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The effect of congestion and agglomeration on multifactor productivity growth in Dutch regions

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Abstract

It is well known that labour productivity growth in Europe is slowing down, against an increasing growth rate in the US. The Netherlands is one of the countries in Europe with the lowest growth rates of productivity. This article looks at this phenomenon from a regional perspective and presents the results of a growth accounting exercise applied to regional industry data of The Netherlands between 1995 and 2002. We find that slow productivity growth in The Netherlands is particularly situated in the economic core regions and is caused by slow multifactor productivity (mfp) growth. A substantial part of this slow mfp-growth can be explained by the fact that positive agglomeration advantages are overruled by negative congestion effects caused by traffic jams.

Keywords: regional growth accounting, labour productivity growth, mfp-growth, agglomeration effects
JEL classifications: O40, O47, R10, R11
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1. Introduction

Since the most recent enlargement of the European Union (EU) with 10 new countries disparities in welfare have substantially increased within the EU at the country level, but even more at the regional level. In the new Member States, 90% of the population is living in regions with per capita GDP below 75% of the EU average, whereas this applies to only 13% of the population in the old EU-15 countries. To improve the welfare situation in all parts of the EU, the Lisbon Agreement is set as a goal to become the world's most competitive and dynamic knowledge-based economy in 2010. With increasing globalisation and deregulation of international markets, productivity growth is the tool to enhance competitiveness. Therefore, instruments are sought that will get the productivity growth rate in European countries back on track. The reason for this is a slowdown in labour productivity growth in European countries and an increasing gap in growth rates between the USA and Europe from the second half of the 1990s onwards (Figure 1).

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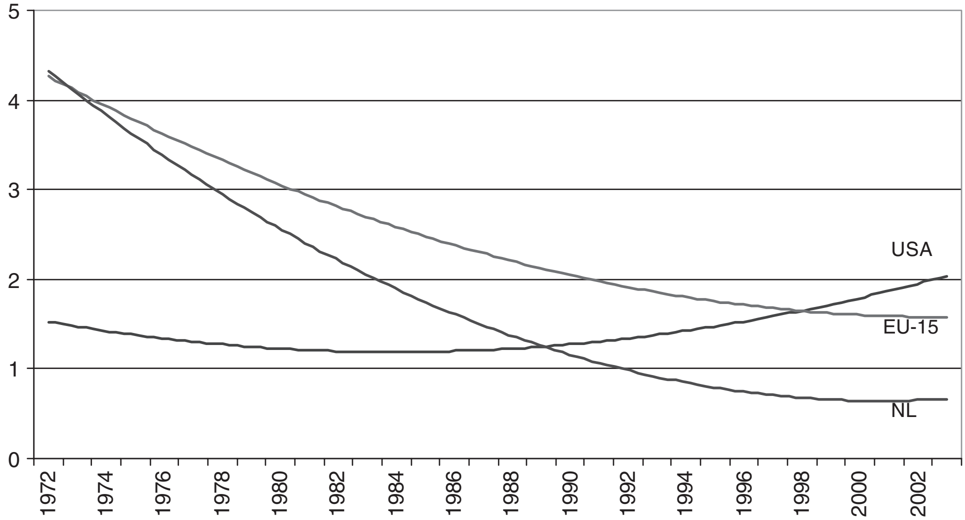

Figure 1. Trends in real labour productivity growth rates (%) in the USA, Europe and The Netherlands, 1972–2003. *Source*: GGDC, Total Economy Database (www.ggdc.net).

Usually the falling growth rate of labour productivity in Europe compared with the US is explained by relatively low innovation and intensity of information and communication technology (ICT) in production in Europe compared with the US and relatively high-regulatory burdens to European product and labour markets. These issues are studied from a country comparative perspective in Oliner and Sichel (2000, 2002), Jorgenson et al. (2002), Daveri (2004), Timmer et al. (2003), van Ark et al. (2002, 2003, 2007) and Gust and Marquez (2004). Crescenzi et al. (2007) look at this transatlantic gap from a spatial perspective. They stress differences in organisation of innovation inputs, like R&D, to explain differences in innovation output, in terms of patents. In its turn, this innovation output is likely to affect productivity growth. We will look at the productivity growth issue from another angle. First of all, we decompose labour productivity growth in effects that can be attributed to its inputs in terms of labour and capital. After controlling for both quantities and qualities of these inputs, multifactor productivity (mfp) growth is the residual of labour productivity growth comprising measurement error and what we term technological factors. However, in a sense, technology here refers to mfp in its most literal sense: the efficiency with which inputs (quantitatively and qualitatively measured) are combined. These technological determinants of mfp-growth are difficult to measure, although theories of the nature and determinants of technological growth have become increasingly abundant in recent years. The economic growth literature suggests that technological growth can be promoted by learning-by-doing, tacit knowledge investment in R&D and human capital accumulation.

Second, we consider this problem from a regional point of view. The reason is that at the regional level additional relevant phenomena can be studied that are often ignored in studies at the national level, like the effect of agglomeration. At the same time, regional mfp-growth is an important driving force for national mfp-growth and hence national labour productivity growth. The nature and causes of regional labour productivity have received a great deal of attention. A range of factors have been identified that are important for determining levels of regional productivity and the effect that productivity growth has in explaining differences in regional economic performance. Recently, a considerable and empirically sophisticated literature has effectuated explaining regional gains by being located in the centre of (economic) activity. Glaeser et al. (1992) and Henderson et al. (1995) focus on the employment gains of such agglomeration at a US metropolitan level, where van Oort (2007) provides empirical evidence for The Netherlands. Sveikauskas (1975) and Rigby and Essletzbichler (2002) did the same for productivity gains of firms being located in a large city, whereas Ciccone and Hall (1996) did the same for US regions. Similar research efforts were conducted, like for Japanese cities (Nakamura, 1985), European regions (Ciccone, 2002) and Dutch regions (Broersma and Oosterhaven, 2007).

Basically all studies found that taking regional characteristics into account adds to the understanding of differences in aggregate labour productivity. In general, agglomeration has a positive effect on the level of employment or productivity. Hence, in concentrated areas productivity (employment) is higher than the thin areas. There is however evidence that concentrated areas tend to grow at a slower pace and contribute less to aggregate productivity growth. This was also noted by the OECD (2006, 69) who goes on to argue that this phenomenon needs to be further developed and researched. In a theoretical paper, Dupont (2007) also argues that if agglomeration generates congestion its positive effect on growth could reverse. Our article is an attempt to explain this phenomenon empirically for The Netherlands. The Netherlands is one of the countries in which the productivity growth has been on a particularly slow-growth path, compared with other European countries who themselves are at a declining path compared with the increasing pace of US productivity growth (Figure 1). At the same time, congestion is particularly fierce in the densely populated, traffic-intensive parts of The Netherlands, specifically compared to similar areas in other European countries and the US. We hypothesise that the declining productivity growth path of The Netherlands is in part caused by increasing traffic congestion, as a reflection of agglomeration diseconomies.

This hypothesis will be tested using a regional growth-accounting approach. In the first stage provincial labour productivity growth will, for eight industries, be decomposed into the contribution of the inputs: labour quality, information technology (IT) capital and non-IT capital deepening, and industry growth reallocation. The residual of this exercise—regional mfp-growth—will in the next stage be explained by factors not captured by the growth-accounting inputs. This analysis provides enough detail to determine both the regional industry contribution and the regional-specific contribution, like agglomeration and congestion, to the lagging Dutch mfp-growth performance of the late 1990s. The results provide useful insights into the determinants of regional productivity growth differences both from an academic and a policy perspective and are also relevant to understand the slowdown in European productivity growth compared with the US.

This article is organised as follows. Section 2 briefly describes both productivity growth and congestion in The Netherlands from an international and from regional perspective. In Section 3, the method of regional industry growth accounting is described. Section 4 presents the outcome when this technique is applied to provincial industry data for The Netherlands. Section 5 elaborates on the regional mfp-growth rates and estimates a relation with agglomeration and congestion. We find that the rise in congestion of the late 1990s contributes to more than 40% to the explained differences in mfp-growth and that this negative congestion effect exceeds the positive agglomeration effect. Hence, the rise in congestion, a phenomenon largely confined to the economic core regions, has caused a substantially lower mfp-growth path countrywide. Section 6 concludes and provides a link back to the productivity gap between The Netherlands, Europe and the US.

2. Dutch productivity and congestion in perspective

2.1. Labour productivity in international perspective

Figure 1 shows the trend paths of labour productivity growth in Europe, the US and The Netherlands between 1972 and 2003. From the second part of the 1990s, the US is at a much steeper growth path than Europe. The Netherlands is at an even slower growth path than the European average. What is the reason for this increasing gap between Europe and the USA? This is an important question in order to find instruments that stimulate the growth rate of productivity. These are part and parcel of the EU's Lisbon Agreement to enhance European innovation and competitiveness.

2.2. Labour productivity in regional perspective

However, these instruments will only be successful if the causes of the slowdown in productivity are made clear. Partly this slowdown will be caused and can be solved by policy measures at the level of the EU and at the country level. However, based on an empirical analysis of regional differences in productivity growth in Dutch regions, we argue that also regional factors like agglomeration and congestion are important explanatory factors and this should be taken into account for the selection of adequate policy measures to enhance the national productivity growth path as well (Broersma and van Dijk, 2005; Broersma and Oosterhaven, 2007).

