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Does Land Use Planning shape Regional Economies?

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Tinbergen Institute Discussion Paper

Does Land Use Planning shape Regional Economies?

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**Does land use planning shape regional economies?
A simultaneous analysis of housing supply, internal migration
and local employment growth in the Netherlands**

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Does land use planning shape regional economies?
A simultaneous analysis of housing supply, internal migration
and local employment growth in the Netherlands

Abstract: *Why has job growth over the past decades been weaker in the Dutch Randstad area than in surrounding regions? In a simultaneous equations analysis, we find that employment adjusts to the regional supply of labour. Net internal migration is predominantly determined by regional housing supply and not by employment growth. Growth of the regional housing stock responds only moderately to changes in the number of people and jobs. This lack of responsiveness to demand conditions is plausibly related to restrictions on residential development, implying that the regional distribution of economic activity in the Netherlands reflects land use planning decisions.*

Keywords: housing supply, land use regulation, regional labour markets, regional development

Classification-JEL: J61, R12, R23, R31, R52

1 Introduction

Government interventions in land and housing markets may have a strong impact on the quantity and location of new residential construction, while reducing the responsiveness of supply to market signals. A literature has built up that provides ample evidence of the negative impact of the stringency of land use regulations on the price elasticity of housing supply. For instance, Quigley and Raphael (2005) show that supply elasticities at the city level correlate negatively to an index of regulatory restrictiveness in California, while Green et al. (2005) report the same relationship for a national sample of US cities. An extensive inquiry into British housing supply indicates that it is almost fully inelastic, at least partly as a consequence of the planning system (Barker, 2003, 2004). Vermeulen and Rouwendal (2007) find that for similar reasons, housing supply in the Netherlands is almost fully inelastic as well.¹

This literature enables us to understand the impact of land use regulation on the functioning of housing markets, but its wider effects on regional economies have received significantly less attention. Restrictions on the supply of housing that limit the number of households in a region affect labour supply and employment. For instance, Glaeser et al. (2006) show that in US cities in which such restrictions are strong, shocks in labour demand push up wages and house prices, while the local employment response is small.² Moreover, it has been well established that the spatial distribution of jobs relates to productivity through the presence of agglomeration economies (cf. Rosenthal and Strange, 2004), so that regional productivity growth may be inhibited by restrictions on residential development too.

An argument along these lines has recently been put forward by the OECD in its Territorial Review of Randstad Holland (OECD, 2007). As one of the most densely populated in the OECD, this area contains the four largest cities in the Netherlands on

¹ Land use in the Netherlands is regulated through zoning, so where and in what quantity residential construction occurs is a policy decision. National spatial planning strategies designate areas that are to remain undeveloped, as well as areas in which growth should be accommodated. For instance, housing supply is highly restricted in the “Green Heart” area between the four largest Dutch cities, while residential development in new towns or so-called growth centres has received various forms of support. Furthermore, the regulated rental sector in the Netherlands has always been large. Until the early 1990s, the construction of social rental housing was subsidized, as rents were set below the free market level. While central planning used to determine housing production to a significant extent through this channel, the government continues to formulate targets for annual construction nowadays.

² Similarly, Glaeser and Gyourko (2005) present evidence for the impact of housing supply on population growth in declining cities in the US. In these cities, the low supply elasticity of housing results from durability of the stock, rather than from restrictive land use regulation. They show that downward demand shocks lead to a fall in house prices, rather than in the stock, so that population decline is attenuated.

about 20% of all the land in this country, and its contribution to the national income presently exceeds 50%. Nevertheless, the Territorial Review points to lagging labour productivity growth in the past few years, relative to other metropolitan areas. Amongst the potential culprits, it discusses the lack of high quality dwellings, as a consequence of rigidities in Dutch housing markets. Motivated by such potentially significant implications, our present paper investigates the extent to which housing supply has shaped the regional distribution of people and jobs in the Netherlands.

