASYMP}}} + \overline{\sum c_{\mathrm{it}}^{\mathrm{RSE}}} + \sum c_{\mathrm{it}}^{\mathrm{DE}_{\mathrm{ASYMP}}} \tag{15}$$

$$\sum c_{\mathrm{it}}^{\mathrm{BGD}_{\mathrm{ASYMP}}} = \sum \left(w_{\mathrm{it}-1} - w_{i0}\right) \overline{\Delta \ln\left(\mathrm{LP}_{\mathrm{it}}\right)} \tag{16}$$

$$\sum c_{\mathrm{it}}^{\mathrm{DE}_{\mathrm{ASYMP}}} = \sum \left(w_{\mathrm{it}-1} - h_{\mathrm{it}-1}\right) \overline{\Delta \ln\left(H_{\mathrm{it}}\right)} \tag{17}$$

$$\Delta \ln\left(\mathrm{LP}_t\right)_{\mathrm{ASYMP}} = \overline{\sum c_{\mathrm{it}}^{W}} + \sum c_{\mathrm{it}}^{\mathrm{SCH}_{\mathrm{ASYMP}}} \tag{18}$$

where the subscript ASYMP refers to the asymptotic value of the variable and the symbol _ stands for the average value of the variable over the whole period.

The asymptotic impact of structural change is determined by the asymptotic impacts of BGD and the Denison effect. On the one hand, BGD will have an increasingly negative impact if stagnant industries gradually gain weight in terms of the nominal value added. On the other hand, the Denison effect will evolve asymptotically if the Baumolian assumption which establishes that the productivity growth differential of progressive industries fully dissipates into the consumers' rent is not met. If progressive industries do not fully share their productivity gains with stagnant industries, progressive industries will experience a cumulative change in terms of nominal value added that is more favourable than the one that they experience in terms of employment. This will gradually increase the nominal productivity level of progressive industries with respect to stagnant industries, giving rise to the asymptotic evolution of the Denison effect.

4 | RESULTS

4.1 | Verdoorn's law

Table 1 shows the results of the estimation of Verdoorn's Law for the five industry groups after applying the two-step system GMM method. Besides this estimation, Appendix A (Table A2) offers additional results for each industry group that stem from considering all the explanatory variables as strictly exogenous.

Regarding high- and medium-high-tech manufacturing (column 1 of Table 1 and column 1 of Table A2), these industries exhibit significant increasing returns to scale in both estimations. The Verdoorn coefficient (that is, the estimated coefficient on output growth, which measures the impact of this variable on productivity growth) reaches an approximate magnitude of 0.4 when endogeneity is not controlled for, while it increases to a value close to 0.6 when the system GMM method is applied. The growth of the capital-output ratio is also significant in the two estimations, with an approximate coefficient of −0.3.[14]

The group of industries that includes distribution services, post and telecommunications, and financial intermediation (column 2 of Table 1 and column 2 of Table A2) shows a Verdoorn coefficient that is similar to that of high- and medium-high-tech manufacturing, with an approximate magnitude of 0.5 when system GMM is applied. However, the growth of the capital-output ratio is only significant when the endogeneity of output growth is not controlled for.

Low- and medium-low-technological manufacturing (column 3 of Table 1 and column 3 of Table A2) exhibit a Verdoorn coefficient that only turns out to be significantly different from zero when considering the output growth as strictly exogenous. Even though system GMM method leads to the finding that these industries show constant returns to scale, this estimation is not reliable due to the fact that the Hansen test does not exceed the value of 0.10 suggested by Roodman (2009).

To complement our estimations for low- and medium-low-technological manufacturing, we apply the continuously updating GMM estimator (GMM-CUE)[15] and instrument output growth with its own rank (Angeriz et al., 2009; Romero & McCombie, 2016a). As column 1 of Table A3 shows, this method confirms the increasing but moderate returns to scale for this group of industries. Likewise, the growth of the capital-output ratio is found to have a significant impact on productivity growth.

Non-market services, personal services, real estate, and business services (column 4 of Table 1 and column 4 of Table A2) only exhibit increasing returns to scale when endogeneity is not addressed.

[14]Since labour productivity growth equals the growth of the capital-labour ratio minus the growth of the capital-output ratio, the latter variable exhibits the expected negative sign in the estimation results.

[15]Compared to other methods such as two-stage least squares, GMM-CUE exhibits superior finite-sample performance, particularly in the presence of weak instruments (Hahn et al., 2004).

TABLE 1 Estimation of Verdoorn's Law with two-step system GMM

	(1) High- and medium-high-tech manufacturing	(2) Distribution services, post and telecommunications, and financial intermediation	(3) Low- and medium-low-tech manufacturing	(4) Non-market services, personal services, real estate, and business services	(5) Agriculture, mining, utilities, and construction
Output growth	0.611***	0.538***	0.107	0.156	0.313
	(0.157)	(0.128)	(0.149)	(0.344)	(0.225)
Growth of the capital-output ratio	−0.306**	−0.124	−0.382**	−0.265**	−0.506**
	(0.142)	(0.120)	(0.147)	(0.126)	(0.244)
Lag of technology gap	−0.00345	−0.00593**	−0.00221	−0.0133***	−0.0112***
	(0.00303)	(0.00285)	(0.00283)	(0.00373)	(0.00343)
Constant	0.0203***	0.000500	0.0311***	−0.00993	0.0125
	(0.00688)	(0.00545)	(0.00416)	(0.0121)	(0.0450)
Observations	216	324	432	426	216
Number of groups	36	54	72	71	36
Number of instruments/Lags	23/2	33/4	35/6	30/6	18/2
Arellano-Bond AR(1) test	0.000	0.001	0.000	0.000	0.001
Arellano-Bond AR(2) test	0.644	0.646	0.188	0.617	0.435
Hansen test	0.282	0.274	0.039	0.264	0.634
Difference in Hansen test for exogenous variables	0.867	0.744	0.914	0.201	0.358
Difference in Hansen test for GMM instruments for levels	0.295	0.453	0.199	0.490	0.782

Note: Robust standard errors in parentheses. Time effects are used in every estimation.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Source: Own elaboration.

When the system GMM method is applied, the Verdoorn coefficient is no longer significantly different from zero. Nevertheless, we find a negative relation between productivity growth and the growth of the capital-output ratio in the two estimations.

Lastly, as in the previous case, agriculture, mining, utilities, and construction show constant returns to scale when endogeneity is controlled for (column 5 of Table 1 and column 5 of Table A2). Interestingly, both the technological gap and the growth of the capital-output ratio make a significant contribution to productivity growth in these industries.

These results are robust according to different tests. First, when using the 2021 release of EU KLEMS, we also find high increasing returns to scale in high- and medium-high-tech manufacturing, distribution services, post and telecommunications, and financial intermediation, increasing but moderate returns in low- and medium-low-technological manufacturing and constant returns to scale in the remaining industries (Table A4). Second, given that the Verdoorn coefficient might change over time (Basu & Foley, 2013; Romero & McCombie, 2016a; Vaciago, 1975), we check its stability by introducing interaction terms between 10-year period dummies and output growth. As Table A5 shows, none of these interaction terms are significant for any group of industries, so we can conclude that the Verdoorn coefficient is constant over these periods. Third, since meaningful productivity estimates cannot be made for the real estate industry, whose output is mostly (imputed) rent, we check whether the exclusion of this industry alters the estimated Verdoorn coefficient for non-market services, personal services, and business services. Even when real estate is excluded, constant returns to scale are found for that group of industries (column 2 of Table A3). Fourth, in light of the poor productivity performance of business services, which even exhibits negative growth rates in some developed economies (Hartwig & Krämer, 2019), and given its high share in nominal value added and employment, we examine whether these services present different returns to scale to non-market services and personal services. After both introducing an interaction term between output growth and a dummy variable for business services (column 3 of Table A3) and estimating Verdoorn's law specifically for business services[16] (column 4 of Table A3), our findings confirm that the Verdoorn coefficient for these services is not significantly different to that of non-market services and personal services, also exhibiting constant returns to scale. Fifth, given that agriculture, mining, utilities, and construction constitute a heterogeneous group, we check whether any of these industries present different returns to scale to the other three industries by introducing interaction terms between output growth and industry dummies. As column 5 of Table A3 shows, these interaction terms are not significant, so the four industries exhibit the same degree of returns to scale, which are not significantly different from zero.