Our empirical analyses will be based on data at the provincial (Nuts-2) levels in The Netherlands, because most regional data are confined at this spatial level. Relatively high levels of labour productivity are found in the western part of the country, comprising the provinces Utrecht, Noord-Holland and Zuid-Holland (Figure 2). These three together harbour the Randstad. This area consists of a ring of the four largest cities (Amsterdam, Rotterdam, Utrecht and The Hague), as well as several medium-sized cites with a rural area in the centre. Figure 6 enumerates the 12 Dutch provinces and positions the Randstad.

Capital-intensive industries usually yield high levels of labour productivity. Dutch regions with a high concentration of capital-intensive basic metal or chemical industries indeed have higher productivity levels than average. These are usually coastal provinces with a major seaport, like in Terneuzen (Zeeland), Rotterdam (Zuid-Holland), IJmuiden/Velzen (Noord-Holland) and Delfzijl (Groningen). On the other hand, high-productivity levels are also found in regions with a high share of knowledge-intensive services, like in Amsterdam (Noord-Holland), The Hague (Zuid-Holland) and in and around the cities of Utrecht and Groningen. In general terms, Figure 2 shows that high-productivity levels are found in the western part of the country, while low levels are found at the eastern border, with an exception of Groningen.[1] The real

1 All regional data in this article are excluding mining (NACE 10–14), because it is difficult to attribute its output to a specific region, and real estate (NACE 70), because we want to exclude the role of dwellings to productivity.

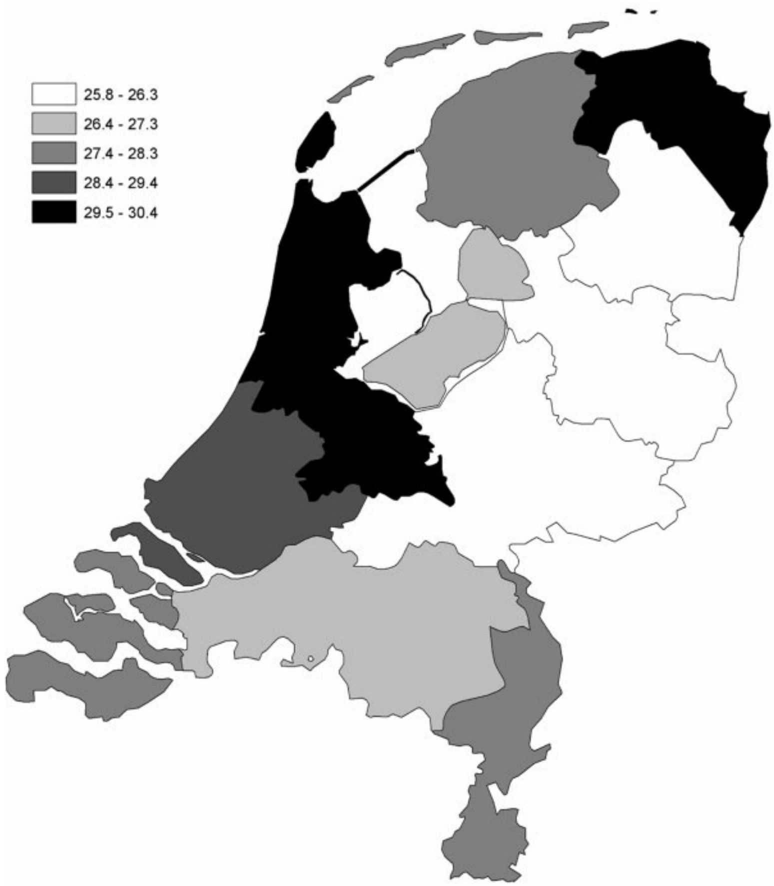

Figure 2. Labour productivity 2002 (euro per hour). *Source*: Statistics Netherlands.

growth rates of labour productivity in Figure 3 show that the central part of The Netherlands has relatively high-growth rates as well as the south and northeast. Growth rates in the western part are relatively modest.

2.3. Mfp-growth in international perspective

Labour productivity growth accounting in an international comparative setting, allows for comparison of mfp-growth rates in Europe and the US (van Ark et al., 2007). Figure 4 shows a similar mfp-gap, also starting at the second half of the 1990s, as the productivity gap of Figure 1. The labour productivity gap is driven by the mfp-gap.

Usually this falling mfp-growth path in Europe is associated to the relatively low-European innovation intensity and relatively high-regulatory burdens to product and labour markets. For more on the difference in the effect of innovation and R&D on performance indicators related to mfp-growth based on European and US regions, see Crescenzi et al. (2007). The effects of regulations on mfp-growth were studied by Nicoletti and Scarpetta (2003).

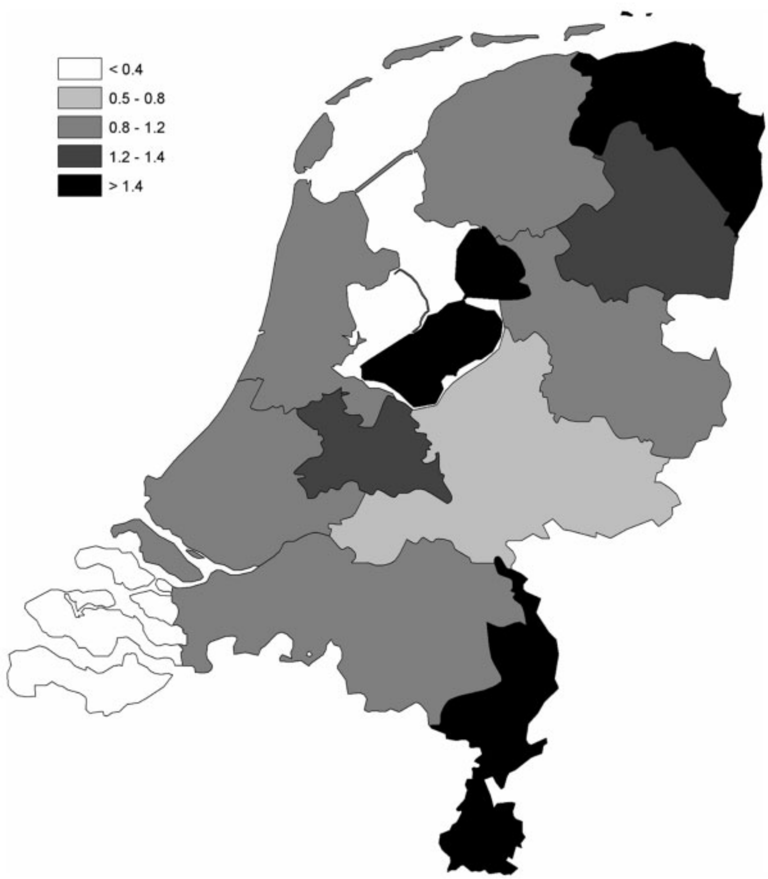

Figure 3. Real annual labour productivity growth 1991–2002 (%). *Source*: Statistics Netherlands.

2.4. Congestion in international perspective

This paragraph will show that congestion in Europe, and The Netherlands in particular, is likely to be much worse than in the USA. Our argument is that this can in part be held accountable for the falling mfp-growth path in Europe and The Netherlands in particular.

First of all we have to stress that congestion is experienced not only by road users, but also by rail and airport travellers. We will, however, focus on road travel, because this is by far the major source of traffic congestion relevant for the problem at hand. Second, international comparison of congestion is hampered by a lack of reliable statistics and common definitions (ECMT, 1995; Annex 3). Still some general remarks can be made. It is a well-established fact that the USA is the most auto-dependent nation in the world. In the second half of the 1990s, the US still had the largest number of cars per person, but their growth rate between the 1980s and 1990s was already much lower then elsewhere (Gerondeau, 1999; Table 1). Other, notably European countries were catching up. By 2000, there were more cars per person in Germany than in the US and nearly as many in France and Sweden (Handy, 2004). Despite worldwide

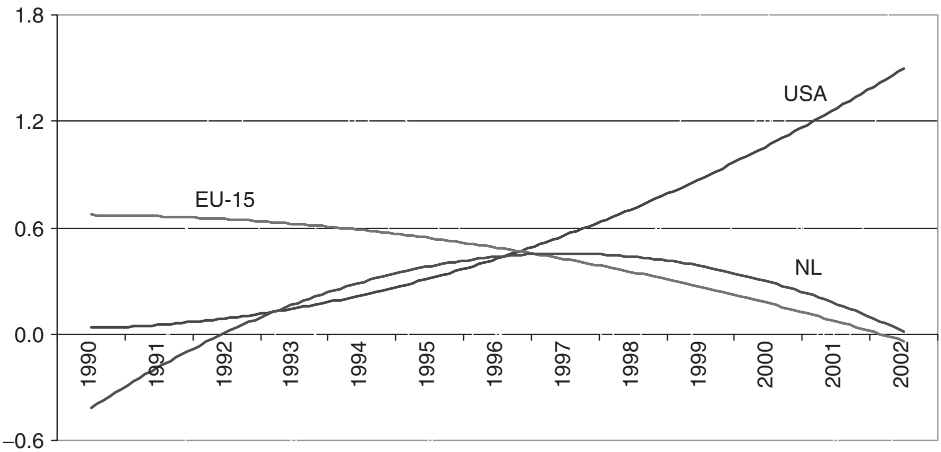

Figure 4. Trend in mfp-growth rates of USA, EU-15 and The Netherlands, 1990–2002. *Source*: EUKLEMS Database.

increases in congestion, there is reason to believe that the extent and impact of this increase is smaller for the US than for Europe.