This research question relates to classical debate in regional science that has come to be known as the issue whether “people follow jobs” or “jobs follow people”. A variety of studies have estimated simultaneous models for the intrametropolitan distribution of people and jobs.³ Housing supply is ignored in the larger part of this literature, which may be justified only if new construction fully accommodates demand. However, at the urban level, an upward sloping housing supply curve is implied already by the limited availability of land at a certain proximity to the city centre.⁴ An increase in the demand for spacious dwellings, due to rising incomes or falling transport costs for instance, will therefore push city boundaries outwards, even if all jobs remain located in a Central Business District (cf. Anas et al., 1998). So in this case, the supply of spacious dwellings drives population growth in suburbs. Simultaneous analyses of the intrametropolitan location of houses, people and jobs in the US have confirmed the empirical relevance of such mechanisms (Greenwood, 1980, Greenwood and Stock, 1990). Our paper takes this debate to a setting where substantial restrictions on residential development near city boundaries exist.⁵

We estimate three simultaneous equations for growth of the housing stock, net internal migration and employment growth on annual regional panel data that span three decades. Our econometric approach essentially follows Carlino and Mills (1987), although we extend their framework in a number of ways. First of all, we introduce an equation for growth of the housing stock as in Greenwood (1980) and Greenwood and Stock (1990). Second, as the regions in our data are not closed in terms of commuting,

³ See for instance Steinnes (1977), Carlino and Mills (1987), Boarnet (1994), Luce (1994), Thurston and Yezer (1994), Deitz (1998), or more recently Boarnet et al. (2005). An overview of this literature is provided in White (1999), who concludes that empirical studies have tended to find that jobs follow people, while people do not follow jobs.

⁴ Estimates of the price elasticity of national housing supply in the US are generally found to be much smaller than infinity (cf. DiPasquale, 1999). This suggests that the assumption of fully accommodative housing supply may not be innocuous at higher levels of spatial aggregation either.

⁵ The Netherlands has approximately the same surface and population size as Los Angeles. Hence, from a US perspective, the spatial level of our analysis may appear as intrametropolitan rather than regional.

spatial interaction is accounted for following Boarnet (1994). Because internal migration is the main channel through which the population adjusts to regional labour and housing market conditions, we model the net internal migration rate rather than population growth (cf. Greenwood and Hunt, 1984). Moreover, the use of regional time series allows us to distinguish short-run and equilibrium adjustment effects in the interaction of our endogenous variables, while controlling fully for all national trends and time-invariant regional determinants.

The remainder of this paper is structured as follows. Main trends in the regional distribution of houses, people and jobs over the past three decades are documented and interpreted in the next section. Section 3 introduces our data more formally and presents all variables used in the simultaneous equations model, which is estimated in Section 4. The paper continues with separate analyses of regional employment growth in sectors that produce for local consumption and export, in order to find out whether adjustments in the spatial distribution of jobs have been driven by local consumer demand or by labour supply. The final section concludes and offers some discussion.

2 Main trends in the spatial distribution of houses, people and jobs

The three regions considered in this section are the Randstad area in the west of the country, an Intermediate zone and a Periphery, shown in Figure 1. This figure also indicates the regional division used in subsequent sections, which consists of so-called COROP regions, coinciding with the European NUTS3 level.⁶ The COROP division has been originally designed to minimize cross-border commuting. Hence, it provides a crude approximation of functional labour market regions.⁷ Throughout this paper, we consider the period from 1973 to 2002.

Please insert Figure 1 somewhere around here.

Figure 2 shows the number of houses, people in the age group 15 - 64 and employment in the Randstad area as a share of the national total. This area

⁶ In Sections 3 to 5, we will exclude the region of Flevoland from our observations, as it is a clear outlier. The number of houses, people and jobs was almost negligible here in the early 1970s, and as a consequence of government policies, this region has experienced double digit growth rates.

accommodates almost half of all houses, people and jobs. The share of jobs exceeds the share of the potential labour force, reflecting the fact that a significant part of the jobs in the Randstad area are held by people in the Intermediate zone. This region also contains a larger share of all houses than of all potential workers because of a relatively large share of singles and couples without children.⁸ However, in spite of the dominance of the Randstad area in terms of levels, the shares of houses, people and jobs in this region have all declined between 1973 and 2002. The share of houses has decreased strongest, with 2.6% in absolute terms and 5.3% in relative terms. The shift in the employment share has been more modest, with an absolute decrease of 0.8% and a relative decrease of 1.7%. Furthermore, it is noteworthy that the share of people and houses decreased most steeply in the 1970s, whereas the share of jobs decreased most steeply in the 1980s and early 1990s.

Please insert Figure 2 somewhere around here.