All in all, these results show that there is substantial heterogeneity in returns to scale within both manufacturing and service industries. Like Magacho and McCombie (2018), Romero and Britto (2017), and Romero and McCombie (2016a), we also find that high- and medium-high-tech manufacturing industries exhibit higher returns to scale than low- and medium-low-tech manufacturing. Likewise, as Di Meglio et al. (2018) and Pieper (2003) previously showed for developing economies, within the service sector there are certain industries that exhibit increasing returns to scale that are similar in magnitude to those of high- and medium-high-tech manufacturing.

4.2 | The impact of structural change on productivity growth[17]

4.2.1 | The average impact of structural change

Table 2 shows the aggregate results of the decomposition of labour productivity growth on average over the period 1978–2007 according to three different perspectives: the Kaldorian–Baumolian framework, Kaldor's Third Law, and the Baumolian framework. The total impact of structural change that

[16]GMM-CUE is used to address the endogeneity of output growth instead of system GMM due to the limited number of groups.

[17]When applying the decomposition formula, we use the Verdoorn coefficients that were obtained in columns 1–2 and 4–5 of Table 1 and column 1 of Table A3. The coefficient is taken as zero when constant returns to scale were found.

TABLE 2 Shift-share analysis of labour productivity growth (1978–2007, in percentage points). Aggregate effects according to different frameworks

		Kaldorian–Baumolian framework		Kaldor's third law		Baumolian framework	
	Total contribution	Within	Structural change	Within	Structural change	Within	Structural change
USA	1.4	2.2	−0.8	1.9	−0.5	1.7	−0.3
UK	2.1	3.3	−1.1	2.7	−0.6	2.6	−0.4
Japan	2.9	2.9	0.0	2.9	0.0	2.8	0.2
Spain	1.6	1.5	0.1	1.2	0.4	1.3	0.3
Italy	1.4	1.4	0.0	1.0	0.4	1.2	0.2
Germany	2.1	2.3	−0.2	2.0	0.1	1.9	0.2
Netherlands	1.5	1.9	−0.4	1.8	−0.3	1.6	−0.1
Finland	2.7	2.7	0.0	2.6	0.2	2.7	0.1
Denmark	1.5	1.6	−0.1	1.5	0.0	1.4	0.1
Austria	2.0	2.3	−0.2	1.9	0.1	2.2	−0.1

Note: The Kaldorian–Baumolian framework considers the following effects within the total structural change effect: the returns to scale effect, BGD, and the Denison effect. Kaldor's Third Law only takes into account the Kaldor effect and the Denison effect, ignoring BGD and the Kaldor–Baumol effect. Lastly, the Baumolian framework only considers BGD and the Denison effect, neglecting the returns to scale effect.

Source: Own elaboration based on EU KLEMS.

stems from the Kaldorian–Baumolian framework differs significantly in several economies from the corresponding estimates of Kaldor's Third Law and the Baumolian framework.[18]

Focusing on the results for the Kaldorian–Baumolian framework, it is apparent that the tertiarisation process has had a significant negative impact on productivity growth only in the US, the UK, and the Netherlands. In contrast, in the remaining seven economies, structural change exerts a limited impact (positive in Spain, negative in Germany, Austria and Denmark and virtually equal to zero in Japan, Italy and Finland).

Looking at the different effects within the total structural change term (Table 3), we find that the returns to scale effect is the one that yields the most negative contribution to productivity growth in the US, the UK, and the Netherlands. Therefore, the expansion of the service sector exerts a substantial negative impact on productivity growth because it is accompanied by a reallocation of labour away from high– and medium-high-tech manufacturing, low– and medium-low-tech manufacturing, distribution services, post and telecommunications, and financial intermediation. However, in comparative terms, these three economies exhibit a negative impact of structural change not only due to the reallocation of labour away from industries with increasing returns to scale, but also because, unlike for the other countries, their Denison effect reinforces (or at least does not ease) the negative contribution of BGD.

[18]Given the observed (average) productivity growth rate per country, the estimate for the within effect varies with the estimate for the effect of structural change. Therefore, the within effect that stems from the Kaldorian–Baumolian framework also differs significantly in several economies from the corresponding estimates of Kaldor's Third Law and the Baumolian framework.

TABLE 3 Decomposition of the structural change effect in a Kaldorian–Baumolian framework (1978–2007, in percentage points)

	Returns to scale effect	Kaldor effect	Kaldor-Baumol effect	BGD	Denison effect
USA	−0.5	−0.4	0.1	−0.2	−0.1
UK	−0.7	−0.4	0.3	−0.3	−0.2
Japan	−0.1	−0.2	0.0	0.0	0.1
Spain	−0.2	−0.1	0.1	−0.2	0.5
Italy	−0.1	−0.1	0.1	−0.3	0.5
Germany	−0.4	−0.3	0.1	−0.3	0.4
Netherlands	−0.3	−0.3	0.1	−0.1	0.0
Finland	−0.1	0.0	0.0	−0.1	0.2
Denmark	−0.2	−0.2	0.0	0.0	0.2
Austria	−0.1	0.0	0.0	−0.3	0.1

Source: Own elaboration based on EU KLEMS.

In contrast, structural change exerts a limited impact in the remaining seven economies because a moderate returns to scale effect is combined with a positive Denison effect,[19] which compensates for the negative magnitude of BGD.[20] Thus, the reallocation of labour to industries with above-average nominal productivity levels allows these economies to restrain the negative impact linked to the cumulative expansion of stagnant industries over the total nominal value added.

The total impact of structural change that stems from the Kaldorian–Baumolian framework differs significantly in several economies from the corresponding estimates of Kaldor's Third Law and the Baumolian framework. On the one hand, Kaldor's Third Law underestimates (overestimates) the negative (positive) impact of structural change with respect to the Kaldorian–Baumolian framework by at least 0.3% points in the US, the United Kingdom, Spain, Italy, Germany, and Austria. Given the irrelevance of the Kaldor–Baumol effect in all these economies (with the only exception of the UK), this divergence is explained by the negative impact of BGD (Table 3).

On the other hand, the Baumolian framework underestimates the negative impact of structural change with respect to the Kaldorian–Baumolian framework by at least 0.3% points in the United States, the United Kingdom, Germany and the Netherlands. In these economies, the reallocation of labour away from industries with increasing returns to scale has led to a substantially negative returns to scale effect (Table 3), which underpins the difference between the results according to the Kaldorian–Baumolian framework and those of the Baumolian framework. Consequently, while both Kaldor's Third Law and the Baumolian framework significantly underestimate (overestimate) the negative (positive) impact of structural change, the Kaldorian–Baumolian framework is able to provide a more complete picture of the effects that stem from the expansion of the service sector.

Lastly, we check the robustness of our results on the average impact of structural change by using the 2021 release of EU KLEMS. Our main findings hold when using this release. First, in 1996–2018, the number of economies where the tertiarisation process has had a significant negative impact is

[19]The magnitude of this positive contribution is mainly explained by the initial share of agriculture in employment given the large negative differential in terms of nominal productivity levels that this industry exhibits when it concentrates more employment.