An important feature in explaining these differences between the US and Europe lies in the time factor (Bovy and Salomon, 1999). The timing of the introduction of various technological and social trends across different parts of the world may explain why present conditions and trends vary in different regions. The private automobile, which lies at the heart of the congestion problem, gained its popularity in Europe at a different time and against a different spatial, economic and social environment than in the US.

The reasons for the occurrence of congestion may also differ between Europe and US. Recurrent congestion generally results from a structural lack of road capacity or, equivalently, excess demand.[2]

(i) As far as capacity is concerned and focusing on densely populated areas, older city centres in Europe constrain the development of high-quality road infrastructure much more than in US metropolitan areas. Moreover, the length of the US road network per 1000 inhabitants exceeds that in most European countries (Bovy and Salomon, 1999).
(ii) Road capacity not only depends on stretches of asphalt, but also on the type of vehicle, the speed and the speed differences between vehicles. A low speed limits the flow of vehicles per road section, but a high speed requires a larger distance between vehicles for safety reasons. In both cases, the optimal capacity cannot be maintained. Hence, there is an optimum speed that allows a maximum number of vehicles per unit of time to pass a certain stretch of road (Schallaböck and Petersen, 1999). For highways the maximum number of vehicles to pass a certain road section per time can be reached at speeds of around 60–80 km/h. The maximum speed limit of 55 miles per hour in the USA (currently left to the discretion of the states) comes closer to this optimum than in Europe, where

2 Some congestion also occurs due to temporary conditions like accidents or road maintenance work, which will not be considered here.

generally much higher speeds are allowed for. At dense traffic, speed differences between vehicles will lead to moving further away from optimal capacity.

(iii) In most US and European metro regions, congestion primarily was an event of radial networks to and from city centres and suburbs. With the ongoing suburbanisation of not only inhabitants, but also of employment and commerce, congestion also started increasing on the circumferential networks. The Netherlands are a notable exception in this respect, because of the specific circular form of The Netherlands' most urbanised area, the Randstad. Because of its circular nature, congestion was predominantly a circumferential phenomenon from the start, which usually is a more serious problem than congested radial networks. Compared to similarly connected cities in Europe, namely, the German Ruhr area and the Belgian Flanders triangle, the Randstad has by far the highest levels of congestion (Bovy and Salomon, 1999). Not just the level, but also the average annual rise in congestion in the late 1990s has been higher in the densely populated economic core regions of The Netherlands than in the periphery (see also Figure 6).[3] As far as country averages are concerned, The Netherlands (Randstad) together with Britain (the greater London area), belongs to the most congested European countries before Germany (Ruhr area, Berlin and Munich) and France (Paris).

Furthermore, comparable data on car density show an average annual growth rate between 1998 and 2002 for Europe that lies ~0.3 percentage points below the Dutch average.[4] Cumulated over these years Dutch congestion growth exceeded the European growth rate by 1.5 percentage point. Figure 5 shows the vehicle kilometres per 1000 inhabitants for the US, Britain and The Netherlands. We find that both Dutch and British vehicle kilometres show a marked decline in their growth path in the early part of the 1990s, whereas the US indicator keeps the same growth path. Per inhabitant, less vehicle kilometres could be made in the European countries, despite the slowdown in population growth. This provides an additional indication of differences in congestion between Europe (where it caused slower growth in vehicle kilometres) and the US (where it did not).

Differences in demand for capacity between the US and Europe are also important. Three factors are usually distinguished.

First, *socio-demographic* factors.

(i) In Europe population growth has largely come to a standstill, but the share of baby-boomers has grown. Moreover, it is not so much the population itself, but the number of households that determines demand for cars and thus road capacity. The number of households in European urban areas is still increasing, due to increasing single person and single parent households.

3 Based on data of Statistics Netherlands the average annual growth rates of cars per kilometre of road rose by 3.8% in the core provinces (Gelderland, Utrecht, Noord-Holland, Zuid-Holland, Zeeland, Noord-Brabant and Flevoland) between 1998 and 2002 against 3.1% in the periphery.

4 Europe, excluding The Netherlands, consisting of Belgium, Denmark, Germany, Spain, France, Netherlands, Austria, Finland, Sweden and the UK. Based on Eurostat-data, the average annual European growth rate, excluding The Netherlands, between 1998 and 2002 was 1.9%. The comparable overall Dutch growth rate was 2.2%.

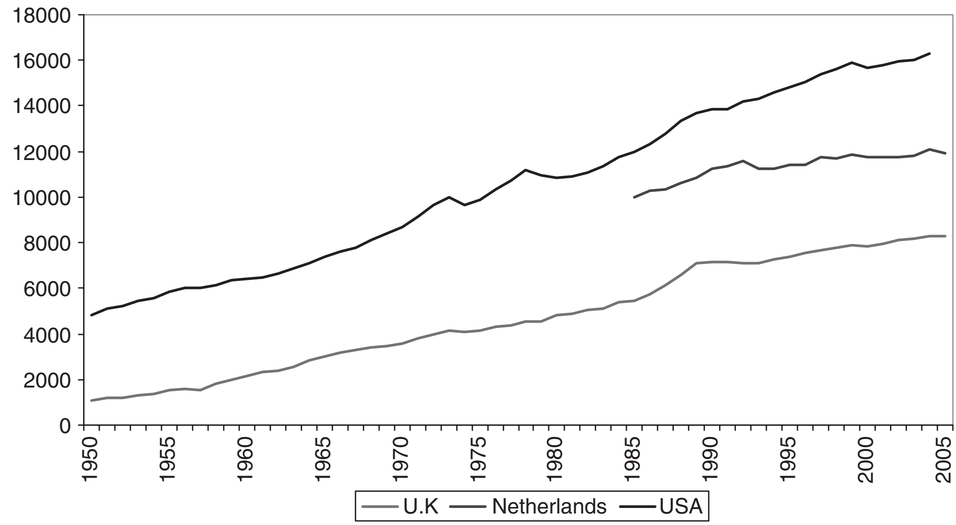

Figure 5. Vehicle kilometres per 1000 inhabitants in the UK, The Netherlands and the USA. *Source*: UK Office of National Statistics, US Department of Transport, Statistics Netherlands.

(ii) Another part is the role of women in society, which developed much earlier in the US than in Europe. The increase in female participation, in combination with household tasks, has increased car use in Europe more than in the US.
(iii) Ageing also contributes to the increase in car use, since more older people of today own a drivers licence than in the past.

Second, *economic* factors

(i) Per capita income is higher in the US than in European countries,[5] and within these nations it is higher in the densely populated core regions than in the periphery. Car use is positively related to wealth.
(ii) A major consequence of this increase in wealth has been the choice of the residential location, which was disconnected from the working location. People started living in private houses in suburban locations. Suburbanisation in Europe came later than in the US and European suburbs are much more condensed than the American ones (Bovy and Salomon, 1999). Dense suburbs increases risks of congestion once people start commuting. The steep increase in commuter flows in The Netherlands in the early 1990s as a result of these phenomena is reported by Ekamper and van Wissen (2000).
(iii) The (fixed) costs of owning a car are relatively high, against the (variable) costs of driving in it. Use-based taxes, like gasoline tax, parking tax and the like hardly have an effect on congestion, as they do not reflect spatial or temporal variation in capacity use. These taxes are more a European than an American phenomenon.

All in all, we have found (circumstantial) evidence that although traffic congestion is increasingly becoming a problem, this is more so in The Netherlands, rather than in

5 Apart from Luxemburg (McGuckin and van Ark, 2005).

other European countries or the US. Congestion in The Netherlands has increased strongly in the past two decades, which might explain the slowdown in Dutch labour productivity growth compared with Europe and the US. Congestion itself is clearly a regional phenomenon and is for The Netherlands confined to the economic core regions, comprising the Randstad and surrounding areas. This sets the stage for the remainder of this article, namely, how to interpret Dutch labour productivity growth in a spatial perspective. Can certain regions or industries in certain regions be identified that account for the slowdown in Dutch productivity and mfp-growth and what role is there for the rise in congestion as explanation for regional mfp-growth differences.

3. Labour productivity growth accounting

3.1. Introduction

The economic theory of productivity measurement goes back to Solow (1957). It has since developed due to major contributions of Jorgenson (1995), Griliches (1995) and Diewert and Nakamura (2007). They reformulated productivity measures in a production function setting and linked it to the analysis of economic growth. This production theoretical approach to productivity measurement is consistent with and integrates the neoclassical theory of the firm, index number theory and national accounts. It is called growth accounting.

This growth-accounting technique examines how much of the observed rate of change of an industry's output can be explained by the rate of change of the combined inputs (usually labour and capital). To construct an index of combined inputs, the rates of change of different inputs have to be weighted appropriately. With these weights, index number theory comes in. From production theory, in addition to some simplifying assumptions, it can be shown that these weights are equal to the factor income shares, e.g. the share of input compensation in total costs. These income shares approximate production elasticities, i.e. the effects of a 1% change in the individual inputs to output.