[20]The only two economies where BGD does not make a negative contribution are Japan and Denmark.

still moderate (Table A6), even if it has slightly grown from three to five with respect to 1978–2007. Second, the economies where structural change exerts a limited impact exhibit a more moderate returns to scale effect and/or a more positive Denison effect, which compensates the negative contribution of BGD (Table A7). And, third, the Kaldorian-Baumolian framework yields an impact of structural change that differs significantly from the corresponding estimates of the other two frameworks, particularly the Baumolian framework in 1996–2018 (due to the fact that the returns to scale effect makes a strong contribution in several economies over this period).

4.2.2 | The asymptotic impact of structural change

The asymptotic impact of structural change on productivity growth depends on the combined asymptotic evolution of BGD and the Denison effect. Regarding the asymptotic impact of the former effect (Figure 1), six of the 10 economies exhibit a clear negative trend in the evolution of their BGD. In Italy, Spain, the UK, Germany, the US, and Austria, stagnant industries have gained weight in terms of the nominal value added. After 30 years of this cumulative structural change, BGD has led to a slowdown in the productivity growth rate in these five economies that varies from −0.3% points in Germany, the US or Austria to −0.8 points in Italy. To the contrary, in the other four economies, either there is no significant trend in the evolution of BGD (this is the case of Finland, Japan and the Netherlands) or there is a reallocation of nominal value added to progressive industries (Denmark).

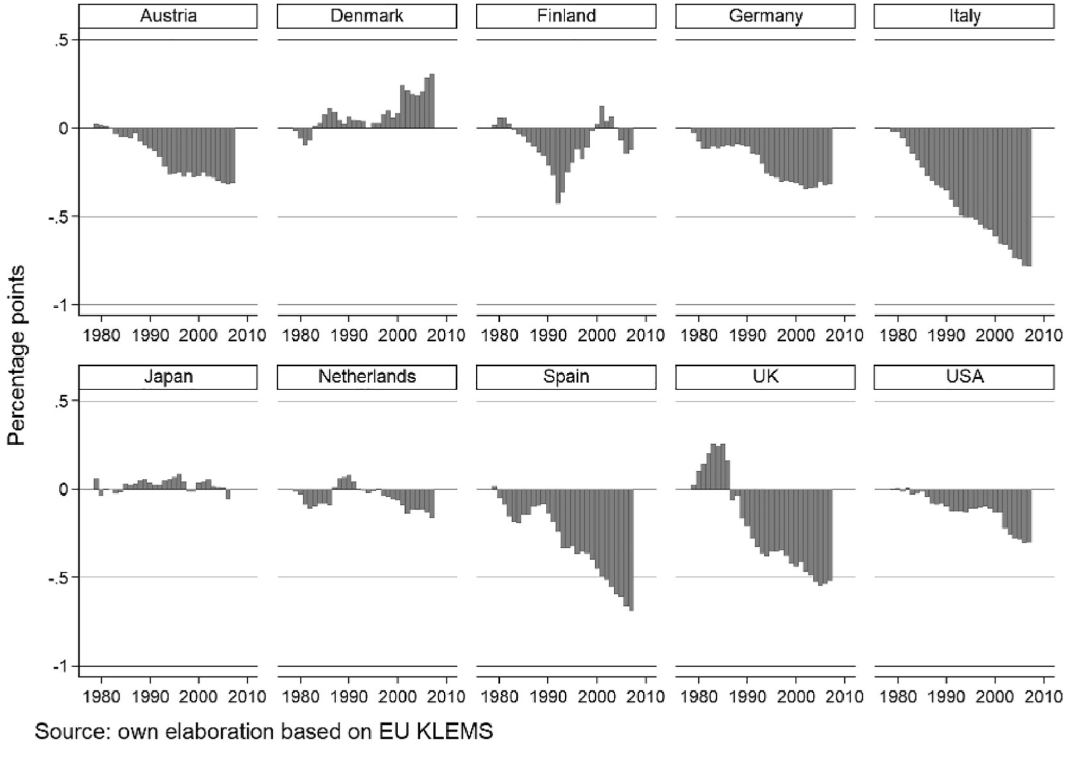

FIGURE 1 Asymptotic impact of BGD on labour productivity growth

As explained in the methodological section, the asymptotic evolution of the Denison effect depends on the divergence between the cumulative changes in terms of employment and in terms of nominal value added. Since the productivity growth differential of progressive industries is usually higher than the relative price growth differential, progressive industries lose more weight in terms of employment than they do in terms of nominal value added. As a result, this process leads to a gradual increase in the nominal productivity level of progressive industries with respect to stagnant industries, giving rise to the asymptotic evolution of the Denison effect in most of these economies (Figure 2).

However, there are three countries (Germany, the US and the UK) that do not show a substantial decline in the Denison effect over the period. For Germany and the US economy, it is the low degree of divergence between the cumulative changes in terms of employment and in terms of nominal value added that explains the limited decrease in the contribution of the Denison effect. On the other hand, the upward trend followed by the Denison effect in the UK is due to the fact that progressive industries lose more weight in terms of nominal value added than in terms of employment, which happens when the fall in the relative price of progressive industries exceeds the magnitude of their productivity growth differential in absolute values.

Regarding the remaining economies, the Denison effect follows a declining trend in Italy, Austria, Finland, Japan, the Netherlands, and Denmark. If we compare the results of the ending year of the period with those of the beginning year, the decrease in the contribution of the Denison effect has slowed down the productivity growth rate by −0.3% points in Austria, Finland, Japan, the Netherlands, and Denmark and by −0.5 points in Italy. Finally, the declining trend in the Spanish

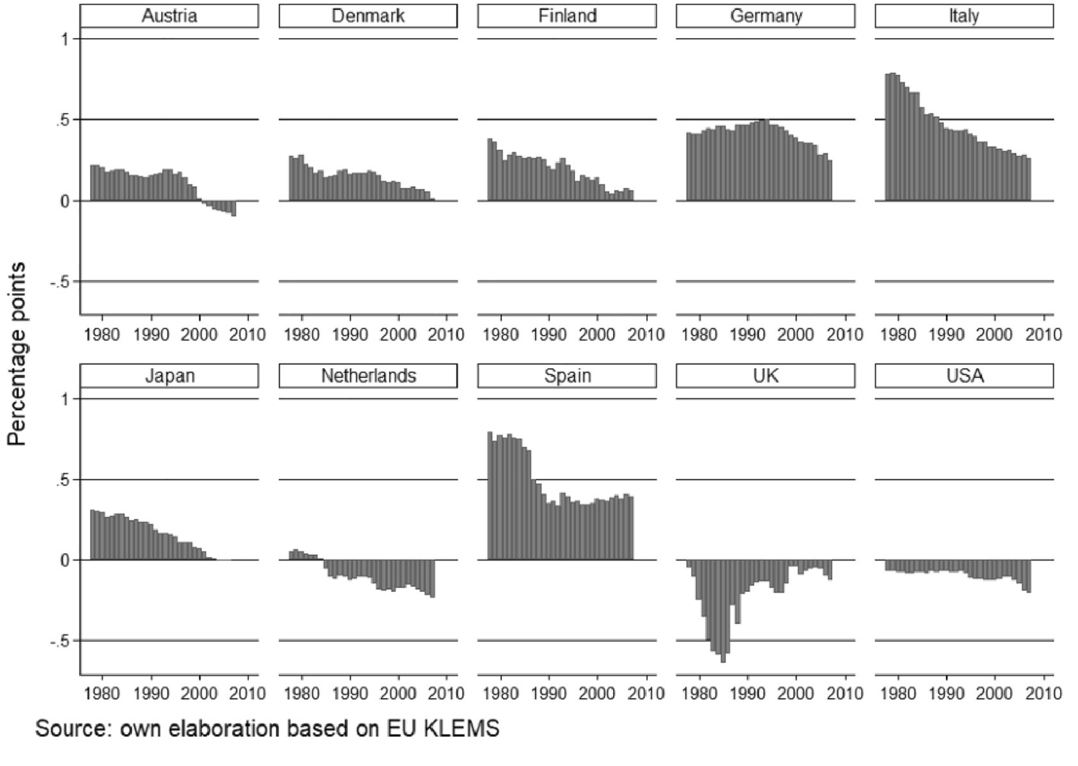

FIGURE 2 Asymptotic impact of the Denison effect on labour productivity growth

economy, while similar to that in Italy for the whole period, does not occur gradually. After an initial sharp fall, the contribution of the Denison effect remains stable in Spain. This decline (which is gradual in the case of Italy, Austria, Finland, Japan, the Netherlands, and Denmark, but abrupt for Spain) undermines the positive contribution of the Denison effect to productivity growth that is observed in the first year.

As a result of the asymptotic trends followed by BGD and the Denison effect, there is a gradual decrease in the total contribution of structural change to productivity growth in all these economies, with the sole exception of Denmark (Figure 3). In Denmark, the gradual decline in the Denison effect is not strong enough to offset the impact of the expansion of progressive industries in the total nominal value added. In the remaining nine economies, the asymptotic fall in the productivity growth rate stemming from structural change varies from −0.4 points in Japan, the US, the Netherlands, and Finland to −1.3 points in Italy. As has been shown, in Germany, the US and the UK the asymptotic decline is linked to BGD rather than to the Denison effect. In Spain, Italy, and Austria, both BGD and the Denison effect contribute to the asymptotic decline. Lastly, in Japan, the Netherlands and Finland, it is only the Denison effect that accounts for the asymptotic decline.

Therefore, the expansion of the service sector implied a progressive fall in the productivity growth rate in nine of the 10 economies over 1978–2007 (Figure 4). This result is also confirmed when using the 2021 release of EU KLEMS. As Figure A1 shows, all these economies suffered a reallocation of employment to the stagnant sector before the 2008 crisis, which led to an asymptotic decline in the

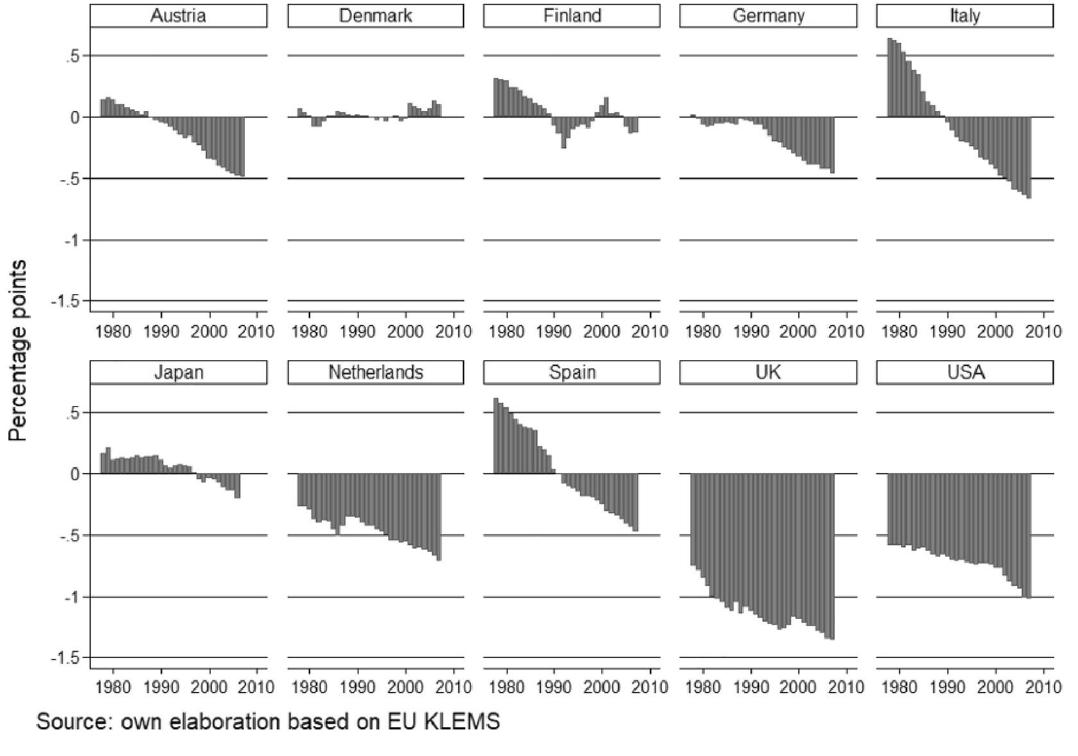

FIGURE 3 Asymptotic impact of structural change on labour productivity growth

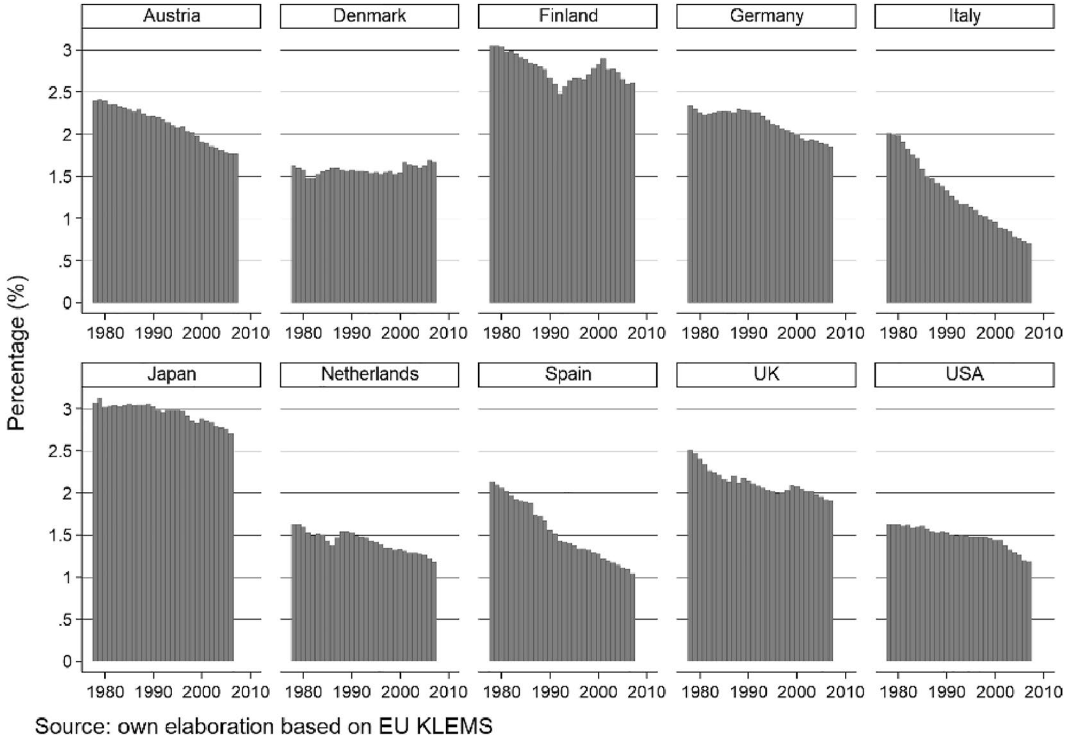

FIGURE 4 Asymptotic productivity growth

contribution of structural change to productivity growth.[21] Even though some economies managed to stop this reallocation after the outbreak of the crisis, they were not able to reverse this process by fostering a reallocation to the progressive sector. As a result, productivity growth in these economies is still strongly affected by the cumulative structural change that took place over 1978–2007.