As an alternative to growth accounting the use econometrics to productivity measurement is advocated. This approach is based on observations of output and input volumes, without postulating relationships between production elasticities and income shares beforehand. Instead these possible relations are estimated and tested empirically in an econometric specification of a production function. However, this approach comes at a price since it is difficult to make a link with economic theory, due to complex econometric issues, lack of robustness and the (small) sample size of observations (OECD, 2001). However, the growth-accounting and econometric approach are not competitors, but can instead supplement one another (Hulten, 2001). Econometric methods can be applied to further explain the productivity residual from growth accounting, which is exactly what we do in our analysis.

Our study applies the basic tools of the growth-accounting approach to industry-level output and inputs in different regions. The residual mfp-growth rate that we find will subsequently be explained using econometric methods. Our analysis employs a very detailed regional dataset, distinguishing not just the quantities of labour (hours) and capital, but also their quality in terms of educational attainment and asset type. Most regional growth-accounting studies merely distinguish the quantities, which imply that regional quality differences appear as mfp-growth,and hence usually becomes the major contributor to regional productivity growth (Hulten and Schwab, 1984; Gerkin, 1994). The data detail of our analysis has the advantage that more explanatory factors are included in the accounting analysis, thereby limiting the role of the (unexplained) residual mfp-growth.

3.2. Decomposition of labour productivity growth

Our point of departure for decomposing the growth rate of output of each region–industry combination is

$$\Delta \log Y_t = \nu_t^L \Delta \log L_t + \nu_t^K \Delta \log K_t + \Delta \log \mathrm{MFP}_t \tag{1}$$

where Δ is the difference operator, so $\Delta \log Y$ is the growth rate of real gross value added in constant prices, $\Delta \log L$ is the growth rate of labour input and $\Delta \log K$ is the growth rate of capital input in constant prices. Here ν^L is the share of current price of labour compensation in current price value added, ν^K is the same for capital compensation in value added and finally MFP is multifactor productivity.

In this study, we can distinguish three different types of labour quality based on educational attainment: high, intermediate and low ($h=3$). Capital can be distinguished in IT capital and non-IT capital ($j=2$). Growth of labour and capital input is defined as the growth rate of each type of labour and capital, respectively, weighted by their two-period average share in total nominal input compensation

$$\Delta \log L_t = \sum\nolimits_h \nu_{h,t}^L \Delta \log L_{h,t} \tag{2}$$

$$\Delta \log K_t = \sum\nolimits_j \nu_{j,t}^K \Delta \log K_{j,t} \tag{3}$$

where

$$\nu_{h,t}^L = \frac{1}{2}\left(\frac{w_{h,t}L_{h,t}}{\sum_h w_{h,t}L_{h,t}} + \frac{w_{h,t-1}L_{h,t-1}}{\sum_h w_{h,t-1}L_{h,t-1}}\right) \tag{4}$$

and

$$\nu_{j,t}^K = \frac{1}{2}\left(\frac{r_{j,t}K_{j,t}}{\sum_j r_{j,t}K_{j,t}} + \frac{r_{j,t-1}K_{j,t-1}}{\sum_j r_{j,t-1}K_{j,t-1}}\right) \tag{5}$$

and w_h, is the nominal wage rate for labour of education level h and r_j is the nominal rental price of capital of asset type j. Finally, L_h is the number of hours worked by labour of education level h and K_j is the capital stock of asset type j. The weights in Equations (4) and (5) are related to the fact that we have heterogeneous labour and capital that cannot be aggregated by simple adding up. Therefore, weights or index numbers are required. The results of this weighted aggregation depend on the index number used. The best option in this respect is to use the so-called Törnqvist index, which is represented in Equations (4) and (5) and throughout the sequel of this section (see for more details OECD (2001); Chapter 7).

The shares of labour and capital compensation in value added of Equation (1) are calculated as

$$\nu_t^L = \frac{1}{2}\left(\frac{\sum_h w_{h,t}L_{h,t}}{p_t Y_t} + \frac{\sum_h w_{h,t-1}L_{h,t-1}}{p_{t-1}Y_{t-1}}\right) \tag{6}$$

and

$$\nu_t^K = \frac{1}{2}\left(\frac{\sum_j r_{j,t}K_{j,t}}{p_t Y_t} + \frac{\sum_j r_{j,t-1}K_{j,t-1}}{p_{t-1}Y_{t-1}}\right) \tag{7}$$

where $p_t Y_t$ reflects the nominal value added at time t. Next, the growth of labour quality is defined as the difference between labour input in Equation (2) and growth of total hours worked (Jorgenson, 1995)

$$\Delta \log q_t^L = \sum\nolimits_h \nu_{h,t}^L \Delta \log L_{h,t} - \sum\nolimits_h \Delta \log L_{h,t} = \Delta \log L_t - \Delta \log H_t \tag{8}$$

in which H_t is defined as the sum of hours over the different labour types. Equation (1) can be rearranged in terms of labour productivity, represented by $y = Y/H$

$$\Delta \log y_t = \Delta \log Y_t - \Delta \log H_t = \nu_t^L \Delta \log q_t^L + \nu_t^K \Delta \log k_t + \Delta \log \mathrm{mfp}_t \tag{9}$$

where $k = K/H$ is the ratio of capital services to hours worked and the residual term is again labelled mfp, but this time in small characters. The distinction between capital goods by asset type (IT assets and non-IT assets) makes that Equation (9) and can be rewritten as

$$\Delta \log y_t = \nu_t^L \Delta \log q_t^L + \nu_t^K\left(\sum\nolimits_{j\in IT} \nu_{j,t}^K \Delta \log k_{j,t} + \sum\nolimits_{j\in N} \nu_{j,t}^K \Delta \log k_{j,t}\right) + \Delta \log \mathrm{mfp}_t \tag{10}$$

We now define IT capital deepening as the growth rate of the ratio of IT capital to hours worked, or $\Delta \log k_t^{IT} = \sum_{j\in IT} \nu_{j,t}^{IT} \Delta \log k_{j,t}$,and the growth rate of IT capital is weighted like before with the average share of capital compensation of each IT asset in total IT capital compensation of the past 2 years

$$\nu_{j,t}^{IT} = \frac{1}{2}\left(\frac{r_{j,t}K_{j,t}}{\sum_{j\in IT} r_{j,t}K_{j,t}} + \frac{r_{j,t-1}K_{j,t-1}}{\sum_{j\in IT} r_{j,t-1}K_{j,t-1}}\right)$$

Non-IT capital deepening is defined analogously. Equation (10) can next be simplified into

$$\Delta \log y_t = \nu_t^L \Delta \log q_t + \nu_t^{IT} \Delta \log k_t^{IT} + \nu_t^N \Delta \log k_t^N + \Delta \log \mathrm{mfp}_t \tag{11}$$

where superscript N refers to non-IT capital and

$$\nu_t^{IT} = \frac{1}{2}\left(\frac{\sum_{j\in IT} r_{j,t}K_{j,t}}{p_t Y_t} + \frac{\sum_{j\in IT} r_{j,t-1}K_{j,t-1}}{p_{t-1}Y_{t-1}}\right) \tag{12}$$

Equation (11) shows that real labour productivity growth can be decomposed into four different sources: (i) labour quality, (ii) IT capital deepening, (iii) non-IT capital deepening and (iv) mfp-growth. This decomposition can be made for each distinctive regional industry level for which data are available. The aggregation of industries to an overall national or regional level is treated in the next section.

3.3. Aggregation

In order to get economy-wide indicators of output and inputs summing regional industry values needs strict requirements (Jorgenson, 1995). We make as little assumptions beforehand as possible and take output and input prices to reflect marginal productivities. Input prices can differ between regions/industries for example because of differences in factor mobility. For this aggregation method, it is necessary to weight region/industry growth rates of output and inputs by their share in aggregate value added.

Like the shares used in the decomposition of labour productivity growth of the previous subsection, we also use a Törnqvist index of value added of region/industry combination i in total value added

$$\nu_{i,t}^{Y} = \frac{1}{2}\left(\frac{p_t Y_{i,t}}{\sum_i p_t Y_{i,t}} + \frac{p_t Y_{i,t-1}}{\sum_i p_t Y_{i,t-1}}\right) \tag{13}$$

For adequate country comparisons of output and inputs use should be made of industry-specific purchasing power parities because industry output prices likely differ between countries. However, when regions within a country are concerned we assume no regional difference in purchasing power, so the actual regional price deflators are used, when available. Aggregation of regions to the country level, or some other spatial level for that matter, is carried in the same way as before, i.e. by weighting with the appropriate regional industry shares in value added.

3.4. Region and industry contribution to productivity growth

Aggregate value-added growth, based on each region/industry i, is defined as

$$\Delta \log Y_t = \sum\nolimits_i \nu_{i,t}^{Y} \Delta \log Y_{i,t} \tag{14}$$

where the weight ν is defined in Equation (13). Aggregate hours worked are simply summed over all industries/regions: $H_t = \Sigma_i H_{i,t}$.