5 | CONCLUDING REMARKS

This study has addressed the impact of the tertiarisation process on labour productivity growth in 10 developed economies in the period 1978–2007 from a Kaldorian–Baumolian perspective. To that end, we have modified shift-share analysis to integrate satisfactorily both Kaldorian and Baumolian effects to produce a better estimate of the impact of structural change on productivity growth. First, the modified shift-share analysis includes the effect emphasised by Kaldorian theory by considering that productivity growth is endogenous and that there are heterogeneous Verdoorn coefficients across industries. In this sense, this analysis also overcomes the usual limitations that empirical studies on the impact of structural change have exhibited, whereby structural change and those variables that affect productivity growth at the industry level (*e.g.* demand expansion) are taken as independent from each other. Second, consistent with the Baumolian framework, this analysis also includes the impact that arises from the cumulative changes that take place in terms of the nominal value added and employment shares.

[21]Besides showing the asymptotic impact of structural change in Figure A1, Figures A2–A4 show the asymptotic impact of BGD, the asymptotic impact of the Denison effect and the asymptotic productivity growth rates, respectively.

Our results stress the necessity of integrating both theories, since either the estimation of Kaldor's Third Law or the Baumolian impact of structural change would substantially underestimate (overestimate) the negative (positive) impact of the tertiarisation process in several economies. Our integrated analysis gives a more precise evaluation of the average impact of the tertiarisation process on productivity growth on average for the whole period; also, by incorporating the Baumolian effect, it allows determination of whether the contribution of structural change has followed a declining trend, leading to a progressive fall in the productivity growth rate that brings the economy closer to the Baumolian asymptotic result.

Moreover, the prior econometric estimation of Verdoorn's Law, which is required in order to apply the decomposition formula, shows that the dichotomy between services and manufacturing (which both Baumol's model and Kaldorian theory assume) is an oversimplification. The results of the estimation of Verdoorn's Law confirm that there is substantial heterogeneity in returns to scale within both manufacturing and service industries. On the one hand, high- and medium-high-tech manufacturing industries exhibit higher increasing returns to scale than low- and medium-low-tech manufacturing. On the other hand, distribution services, post and telecommunications, and financial intermediation show increasing returns comparable to those of high- and medium-high-tech manufacturing, while non-market services, personal services, real estate, and business services exhibit constant returns to scale.

Regarding the results of the shift-share analysis for the 10 economies, it must be highlighted that the average impact of structural change on productivity growth has been substantially negative in only three economies (the US, the UK, and the Netherlands), though the cumulative reallocation of employment to stagnant industries has led to a gradual decrease in the contribution of structural change in nine of the 10 economies. These results make clear that, for most of these economies, tertiarisation does not substantially undermine productivity growth in the short term, mainly because it does not strongly limit the extent of the market in industries with increasing returns. However, in the long term, tertiarisation comes with the gradual fall in employment of the technologically progressive sector of the economy, thereby imposing an ever-increasing structural burden for aggregate productivity growth. Consequently, the empirical evidence found in this paper supports Baumol's seminal fear concerning the long-term stagnation of productivity growth that might be brought about by an ongoing tertiarisation process.

Despite its achievements, our analysis also presents some limitations. First, to the extent that our decomposition formula did not take into account the fact that the growth of the capital-output ratio depends on the growth of demand, the analysis neglected the impact that stems from the reallocation of employment across industries that exhibit heterogeneous elasticities of the capital-output ratio with respect to demand. Second, this decomposition formula assumes that the Verdoorn coefficient is exogenous within each country-industry panel, but there is empirical evidence that shows that its magnitude depends on factors such as the level of development (Magacho & McCombie, 2018), the rate of expansion of demand (Alexiadis & Tsagdis, 2009; Pieper, 2003), or the innovative effort (Romero & Britto, 2017). Third, since it is a decomposition technique, although it incorporates the impact of structural change that arises from the reallocation of labour across industries with heterogeneous returns to scale, it neglects the causal relationships that define a growth process with structural change and cumulative causation. In this sense, it would be necessary to formulate a model in which structural change is endogenised, incorporating the different factors that explain, for each industry or sector, its demand growth differential as well as its productivity growth differential (Araujo, 2013). Given that the Kaldorian literature has barely delved into the factors that determine the interrelationship between structural change and economic growth (Romero, 2016), we intend to address these issues in a future investigation.

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APPENDIX A: ADDITIONAL TABLES AND FIGURES

TABLE A1 Classification of economic activities

Description	NACE rev. 1 [KLEMS code]
Agriculture, hunting, forestry and fishing	AtB
Mining and quarrying	C
Food, beverages and tobacco	D15t16
Textiles, textile, leather and footwear	D17t19
Wood and of wood and cork	D20
Pulp, paper, paper, printing and publishing	D21t22
Coke, refined petroleum and nuclear fuel	D23
Chemicals and chemical products	D24
Rubber and plastics	D25
Other non-metallic mineral	D26
Basic metals and fabricated metal	D27t28
Machinery, NEC	D29
Electrical and optical equipment	D30t33
Transport equipment	D34t35
Manufacturing NEC; recycling	D36t37
Electricity, gas and water supply	E
Construction	F
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	G50
Wholesale trade and commission trade, except of motor vehicles and motorcyles	G51
Retail trade, except of motor vehicles and motorcycles; repair of household goods	G52
Hotels and restaurants	H
Transport and storage	I60t63
Post and telecommunications	I64
Financial intermediation	J
Real estate activities	K70
Renting of m&eq and other business activities	K71t74
Public admin and defence; compulsory social security	L
Education	M
Health and social work	N
Other community, social and personal services	O
Private households with employed persons	P

Source: Own elaboration based on EU KLEMS.

TABLE A2 Estimation of Verdoorn's Law with fixed effects

	(1) High- and medium-high-tech manufacturing	(2) Distribution services, post and telecommunications, and financial intermediation	(3) Low- and medium-low-tech manufacturing	(4) Non-market services, personal services, real estate and business services	(5) Agriculture, mining, utilities, and construction
Output growth	0.409***	0.505***	0.220***	0.377***	0.363***
	(0.0964)	(0.0576)	(0.0648)	(0.111)	(0.116)
Growth of the capital-output ratio	−0.379***	−0.285***	−0.303***	−0.177***	−0.442***
	(0.112)	(0.0504)	(0.0547)	(0.0606)	(0.104)
Lag of technology gap	−0.00399	0.0132***	−0.00990**	−0.0186	−0.0304***
	(0.00427)	(0.00438)	(0.00425)	(0.0116)	(0.00819)
Constant	0.0216***	0.0135***	0.0254***	−0.00879**	0.00254
	(0.00355)	(0.00251)	(0.00183)	(0.00386)	(0.00477)
Observations	216	324	432	432	216
R-squared	0.708	0.694	0.478	0.271	0.711
Number of groups	36	54	72	72	36

Note: Robust standard errors in parentheses. Time effects are used in every estimation.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Source: Own elaboration.

TABLE A3 Robustness check for Verdoorn's Law

	(1) Low- and medium-low-tech manufacturing (GMM-CUE)	(2) Non-market services, personal services, and business services (excluding real estate) (two-step system GMM)	(3) Non-market services, personal services, real estate, and business services (two-step system GMM)	(4) Business services (GMM-CUE)	(5) Agriculture, mining, utilities, and construction (two-step system GMM)
Output growth	0.252***	0.392	0.503	0.164	0.449
	(0.0831)	(0.268)	(0.314)	(0.178)	(0.575)
Growth of the capital-output ratio	−0.279***	−0.263*	−0.257*	−0.174**	−0.538*
	(0.0729)	(0.137)	(0.153)	(0.0697)	(0.298)

TABLE A3 (Continued)

	(1) Low- and medium-low-tech manufacturing (GMM-CUE)	(2) Non-market services, personal services, and business services (excluding real estate) (two-step system GMM)	(3) Non-market services, personal services, real estate, and business services (two-step system GMM)	(4) Business services (GMM-CUE)	(5) Agriculture, mining, utilities, and construction (two-step system GMM)
Lag of technology gap	−0.00983*	−0.0109*	−0.0122**	−0.0332*	−0.00668
	(0.00522)	(0.00557)	(0.00561)	(0.0192)	(0.00901)
Dummy business services x Output growth			−0.331		
			(0.671)		
Dummy agriculture x Output growth					−0.0587
					(0.943)
Dummy mining x Output growth					0.162
					(0.756)
Dummy construction x Output growth					−0.656
					(0.663)
Constant		−0.00175	−0.00236		0.0192
		(0.0122)	(0.0128)		(0.0321)
Observations	432	372	378	54	216
R-Squared	0.477			0.462	
Number of groups	72	62	63	9	36
Kleibergen-Paap rk Wald F statistic	232.009			78.649	
Number of instruments/Lags		30/6	30/6		24/3
Arellano-Bond AR(1) test		0.001	0.001		0.021
Arellano-Bond AR(2) test		0.152	0.157		0.507
Hansen test		0.376	0.295		0.496
Difference in Hansen test for exogenous variables		0.120	0.220		0.350
Difference in Hansen test for GMM instruments for levels		0.685			

Note: Robust standard errors in parentheses. Time effects are used in every estimation. Even though the model in column 3 includes a dummy for business services and the model in column 5 includes dummies for agriculture, mining and construction, their coefficients are not shown in the table.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Source: Own elaboration.

TABLE A4 Additional estimations of Verdoorn's Law using the 2021 release of EU KLEMS

	(1) High- and medium-high-tech manufacturing (two-step system GMM)	(2) Distribution services, post and telecommunications, and financial intermediation (two-step system GMM)	(3) Low- and medium-low-tech manufacturing (GMM-CUE)	(4) Non-market services, personal services, real estate, and business services (two-step system GMM)	(5) Agriculture, mining, utilities, and construction (two-step system GMM)
Output growth	0.630***	0.741***	0.348***	0.175	0.244
	(0.139)	(0.193)	(0.103)	(0.233)	(0.224)
Growth of the capital-output ratio	−0.124	0.160	−0.102	−0.340**	−0.453*
	(0.108)	(0.162)	(0.0626)	(0.157)	(0.226)
Lag of technology gap	−0.321	0.446	−3.620***	0.172	−0.505
	(0.258)	(0.445)	(1.247)	(0.424)	(0.357)
Constant	0.182	−0.464		0.561	1.588***
	(0.769)	(0.698)		(0.531)	(0.541)
Observations	145	200	300	350	195
R-squared			0.391		
Number of groups	29	40	60	70	39
Number of instruments/Lags	24/4	24/4		20/4	18/2
Arellano-Bond AR(1) test	0.088	0.002		0.036	0.022
Arellano-Bond AR(2) test	0.836	0.565		0.995	0.303
Hansen test	0.244	0.304		0.562	0.293
Difference in Hansen test for exogenous variables	0.234	0.108		0.612	0.158
Difference in Hansen test for GMM instruments for levels	0.366	0.133		0.730	0.241
Kleibergen-Paap rk Wald F statistic			151.144		

Note: Robust standard errors in parentheses. Time effects are included in every estimation.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Source: Own elaboration.

TABLE A5 Additional estimations of Verdoorn's Law including interaction terms between output growth and period dummies

	(1) High- and medium-high-tech manufacturing (two-step system GMM)	(2) Distribution services, post and telecommunications, and financial intermediation (two-step system GMM)	(3) Low- and medium-low-tech manufacturing (GMM-CUE)	(4) Non-market services, personal services, real estate, and business services (two-step system GMM)	(5) Agriculture, mining, utilities, and construction (two-step system GMM)
Output growth	0.615**	0.707*	0.356***	0.253	0.178
	(0.283)	(0.416)	(0.118)	(0.487)	(0.461)
Growth of the capital-output ratio	−0.164	−0.0813	−0.218***	−0.266	−0.626***
	(0.152)	(0.127)	(0.0732)	(0.169)	(0.206)
Lag of technology gap	−0.00241	−0.00408	−0.00987*	−0.0114**	−0.0108***
	(0.00263)	(0.00664)	(0.00581)	(0.00554)	(0.00358)
Dummy 1988–1997 x	−0.210	−0.150	−0.132	−0.0383	0.220
Output growth	(0.375)	(0.424)	(0.115)	(0.659)	(0.560)
Dummy 1998–2007 x	0.114	−0.0719	−0.0917	−0.237	0.245
Output growth	(0.312)	(0.498)	(0.0868)	(0.484)	(0.607)
Constant	0.0246	−0.00198		−0.0142	0.0370**
	(0.0153)	(0.0145)		(0.0154)	(0.0165)
Observations	216	324	432	426	216
R-squared			0.449		
Number of groups	36	54	72	71	36
Kleibergen-Paap rk Wald F statistic			156.814		
Number of instruments/Lags	18/2	28/4		30/6	18/2
Arellano-Bond AR(1) test	0.000	0.004		0.000	0.002
Arellano-Bond AR(2) test	0.290	0.414		0.608	0.828
Hansen test	0.293	0.361		0.188	0.595

(Continues)

TABLE A5 (Continued)

	(1) High- and medium-high-tech manufacturing (two-step system GMM)	(2) Distribution services, post and telecommunications, and financial intermediation (two-step system GMM)	(3) Low- and medium-low-tech manufacturing (GMM-CUE)	(4) Non-market services, personal services, real estate, and business services (two-step system GMM)	(5) Agriculture, mining, utilities, and construction (two-step system GMM)
Difference in Hansen test for exogenous variables	0.786	0.825		0.211	0.757
Difference in Hansen test for GMM instruments for levels	0.708	0.252		0.393	0.583

Note: Robust standard errors in parentheses. Time effects are used in every estimation. Even though every estimation includes dummies for 1988–1997 and 1998–2007, their coefficients are not shown in the table.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Source: Own elaboration.