Labour productivity growth is calculated by subtracting the growth rate of real value added by the growth in total hours worked, or $\Delta \log y_t = \Delta \log Y_t - \Delta \log H_t$. Using the aggregation procedure of Equation (14) enables us to decompose aggregate labour productivity growth as

$$\begin{aligned}\Delta \log y_t &= \sum\nolimits_i \nu_{i,t}^{Y} \Delta \log Y_{i,t} - \sum\nolimits_i \Delta \log H_{i,t} \\ &= \sum\nolimits_i \nu_i^{Y} \Delta \log y_{i,t} + \left(\sum\nolimits_i \nu_{i,t}^{Y} \Delta \log H_{i,t} - \Delta \log H_t\right)\end{aligned} \tag{15}$$

where the terms between brackets equals reallocation of hours worked to high-productivity industries (Nordhaus, 2002; Stiroh, 2002). The first term between brackets is the value-added share weighted hours worked growth rate. The second term merely represents the aggregate hours worked growth rate. This reallocation term shows that the movement of labour from low-productivity-level regions/industries to high-productivity-level ones will raise productivity even when the actual productivity growth rates in both is zero. In other words, this term is positive when regional industries with an above-average labour productivity level have positive employment growth or likewise with below-average productivity levels have falling employment. Negative values show that high-productivity regions/industries and region/industry employment growth do not go hand-in-hand in the same sector.

When combining IT or non-IT capital deepening by region/industry with their shares in value added, we get the contribution of IT or non-IT capital deepening in each industry to aggregate labour productivity growth. Omitting the time subscript t Equations (11), (14) and (15) reflect the contribution of the inputs and mfp-growth for each region/industry to aggregate productivity growth

$$\Delta \log y = \sum_i v_i^Y \left(v_i^L \Delta \log q_i^L + v_i^{IT} \Delta \log k_i^{IT} + v_i^N \Delta \log k_i^N + \Delta \log mfp_i \right) + R \qquad (16)$$

where R is the reallocation of working hours defined in Equation (15). Equation (16) also shows that aggregation over regions/industries requires weighting with their share in value added.

The contribution of IT capital deepening of region/industry i to aggregate productivity growth is

$$LPCON_i^{IT} = v_i^Y \left(v_i^{IT} \Delta \log k_i^{IT} \right) \qquad (17)$$

The contribution of the other inputs to aggregate productivity growth is defined analogously.

3.5. Data issues

This subsection briefly summarises the main data issues that arise when conducting this regional industry growth accounting for The Netherlands. More details on data and definitions are available upon request.

3.5.1. Output

In each region, output by industry is measured as value added. In all regions, mining (ISIC 10–14, according to the International Standard Industrial Classification–ISIC) and real estate (ISIC 70) are omitted from the analysis throughout this article (see Footnote 1). As output deflator the regional GDP price index by industry is used, which is defined as the national GDP deflator adjusted to the regional sector composition. This regional price index is only available at a very high level of industry aggregation, which limits the industrial detail for each region.

3.5.2. Labour

Regional labour input by industry is measured as the total number of hours worked by both employees and self-employed. Regional hours worked by employees are simply the number of full-time equivalent (fte) jobs by industry per region times the annual working hours for full-time jobs by industry nation-wide. Regional self-employment by industry is taken into account by adjusting regional working hours of employees by the ratio of self-employed to employees by industry nation-wide.

3.5.3. Capital

Regional capital inputs by type of capital good (IT versus non-IT) by industry are measured as capital service flows. This means that each type of capital good is based on its user cost. Capital services are defined as the flow of productive services from the cumulative capital stock, based on the combination of past investments and depreciation rates. The flow of services from any asset is generally assumed to be proportional to the capital stock.

At a detailed industry level, particularly for IT-manufacturing industries, no adequate deflators are available for specific IT assets, like semiconductors, that take account of the rapid increase in their performance and quality. For that reason country comparisons are often made using harmonised US price deflators on semiconductors for all countries involved. However, our regional data do not allow for in-depth industry details by distinguishing specific-IT producing or IT-using industries. Therefore, we use the more appropriate national IT investment price deflator, instead of US deflators, for IT investment goods. Similarly, for non-IT investment goods the national deflator on total investment is used.

3.5.4. Labour quality

Regional labour quality is based on the regional employed labour force by industry and education, where distinction is made in low, intermediate and high levels of education, according to the International Standard Classification of Education (ISCED). For each region and industry the employment shares by educational level are used to obtain regional and industry hours worked by education.

3.5.5. Labour compensation

National information of hourly employee wages by industry and education multiplied by regional hours worked by industry and education yields regional labour compensation per hour worked.

3.5.6. Sample period

Adequate data on IT and non-IT capital by industry are limited to 1995–2002. This means that the sample period with which to conduct a regional growth accounting exercise for The Netherlands is 1995–2002.

4. Results

Equation (16) shows that real labour productivity growth can be decomposed into five different sources: (i) labour quality, (ii) IT capital deepening, (iii) non-IT capital deepening, (iv) labour reallocation and (v) mfp-growth. Figure 6 presents an overview of the results of this decomposition of aggregate productivity growth during the period 1995–2002 for each of the 12 provinces under consideration, a subdivision in core and peripheral regions and for The Netherlands as a whole. Table 1 in Appendix 1 presents a more detailed overview of all the sector and provincial growth accounting results.

The first phenomenon that catches the eye in Figure 5 is the divergent pattern for the province of Flevoland. This is the sole region with a negative mfp-growth rate, while the contribution of IT capital deepening to productivity growth is quite large. That is why we first need to elaborate on this province, before we discuss the results for the other provinces in Section 4.2.

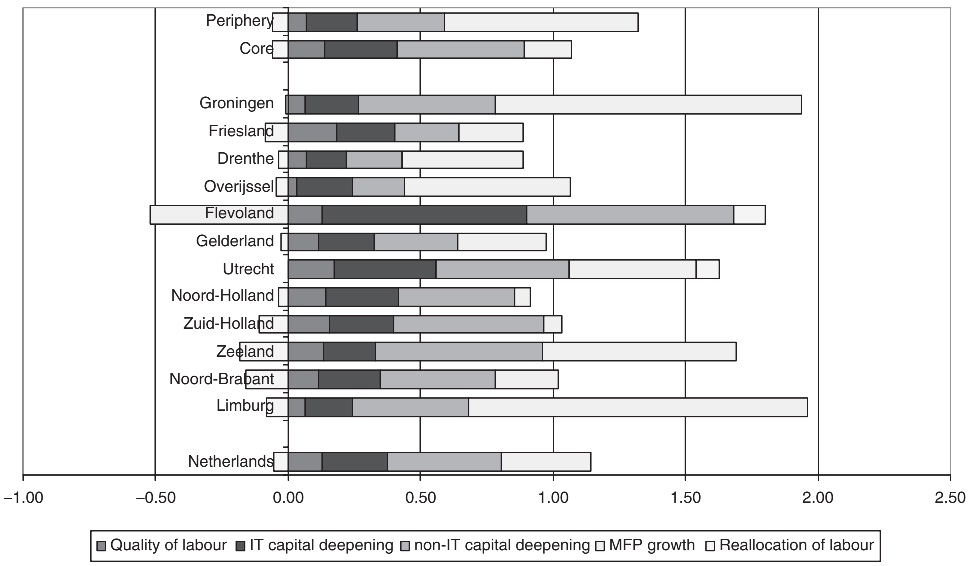

Figure 6. Sources of labour productivity growth in The Netherlands at regional level, 1997–2002.

4.1. The special case of Flevoland

Flevoland is the newest province of The Netherlands, established in 1986, and composed of newly conquered land from the IJsselmeer (Figure 7). On this new land, new cities are created, so growth in this province has an atypical character that deviates largely from the Dutch average, in terms of population, employment and output. The province is further characterised by high levels of commuting, especially to the Randstad area. In 2001 more than 60 000 workers, i.e. 41% of the working population in Flevoland, were commuting out to Noord-Holland, Zuid-Holland and Utrecht. The build-up from scratch of this province also implies that many new or relocated firms started with state of the art technology, whereas firms in other provinces may still use more dated technologies. At the same time a negative commuting balance implies a relatively low GDP in Flevoland itself, because a large part of the production of its residents takes place outside the province in the region where the commuters go. Both points imply that Flevoland has the highest share of IT investments in GDP of all provinces, as can be seen from Statistics Netherlands databases. It also explains why Flevoland has such a large contribution of IT capital deepening to productivity growth compared to other provinces, for which mainly financial and business services are responsible (Appendix 1). However, this exact same industry is also largely responsible for the negative mfp-growth rate in Flevoland.

Hence, the combination of advert patterns of (catch-up) growth, commuting and as a consequence low-GDP levels in combination with high shares of IT investment may give rise to this adverse pattern of growth contributions in Flevoland.

4.2. The other provinces

For the other 11 provinces the contribution of the different sources to productivity growth are more in line with each other, but there is still considerable regional variation.

Figure 7. Provinces in The Netherlands and indication of a core—periphery subdivision.

4.2.1. IT capital deepening

Figure 5 shows that the contribution of IT capital deepening (growth of IT capital per hour worked) has been positive in all regions. This contribution was particularly large in Utrecht and Noord-Holland, because of high-IT deepening of the financial and business services. In fact, this sector made by far the highest contribution to IT capital deepening in all provinces, except in Drenthe (social/non-market services) and Zeeland (manufacturing and social/non-market services). Financial and business services are also the ones with a high contribution of IT capital deepening to national productivity growth according to Inklaar et al. (2003; table B6 in p. 54). They are intensive users of IT capital and this is an important explanation for their high-labour productivity growth performance (see van Ark et al., 2003; appendix A).