TABLE A6 Shift-share analysis of labour productivity growth using the 2021 release of EU KLEMS (1996–2018, in percentage points). Aggregate effects according to different frameworks

		Kaldorian–Baumolian framework		Kaldor's third law		Baumolian framework	
	Total contribution	Within	Structural change	Within	Structural change	Within	Structural change
USA	1.5	2.0	−0.6	1.8	−0.4	1.6	−0.1
UK	1.2	1.4	−0.2	1.3	−0.1	0.9	0.3
Japan	0.7	0.7	0.0	0.6	0.1	0.5	0.3
Spain	0.7	0.8	−0.1	0.5	0.2	0.4	0.3
Italy	0.3	0.6	−0.3	0.4	−0.2	0.3	0.0
Germany	1.1	1.4	−0.3	1.3	−0.2	1.1	0.0
Netherlands	1.0	2.0	−0.9	1.8	−0.8	1.3	−0.3
Finland	1.1	1.9	−0.7	1.6	−0.5	1.3	−0.2
Denmark	1.0	1.3	−0.2	1.0	0.0	1.1	−0.1
Austria	1.2	1.3	−0.1	1.2	0.1	1.1	0.1

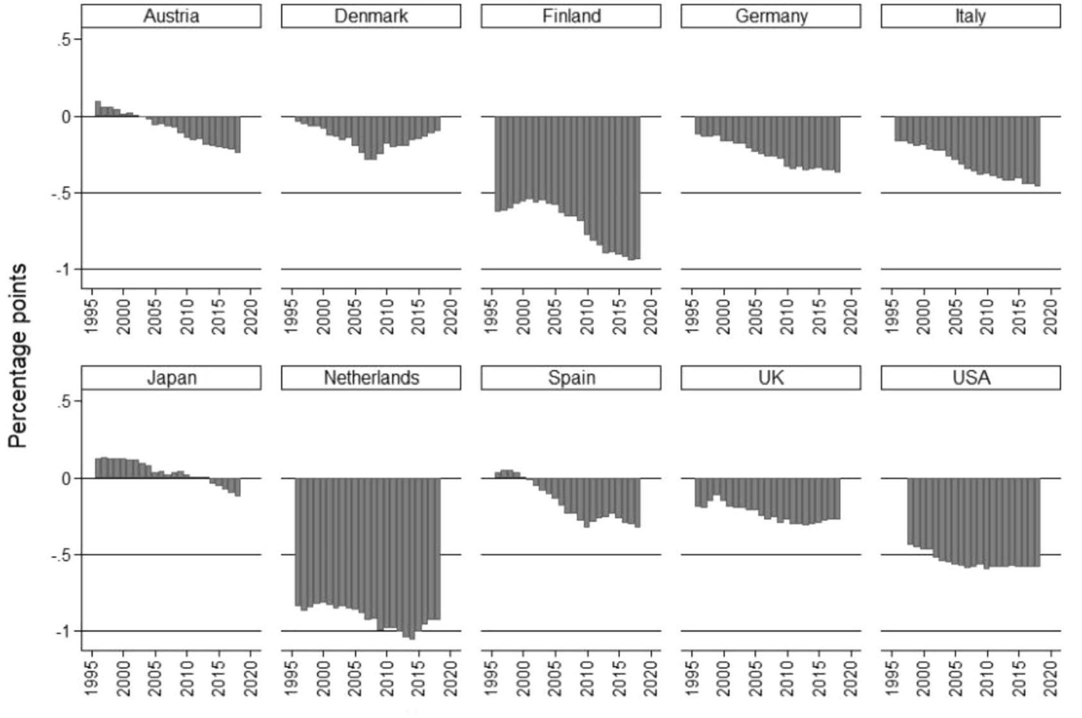
Note: the Kaldorian–Baumolian framework considers the following effects within the total structural change effect: the returns to scale effect, BGD, and the Denison effect. Kaldor's Third Law only takes into account the Kaldor effect and the Denison effect, ignoring BGD and the Kaldor–Baumol effect. Lastly, the Baumolian framework only considers BGD and the Denison effect, neglecting the returns to scale effect.

Source: Own elaboration based on EU KLEMS.

TABLE A7 Decomposition of the structural change effect in a Kaldorian–Baumolian framework using the 2021 release of EU KLEMS (1996–2018, in percentage points)

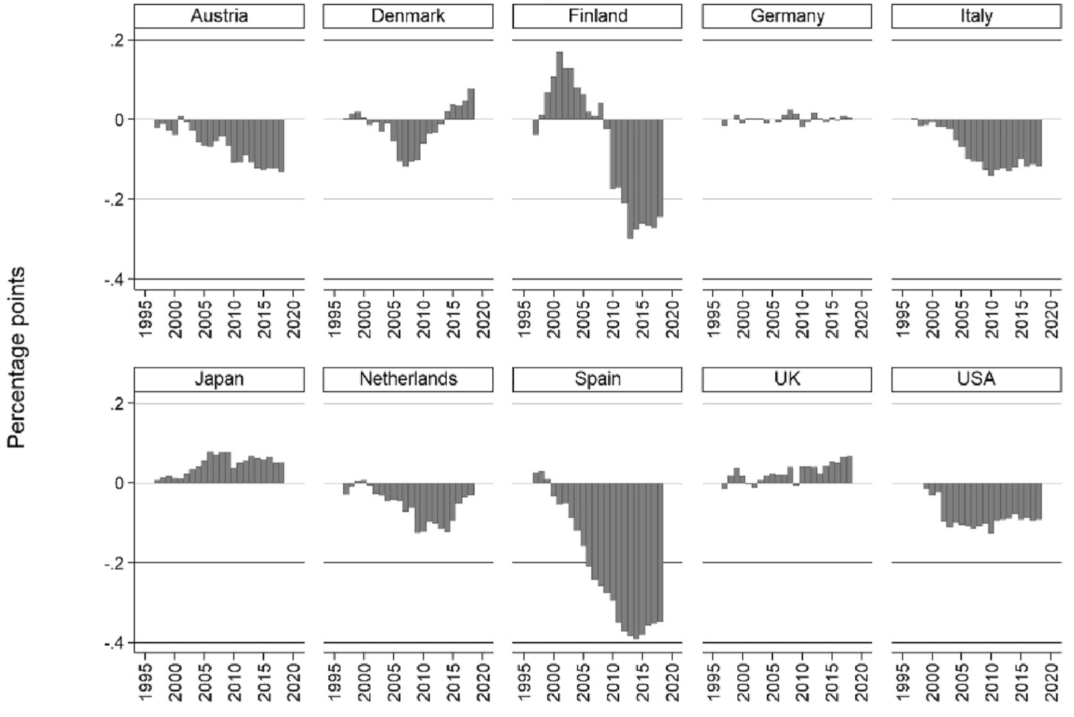
	Returns to scale effect	Kaldor effect	Kaldor-Baumol effect	BGD	Denison effect
USA	−0.4	−0.4	0.1	−0.1	0.0
UK	−0.5	−0.4	0.1	0.0	0.3
Japan	−0.2	−0.2	0.1	0.0	0.3
Spain	−0.4	−0.3	0.2	−0.1	0.4
Italy	−0.3	−0.3	0.1	−0.1	0.1
Germany	−0.3	−0.3	0.0	−0.1	0.1
Netherlands	−0.6	−0.5	0.1	−0.1	−0.2
Finland	−0.6	−0.5	0.1	−0.1	0.0
Denmark	−0.2	−0.1	0.1	−0.2	0.1
Austria	−0.2	−0.1	0.1	−0.1	0.2

Source: Own elaboration based on EU KLEMS.