Another IT-intensive industry is wholesale trade. The contribution of our composite sector of trade and hotels to IT capital deepening, is indeed relatively high in provinces with a high share of wholesaling, as in Utrecht, Noord-Holland and Noord-Brabant. It is therefore likely that, particularly in these provinces, IT capital deepening in wholesale trade has made a substantial contribution to labour productivity growth. Hence, IT capital deepening in IT-intensive service industries has made important contributions to labour productivity growth in all provinces, but particularly in the central and southern ones. This corroborates the importance of IT use as carrier of productivity growth.

4.2.2. Non-IT capital deepening

Non-IT capital deepening (growth of non-IT capital per hour worked) has generally made an even larger positive contribution to labour productivity growth than IT capital deepening. In most regions, non-IT capital deepening is highest in the manufacturing sector. Only in Friesland and the three Randstad-provinces of Utrecht, Noord-Holland and Zuid-Holland the financial and business services sector has the largest contribution. Friesland has an overrepresentation of financial services, while both financial and business services are dominant in the Randstad-provinces. Another important sector in this respects are social and non-market services, comprising government, education and health care among others, that have a negative contribution of non-IT capital deepening to labour productivity growth.

4.2.3. Labour quality

The overall contribution of labour quality to labour productivity growth is also positive in all provinces, but is relatively high in the Randstad-provinces of Utrecht, Noord-Holland and Zuid-Holland and relatively low in the peripheral provinces of Overijssel, Drenthe, Groningen and Limburg. In the Randstad-regions, all industries contribute positively to the effect of labour quality, particularly financial and business services. In fact the same is true for the peripheral regions, but to a lesser extent. Only in Overijssel financial and business services do not contribute to the effect labour quality, instead manufacturing is the dominant industry.

4.2.4. Reallocation of hours work

Equation (15) derives the region/industry reallocation of employment. This term is positive when regions/industries with an above-average labour productivity level show positive employment growth or likewise with below-average productivity levels have falling employment. Negative values show that high-productivity regions/industries and employment growth do not go hand-in-hand in the same region/industry.

Figure 5 shows that in almost all provinces this reallocation term is negative. This means that the expansion of employment in the second half of the 1990s in these provinces mainly took place in the less productive sectors. Only in Utrecht and Flevoland the opposite occurred. Between 1997 and 2002 employment increased strongly in all provinces. In many cases, the effect of the employment rise in high-productive jobs, like in financial institutions and knowledge-intensive business services (KIBS), was counteracted by an even larger rise in less productive industries, like health care, cleaning, security and temporary work agencies.

The positive reallocation in Flevoland is also connected to the catch-up growth mentioned earlier, because employment growth in this province was the highest of all for all industries. Utrecht, on the other hand, was the only province with a clear employment rise in high-productive industries like communication, financial institutions and KIBS, whereas the rise in less productive industries, like health care, was only modest.

4.2.5. Mfp-growth

Mfp-growth is the largest contributor to labour productivity growth rates in the majority of the provinces. Only in Noord-Holland and Zuid-Holland its impact is very small, and to a lesser extent this is also the case in Noord-Brabant and Friesland. In fact the low mfp-growth in these provinces is the main reason for their low-labour productivity growth rates.

Particularly the financial and business services industry attributes to this low mfp-growth in all four provinces. The detailed industry analysis of Inklaar et al. (2003; table B10 in p. 56) on a national scale corroborates the negative mfp-growth rates for financial institutions. They also report a large positive contribution to Dutch mfp-growth of wholesale trade. In all provinces, we find that the composite trade and restaurant sector has indeed relatively strong mfp-growth rates, particularly in Utrecht. Since Utrecht is the province with the highest share of workers in wholesale trade, this supports their findings as well.[6] For Noord-Brabant agriculture contributes negatively to the overall provincial mfp-growth. Manufacturing in Zuid-Holland also contributes negatively for that province. Agriculture in Noord-Brabant is traditionally dominated by factory farming of pigs. The negative mfp-growth in agriculture of Noord-Brabant primarily refers to 1997, when this province was struck by the pig fever. Manufacturing in Zuid-Holland is dominated by the oil industry, which on a national scale has a negative mfp-contribution, as reported by Inklaar et al. (2003; table B10).

The highest positive contribution of mfp-growth to productivity growth is found in Groningen and Limburg. In Groningen this is mainly the result of the transport and communication sector and in Limburg of manufacturing. Transport and communication in Groningen is dominated by communication, which, nationally, has a high mfp-growth rate according to Inklaar et al. (2003; table B10).[7] Therefore, the large contribution of mfp-growth to labour productivity growth in Groningen can largely be attributed to communication. For mfp-growth in Limburg the same can be said of the dominant chemical industry. In this way regional mfp-growth rates depend on the regional sector mfp-growth rates. It is however also possible that, besides sector structure, they depend on region-specific attributes.

4.3. Peripheral versus core regions

Figure 6 also shows the sources of aggregate labour productivity growth for a subdivision of provinces into an economic core and a peripheral region. The core region is identified as all provinces that roughly fall within a 100 km radius of the (circular) Randstad formed by Utrecht, Amsterdam, Rotterdam and The Hague and covers the area that suffers most from congestion. The provinces Groningen, Friesland, Drenthe, Overijssel and Limburg with a distance of >100 km of these cities are labelled peripheral regions.

Figure 7 presents a map of the Dutch provinces in which these core and periphery can be identified. Note that this core-periphery subdivision is by no means an established

6 Provincial employment data by industry of 2002 show that in Utrecht 35% of all employees in the composite trade and restaurant sector (NACE 50–55) work in wholesale trade (NACE 51) against 29% nation-wide (source: Statistics Netherlands, EWL).

7 Provincial employment data by industry of 2001 show that 47% of all employees in transport and communication (NACE 60–64) in Groningen are in fact working in communications (NACE 64) against a share of 28% nation-wide (source: Statistics Netherlands, EWL, REJ).

fact as other subdivisions are also possible. It merely serves to illustrate our point of a relation between economics on the one hand and mobility and infrastructure on the other hand. We take a 100 km boundary, ~1 hour drive, go grasp the influence of the Randstad on its surroundings, both in terms productivity growth and in terms of agglomeration and congestion. Figure 6 shows the core regions have a slightly higher effect of labour quality and of IT and non-IT capital deepening, but by far a lower contribution of mfp-growth. This low rate of mfp-growth also corresponds to the main source for the Dutch labour productivity slowdown in the second half of the 1990s.

The lagging mfp-growth rate is a phenomenon that occurred particularly in the core regions, mainly Noord-Holland, Zuid-Holland and Noord-Brabant. These three provinces together account for 55% of the entire Dutch GDP, so they have a large weight in aggregate productivity growth. This also means that much of the slowdown in national mfp-growth for the period 1997–2002 (Figure 4) can be attributed to these regions. There is a sectoral aspect of this lag, e.g. because of the low mfp-growth in agriculture and in financial and business services (see also Appendix 1). On the other hand, there might also be region-specific aspects that cause lagging mfp-growth rates, like congestion and agglomeration. Both aspects will be dealt within the sequel.

From the growth accounting exercise we can now conclude that over the period 1997–2002 the average national real labour productivity growth rate of 1.1% per year can be decomposed into four different positive sources that account on average 0.13 to labour quality, 0.25 to IT capital deepening, 0.43 to non-IT capital deepening and 0.34 to mfp-growth. The reallocation of labour to less-productive sectors lowers the productivity growth with 0.05. When we compare the peripheral provinces with the provinces in the core it is clear that the higher labour productivity growth in the periphery is largely due to a much higher contribution of mfp-growth.

5. Explaining regional mfp-growth

Mfp-growth is the residual part of labour productivity growth that cannot be attributed to changes in the inputs. The more inputs can be incorporated, the smaller this residual. We have incorporated all viable input variables for which regional data were available in a growth accounting setting. These are hours worked, quality of labour, capital by asset, i.e. IT and non-IT assets. Job reallocation comes as a by-product of aggregation. The residual mfp-growth is related to a multitude of explanatory variables. Regional differences in mfp-growth are usually related to differences in innovative capacity, agglomeration, regulatory burdens, cultural differences and the like. In the discussion of the differences in provincial growth accounting results, we already noted that differences in regional sector structure may be important for explaining differences in regional mfp-growth. This, however, does not imply that the effects of region-specific aspects should be underestimated.

Regional growth accounting has so far mainly been confined to the USA. Hulten and Schwab (1984) found that US regional labour productivity growth was primarily driven by mfp-growth. They made however no link to agglomeration economies. Dekkle (2002) related mfp-growth of Japanese cities to the level of density and found a positive effect. Domazlicky and Weber (2006) investigated the effect of (too) large agglomerations on mfp-growth, where US state mfp-growth was derived from data envelopment analysis (DEA) instead of growth accounting. They found that in case one of the 20 largest US metropolitans was located in a state, this had a negative though insignificant effect on mfp-growth. This negative sign corroborates the fact that too highly concentrated density may lead to diseconomies of agglomeration, but so far these effects do not seem to be significant yet for the US.

In an econometric approach to regional labour productivity growth differences, Ciccone and Hall (1996) also specifically investigate the effect of agglomeration on regional US labour productivity. They found that doubling job density in a region added 6% to the relative level of labour productivity of that region. Similar effects were found in other studies, like Ciccone (2002) for European countries and Broersma and Oosterhaven (2007) for The Netherlands.