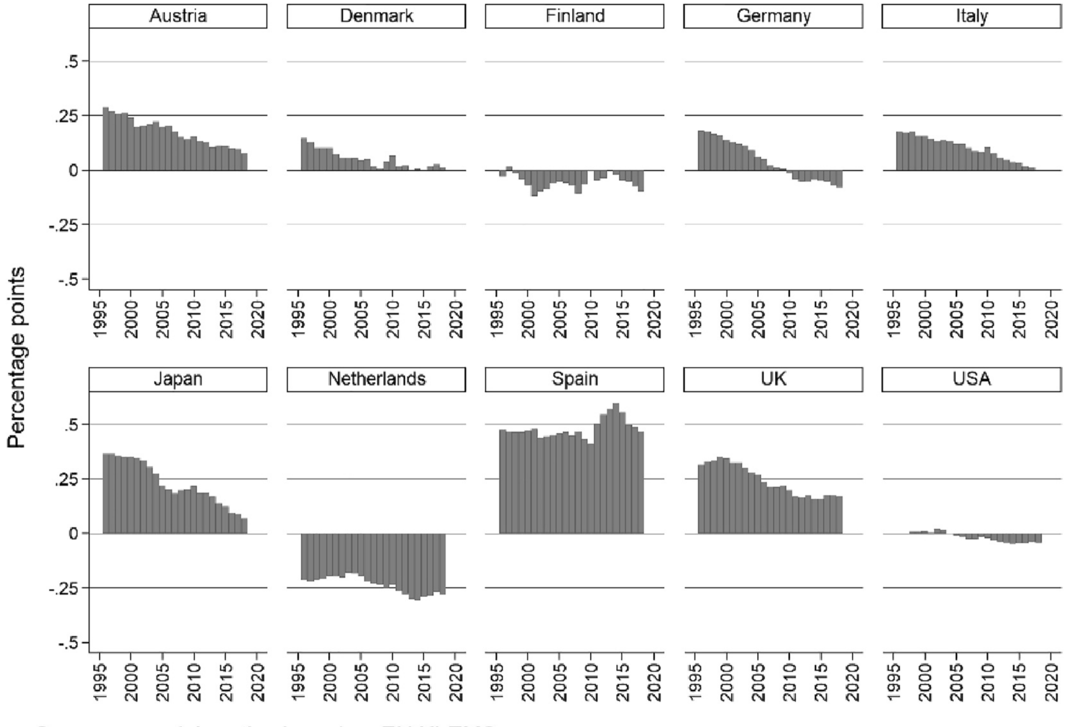
Source: own elaboration based on EU KLEMS

FIGURE A1 Asymptotic impact of structural change on labour productivity growth using the 2021 release of EU KLEMS



Source: own elaboration based on EU KLEMS

FIGURE A2 Asymptotic impact of BGD on labour productivity growth using the 2021 release of EU KLEMS



Source: own elaboration based on EU KLEMS

FIGURE A3 Asymptotic impact of the Denison effect on labour productivity growth using the 2021 release of EU KLEMS

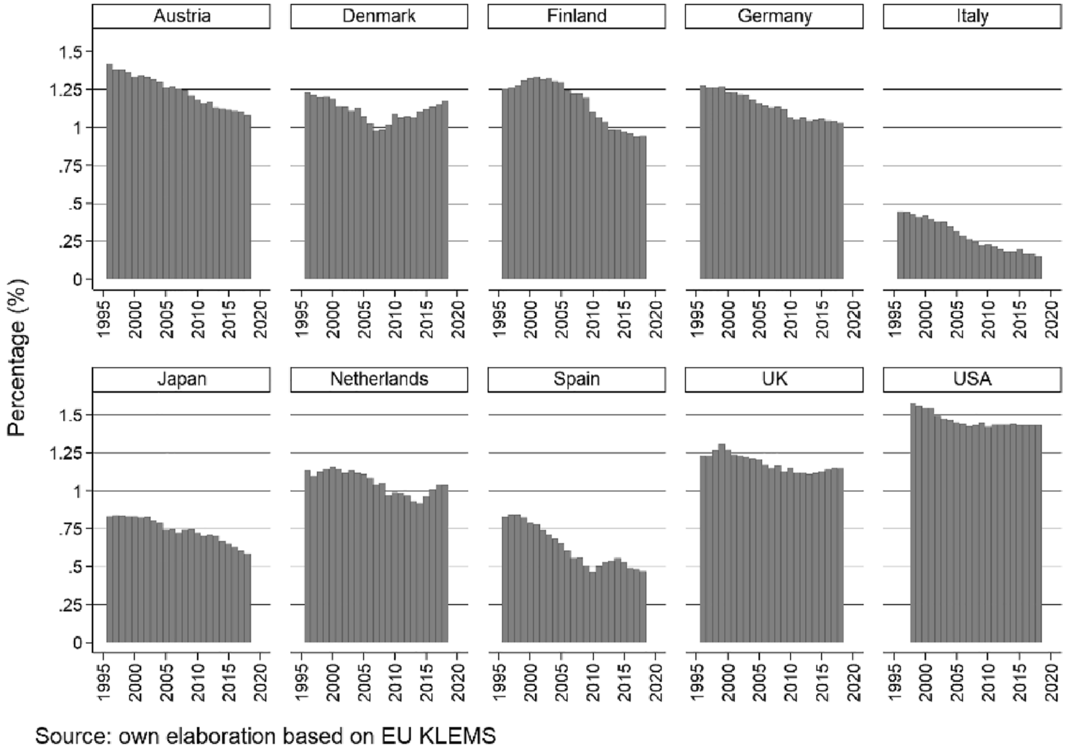


FIGURE A4 Asymptotic productivity growth using the 2021 release of EU KLEMS [Colour figure can be viewed at wileyonlinelibrary.com]

APPENDIX B: DEVELOPMENT OF THE DECOMPOSITION OF AGGREGATE LABOUR PRODUCTIVITY GROWTH IN A KALDORIAN–BAUMOLIAN FRAMEWORK

In Subsection 3.3.1, we omitted the following step in the development of our decomposition formula:

$$\begin{aligned}\Delta \ln(\text{LP}_t) = & \sum w_{\text{it}-1}\Delta \ln(\text{LP}_{\text{it}}) - \sum w_{\text{it}-1}(\Delta \ln(H_{\text{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) \\ & + \sum w_{\text{it}-1}(\Delta \ln(H_{\text{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) + \sum(w_{\text{it}-1} - h_{\text{it}-1})\Delta \ln(H_{\text{it}}) \\ = & \sum w_{\text{it}-1}\left(\Delta \ln(\text{LP}_{\text{it}}) - (\Delta \ln(H_{\text{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right)\right) \\ & + \sum w_{\text{it}-1}(\Delta \ln(H_{\text{it}}) - \Delta \ln(H_t))\left(\frac{\beta_i}{1-\beta_i}\right) \\ & + \sum(w_{\text{it}-1} - h_{\text{it}-1})\Delta \ln(H_{\text{it}})\end{aligned}$$

$$= \sum (w_{i0} + (w_{\mathrm{it}-1} - w_{i0})) \left(\Delta \ln (\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) \right)$$

$$+ \sum w_{\mathrm{it}-1} (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) + \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1}) \Delta \ln (H_{\mathrm{it}})$$

$$= \sum w_{i0} \left(\Delta \ln (\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) \right)$$

$$+ \sum (w_{\mathrm{it}-1} - w_{i0}) \left(\Delta \ln (\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) \right)$$

$$+ \sum w_{\mathrm{it}-1} (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) + \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1}) \Delta \ln (H_{\mathrm{it}})$$

$$= \sum w_{i0} \left(\Delta \ln (\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln (\mathrm{H}_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) \right)$$

$$+ \sum (w_{\mathrm{it}-1} - w_{i0}) \Delta \ln (\mathrm{LP}_{\mathrm{it}}) - \sum (w_{\mathrm{it}-1} - w_{i0}) (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right)$$

$$+ \sum w_{\mathrm{it}-1} (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) + \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1}) \Delta \ln (H_{\mathrm{it}})$$

$$= \sum w_{i0} \left(\Delta \ln (\mathrm{LP}_{\mathrm{it}}) - (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right) \right)$$

$$+ \sum (w_{\mathrm{it}-1} - w_{i0}) \Delta \ln (\mathrm{LP}_{\mathrm{it}}) + \sum w_{i0} (\Delta \ln (H_{\mathrm{it}}) - \Delta \ln (H_t)) \left(\frac{\beta_i}{1 - \beta_i} \right)$$

$$+ \sum (w_{\mathrm{it}-1} - h_{\mathrm{it}-1}) \Delta \ln (H_{\mathrm{it}})$$