In contrast to the above-mentioned studies that analyse the effects of the 'level' of agglomeration on the level or growth of labour productivity, we focus on the relation between mfp-'growth' and 'growth' in agglomeration. This gives insight in the dynamics of regional productivity and is relevant from policy point of view. Policy measures are directed to enhance the productivity growth path rather than simulate the level of productivity. In addition, relating density levels to productivity growth conflicts the theoretical background of agglomeration effects on productivity, as presented in Ciccone and Hall (1996). Their theory relates levels of agglomeration/congestion and productivity levels. It is unclear how in their framework the level agglomeration would relate to productivity growth.

Few have done research into a possible dampening effect that a rise in congestion has on productivity growth. Using an econometric approach to labour productivity growth, Broersma and Oosterhaven (2007) found a negative effect of agglomeration growth on labour productivity growth for The Netherlands based on regional data. The OECD (2006) notes that metro-regions, i.e. high and rising agglomerations, have a negative effect on productivity growth. We have applied a region/industry growth accounting and our hypothesis is that as far as mfp-growth is concerned there exist agglomeration diseconomies, which can be interpreted as the negative effect of increasing congestion. This will particularly be the case in densely populated, core regions. This section will show what the effect of rising congestion on mfp-growth is from the regional perspective.

In this analysis, we are particularly interested in the region-specific effect. As argued before, the regional sector structure is also likely to explain part of regional mfp-growth. This regional sector structure is captured by adding the industry value-added shares for each province. Region-specific effects can be represented by many different phenomena. We use job density, i.e. the number of regional jobs per surface of land of the region, as measure of agglomeration economies. In addition we use car density, i.e. the number of regionally registered cars per kilometre of road in the region. This serves as an indicator for (the likelihood of) regional congestion: the more cars per stretch of road, the busier it is and the more likely congestion will occur. Because most regulations in The Netherlands hardly show regional variation and information about region-specific regulations is not available, they will not be incorporated in the empirical model. Regional data on R&D expenses are available and will be included to assess their contribution to explaining regional mfp-growth.

We use a panel of regional data for 12 provinces and 6 years (1997 through 2002) for estimation. We will adopt a specification analysis from general to specific and the model we start with is

$$\Delta \log mfp_{r,t} = \mu_0 + \sum\nolimits_{r=1}^{12} \mu_r D_{r,t} + \sum\nolimits_{t=1997}^{2002} \mu_t D_{r,t} + \sum\nolimits_{j=1}^{6} \eta_j \left(\frac{Y_{j,r,t}}{\sum_j Y_{j,r,t}} \right) + \rho \log\left(\frac{R\&D_{r,t-1}}{Y_{r,t-1}} \right) + \alpha \Delta \log\left(\frac{JOBS_{r,t}}{SURF_{r,t}} \right) + \beta \Delta \log\left(\frac{CARS_{r,t}}{ROADS_{r,t}} \right) \quad (18)$$

The first part comprises the 'control' variables where μ_0 is the intercept, μ_r represent regional fixed effects, μ_t are the period fixed effects and the industry effects are captured by the η_j's. The second part shows the region-specific effects of lagged R&D (as share of value added) on mfp-growth and the effects of changes in agglomeration, represented by job density (thousand jobs per square kilometre) and congestion, represented by car density (cars per kilometre). Our specific interest lies in the sign and value of parameters α capturing the agglomeration effect and β for the congestion effect, because it tells us to what extent these parameters can account for the slowdown in the trend of Dutch mfp-growth as shown in Figure 7.

Table 1 shows the estimation results of the specification analysis applied to model (18) for all Dutch provinces. The top part of the first column shows the parameters of Equation (18) and the bottom part shows diagnostics, like R^2, the Durbin–Watson (DW) and Jarque–Bera (JB) test statistics on residual autocorrelation and normality

Table 1. Explaining mfp-growth using model specification Equation (18), 1998–2002

	General model	Simplified model
Intercept (μ_0)	−31.59 (−0.707)	−0.477 (−0.889)
Fixed effects included:		
Regional (μ_r)	Yes	No
Period (μ_t)	Yes	No
η_j for		
Agriculture	−0.329 (−0.516)	
Manufacturing	0.493 (1.509)	0.051 (2.891)
Construction	−0.113 (−0.130)	
Trade and hotels	0.633 (0.640)	
Transport and communication	0.690 (1.317)	
Finance/bus services	0.433 (0.653)	
Agglomeration/job density (α)	0.341 (1.262)	0.357 (4.406)
Congestion/car density (β)	−0.285 (−1.200)	−0.455 (−4.752)
R&D (ρ)	0.088 (0.104)	0.104 (0.569)
Adjusted R^2	0.522	0.411
N	60	60
Standard error residuals	0.706	0.784
DW	2.242	1.556
JB	5.358	2.416
F-test on parameter restrictions		1.402

Notes: t-values are within parentheses.

and an *F*-test on the parameter restrictions to test the validity of the moving from the general to the specific specification.

Our specification analysis starts with estimating the general model of Equation (18) including both region and period fixed effects. Simplification of this model shows a few noteworthy phenomena. First, both region and period fixed effects do not have much additional explanatory power and can validly be deleted, along with part of the sector structure.[8] Second, there is only a significant positive industry effect for manufacturing on mfp-growth. So regions in which manufacturing is a dominant industry benefit from higher mfp-growth rate than other regions. Third, R&D has no effect on regional mfp-growth. Finally, looking at the agglomeration and congestion variables, we find that growth in job density enhances the mfp-growth path, while increasing car density leads to a slowdown in mfp-growth. Hence, an increasing rate of concentration of economic activities adds to mfp-growth, but the side-effect of that rise in concentration is more traffic and congestion, which slows mfp-growth down. The latter effect clearly dominates the former. Hence, traffic congestion is an important—and often neglected—explanatory factor in the slowdown of Dutch mfp-growth (and hence labour productivity growth) of the past decade. A one percentage point rise in car density growth leads to a 0.46 percentage point fall in mfp-growth, while a similar rise in job density (agglomeration) raises the mfp-growth path with only 0.36 percentage points.

As a final step Table 2 shows the contribution of sector structure and each of the region-specific variables to the explained variation of regional mfp-growth, based on the simplified model of Table 1. We find that the regional specific variables contribute more to mfp-growth than sector structure. Overall sector structure explains 27% of the variation in regional mfp-growth. Of the regional-specific variables, we find that 40% of the explained variation in regional mfp-growth can be attributed to congestion and roughly 30% is accounted for by agglomeration. The contribution of R&D is in this respect very limited.

Nevertheless, we have to bear in mind that the explained variation itself is relatively low, as the R^2 is 0.41. Hence, much of the explanation of mfp-growth is still unaccounted for. Many variables still have to be discovered that account for regional differences in mfp-growth. This study has identified two important ones in the form of growth in agglomeration and congestion. These other explanatory variables may be difficult to measure and obtain at the regional level. Possible candidates are changes in the extent and quality of regional, national and international trade and innovation linkages, representing alternative forms of spillovers than mere agglomeration, regional differences in financial and credit facilities, regional differences in firm size, presence of firm headquarters and foreign-owned firms, regional differences in firm dynamics, cultural differences and so on.

The foregoing analysis was carried out with regional data for all provinces in The Netherlands. Regional growth accounting results show that mfp-growth in the provinces comprising the economic core regions has been much slower than in the peripheral regions (Figure 5 and Appendix 1). Application of our econometric specification analysis to these core and peripheral mfp-growth rates runs into practical problems as the number of observations (N) becomes very small in relation to the size

8 The *F*-statistic of 1.402 should be compared to $F(22,33) = 1.86$ as 5% critical value, so simplification cannot be rejected at 5% significance.

Table 2. Contributions to the regional variation in mfp-growth, 1998–2002

Variable	Average absolute regional deviation	Average effect on mfp-growth	Contribution to explaining mfp-growth (%)
Size manufacturing sector	21.0	1.1	27.2
Job density growth	3.4	1.2	31.0
Traffic density growth	3.5	−1.6	40.5
R&D	0.5	0.0	1.2

of the model, which makes the models suffer from lack of degrees of freedom.[9] This seriously hampers estimation and inference and will therefore not be considered further.

6. Concluding remarks

Since the second half of the 1990s, European countries are lagging behind the US in terms of labour productivity growth rates and the Netherlands shows an even slower growth rate than the European average. In this article, we argue that a possible explanation for the slowdown in productivity growth might be that the positive agglomeration effect is overruled by negative congestion effects especially in the economic core region of The Netherlands. To verify his hypothesis, regional differences in labour productivity growth in The Netherlands are analysed in a regional growth accounting exercise. Labour productivity growth appears to be higher in the peripheral provinces of the north and south than in the economic core. The main reason for this lagging growth performance is the slow mfp-growth in the core provinces. As a next step these provincial mfp-growth rates were analysed and explained by provincial differences in sector structure and by region-specific explanatory variables, primarily agglomeration and congestion.

We found that the size of the manufacturing sector and the growth in agglomeration have a positive effect on regional mfp-growth. The rise in congestion, on the other hand, has affected mfp-growth negatively. This congestion effect exceeds the agglomeration effect. Hence, our results confirm the hypothesis that the negative congestion effect dominates the positive agglomeration effect. Given the weight of the core regions in the Dutch economy, the slowdown in mfp-growth of the core has also had consequences for the national slowdown in mfp-growth.

This study also shows the importance of the links between economics on the one hand and mobility and infrastructure on the other. Congestion plays an important—and so far still neglected—role in explaining the slowdown in mfp-growth of The Netherlands in the 1990s and early 2000s. International studies have corroborated the fact that congestion in the core regions of The Netherlands is by far more severe than in any other comparable European region. So if the less severe US or European congestion growth rates would apply to The Netherlands, its mfp-growth rate (and hence labour productivity growth) would have been much higher than it is now. So the slowdown in Dutch mfp-growth compared to Europe and particularly the US is in part caused by the strong increase in Dutch congestion of the 1990s.

9 The starting point of peripheral mfp-model comprises 20 variables (including fixed effects) and 25 observations; the core mfp-model has 22 variables and 35 observations.

Although the Netherlands is not representative for all of Europe, the similarities in terms of lower productivity growth and congestion are quite strong among European countries and quite different from the patterns in the US. Therefore, our results also provide tentative evidence for the explanation of labour productivity differences between Europe and the US. Of course, more robust results would have been possible if the analysis was done on a combined dataset with regional information from several European countries and the US. However, our analysis requires a lot of detailed regional data that are, to the best of our knowledge, not available to permit such an analysis. However, studies like ours at the regional level for other countries might lead to additional empirical evidence for the hypothesis we verified for The Netherlands.

Our finding that negative congestion effects might overrule positive agglomeration effects is not only of relevance from scientific point of view, but also has important policy implications. At the moment most of the budget for regional policy in The Netherlands is allocated to the core regions, because it is supposed to give the highest return on investment and to lead to an extra boost of productivity growth. The main reason for focusing on these regions is the assumption that they have agglomeration advantages due economies of scale, spillovers and vicinity of other economic activities. A crucial question in this debate is the relation between agglomeration and congestion effects and productivity. Our results suggest that investing in already highly dense regions may lead to more congestion and less space, which in the end leads to even a further slowing down of productivity growth. Instead investing in less dense regions might be a more promising route to get the productivity growth rate back on track. It implies that from a regional policy perspective there is no longer a trade-off between allocating the budget to the core regions in order to stimulate productivity growth at the national level or to allocate funds to peripheral regions in order to reduce regional disparities, but that both goals are served by stimulating investments in peripheral regions. Of course our results should be interpreted with care. The Netherlands is a small country with only limited regional differences, and the conclusions might be different for countries where peripheral regions are really lagging. According to Polèse and Shearmur (2007) some regions have pre-conditions that lead almost unavoidably to decline and overwhelm even the best-conceived regional development strategies. However, for many regions the perspectives might be much better and investing in less congested regions might be preferred both from regional and national point of view above investing in congested core regions.

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Appendix 1. Detailed results of growth accounting

Table A1. Results of growth accounting of labour productivity growth Equation (16); contributions by region and industry, The Netherlands, 1996–2002

Source of aggregated productivity growth	Industry	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland	Utrecht	Noord-Holland	Zuid-Holland	Zeeland	Noord-Brabant	Limburg	Netherlands	Core	Periphery
Labour productivity	Agriculture and fishery	0.14	0.22	0.20	0.04	0.28	0.08	0.02	0.02	0.00	0.10	−0.15	−0.01	0.01	0.00	0.08
Growth	Manufacturing and utilities	0.46	0.26	0.34	0.34	0.05	0.23	0.21	0.26	0.19	1.11	0.47	1.17	0.35	0.29	0.60
	Construction	0.01	0.00	−0.07	−0.03	−0.01	−0.02	0.00	−0.02	0.00	−0.01	−0.04	−0.04	−0.02	−0.01	−0.03
	Trade, hotels and restaurants	0.20	0.21	0.23	0.37	0.37	0.30	0.64	0.46	0.33	0.38	0.31	0.30	0.37	0.39	0.29
	Transport and communication	0.92	0.15	0.05	0.26	0.14	0.09	0.49	0.33	0.49	0.26	0.16	0.51	0.34	0.32	0.40
	Financial and business services	0.33	0.19	0.14	0.10	0.41	0.18	0.05	−0.11	−0.04	0.03	0.27	0.16	0.08	0.05	0.17
	Social and non-market services	−0.10	−0.13	0.00	−0.02	−0.08	0.10	0.12	−0.02	0.06	−0.18	0.00	−0.13	0.01	0.03	−0.08
	Total economy	1.93	0.80	0.85	1.02	1.28	0.95	1.63	0.88	0.93	1.51	0.86	1.88	1.14	1.01	1.47
Contribution of: quality of labour	Agriculture and fishery	0.00	−0.01	0.00	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacturing and utilities	0.02	0.03	−0.05	0.03	−0.02	0.04	0.03	0.02	0.01	0.02	0.04	0.04	0.02	0.03	0.02
	Construction	−0.01	−0.02	0.03	0.02	0.00	0.01	0.03	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
	Trade, hotels and restaurants	0.02	0.04	−0.03	−0.01	0.12	0.00	0.03	0.05	0.01	0.03	0.02	0.00	0.02	0.02	0.00
	Transport and communication	−0.02	−0.01	0.02	0.01	0.03	0.01	0.00	0.01	0.02	0.00	0.01	0.00	0.01	0.01	0.00
	Financial and business services	0.09	0.13	0.06	0.00	0.05	0.05	0.08	0.06	0.08	0.06	0.05	0.04	0.06	0.06	0.05
	Social and non-market services	−0.03	0.01	0.04	−0.01	−0.05	0.00	0.00	0.00	0.04	0.03	−0.02	−0.01	0.01	0.01	−0.01
	Total economy	0.07	0.19	0.07	0.03	0.13	0.11	0.18	0.14	0.16	0.13	0.12	0.07	0.13	0.14	0.07
IT capital deepening	Agriculture and fishery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacturing and utilities	0.03	0.02	0.03	0.05	0.03	0.02	0.03	0.03	0.04	0.07	0.04	0.04	0.03	0.03	0.04
	Construction	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01

	Trade, hotels and restaurants	0.02	0.02	0.02	0.03	0.06	0.04	0.07	0.06	0.03	0.02	0.05	0.03	0.04	0.05	0.03
	Transport and communication	0.03	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.02	0.01
	Financial and business services	0.08	0.12	0.04	0.07	0.62	0.09	0.23	0.14	0.10	0.03	0.08	0.05	0.11	0.13	0.07
	Social and non-market services	0.04	0.05	0.05	0.04	0.06	0.04	0.04	0.03	0.04	0.06	0.04	0.04	0.04	0.04	0.04
	Total economy	0.20	0.22	0.15	0.21	0.78	0.21	0.38	0.27	0.24	0.19	0.23	0.18	0.25	0.27	0.19
Non-IT capital deepening	Agriculture and fishery	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	Manufacturing and utilities	0.31	0.06	0.16	0.17	−0.02	0.21	0.08	0.10	0.20	0.41	0.21	0.46	0.19	0.17	0.27
	Construction	0.01	0.02	0.02	0.02	−0.03	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.01	0.02	0.02
	Trade, hotels and restaurants	0.03	−0.01	0.01	0.04	−0.09	0.03	0.04	0.00	0.06	0.07	0.00	0.04	0.03	0.03	0.03
	Transport and communication	0.23	0.03	0.00	0.04	−0.05	0.03	0.03	0.13	0.15	0.17	0.03	−0.02	0.08	0.09	0.05
	Financial and business services	0.07	0.27	0.10	0.02	1.09	0.11	0.40	0.29	0.23	0.05	0.24	0.06	0.21	0.26	0.09
	Social and non-market services	−0.13	−0.13	−0.09	−0.10	−0.14	−0.09	−0.04	−0.09	−0.09	−0.09	−0.08	−0.13	−0.09	−0.08	−0.12
	Total economy	0.52	0.24	0.21	0.20	0.78	0.31	0.50	0.44	0.57	0.63	0.43	0.44	0.43	0.48	0.33
Reallocation of hours		−0.01	−0.09	−0.03	−0.04	0.12	−0.03	0.09	−0.03	−0.11	−0.18	−0.16	−0.08	−0.05	−0.06	−0.06
Mfp-growth	Agriculture and fishery	0.14	0.22	0.20	0.04	0.27	0.07	0.02	0.01	0.00	0.09	−0.15	−0.01	0.01	−0.01	0.08
	Manufacturing and utilities	0.09	0.15	0.20	0.09	0.06	−0.04	0.08	0.12	−0.06	0.61	0.18	0.62	0.10	0.06	0.27
	Construction	0.01	−0.01	−0.14	−0.08	0.01	−0.05	−0.05	−0.03	−0.03	−0.03	−0.09	−0.06	−0.05	−0.05	−0.06
	Trade, hotels and restaurants	0.14	0.16	0.22	0.31	0.29	0.24	0.51	0.35	0.22	0.26	0.24	0.23	0.28	0.29	0.23
	Transport and communication	0.68	0.13	0.03	0.20	0.14	0.04	0.44	0.19	0.30	0.09	0.12	0.51	0.24	0.21	0.34
	Financial and business services	0.09	−0.34	−0.05	0.02	−1.35	−0.07	−0.65	−0.61	−0.44	−0.11	−0.11	0.01	−0.30	−0.40	−0.04
	Social and non-market services	0.02	−0.07	0.00	0.05	0.05	0.15	0.13	0.03	0.08	−0.17	0.05	−0.03	0.06	0.07	0.00
	Total economy	1.16	0.24	0.45	0.62	−0.52	0.34	0.48	0.06	0.07	0.73	0.24	1.28	0.34	0.18	0.73

Note: mining and real estate were not included.