The number of houses, people in the age group 15 - 64 and employment in the Intermediate zone as a share of the national total are shown in Figure 3. This region accounts for about a quarter of all houses, people and jobs. As a significant part of the residents work in the Randstad area, the share of people exceeds the share of jobs and households are relatively large in this region, so that the share of people exceeds the share of houses too. The shares of houses, people and jobs have all increased by more in absolute terms than the decrease of these shares in the Randstad area, so the Intermediate zone has also expanded at the expense of the Periphery. In relative terms, these shifts are quite substantial. In particular, the share of houses has increased relative to its 1973 level by almost 15%. Furthermore, the figure indicates that while the shares of houses and people have increased rather homogeneously over the past decades, the share of employment started rising significantly only in the second half of the 1980s.

Please insert Figure 3 somewhere around here.

⁷ The average share of workers that work outside their region of residence is about 20 percent. Another criterion was that COROP regions should consist of municipalities, and add up to provinces (European NUTS2).

⁸ The difference between these two shares has decreased over time, which should probably be explained by the increasing share of foreign immigrants in the Randstad area, who tend to live in larger households.

Finally, Figure 4 contains the same variables as Figures 2 and 3 for the Periphery. In this area, the employment share is significantly lower than the shares of the other two variables, which is probably related to a higher unemployment rate, a lower participation rate and a higher rate of self employment. All shares have decreased over the past decades, but these developments were modest in absolute terms, when compared to developments in the other two areas. With a decrease of 5.1%, the share of people has fallen strongest in relative terms. Nevertheless, the Figures 2 to 4 suggest that most of the interesting dynamics for our purposes has occurred in the Randstad and Intermediate zone.

Please insert Figure 4 somewhere around here.

The trends in these figures give a clear indication with respect to the question whether employment growth has been a driver of regional development. While the housing stock and the potential labour force have risen faster in the Intermediate zone than in the Randstad throughout the 1970s, employment growth started picking up only in the second half of the 1980s. It seems unlikely, therefore, that local employment growth has driven the shift of houses and people towards the Intermediate zone. Another indication in support for the hypothesis that “jobs have followed people” in this case is that the industrial composition was relatively favourable in the Randstad area, with a large share of employment in services. Moreover, the density of people and jobs was highest here, so that economies of agglomeration may have pushed up local labour demand too. If “people would follow jobs” at this regional level, population growth should therefore be highest in the Randstad area. As the opposite has happened, we would infer that the regional distribution of employment has adjusted to shifts in local population growth instead, although the figures suggest that this adjustment has taken some time.

If it was not a shift in regional labour demand, what else could have driven growth in the Intermediate zone? A standard explanation from urban economic theory would be that rising incomes and falling transport costs have made it attractive for people to live in larger houses at a greater distance from their jobs. In unregulated land markets, these houses would typically be provided at the city fringe. The resulting process of urban sprawl or suburbanization has been observed almost everywhere in the

developed world (cf. Anas et al., 1998).⁹ However, restrictions on residential development at the fringe of cities in the Randstad may have implied that increased demand for spacious dwellings has been satisfied at locations further away, in the Intermediate zone. For instance, the so-called Green Heart area between the four largest cities has been almost fully exempted from new construction, but growth at specific towns, of which some are located in the Intermediate zone, has been stimulated by the national government in variants of a “clustered deconcentration” policy.

The trends in Figures 2, 3 and 4 do not offer clear insights into the validity of this account, but some support for it may be found in land use statistics.¹⁰ In the year 2000, 16% of all land in the Randstad area was built-up and 62% was used for agriculture, against 9% built-up land and 64% agricultural land in the Intermediate zone. This observation is difficult to reconcile with accommodative supply responses to increased demand for spacious dwellings at city fringes, because we would then expect to find a much smaller share of agricultural land in the Randstad area. Hence, land use information appears to be consistent with the hypothesis that sufficient space for residential development would have been available in this area, but that policies have prevented its usage.¹¹

3 Data and model variables

Annual information on the regional housing stock and population stems from administrative data in the Netherlands.¹² Statistics Netherlands keeps track of all changes in the housing stock, either through new construction, demolitions or

⁹ This is a competing explanation for urban sprawl, generally referred to as the “flight from blight” hypothesis, which asserts that rich households have left city centres because of a lack of public goods like high-quality schools and protection against crime (cf. Nechyba and Walsh, 2004). As the provision of such local public goods is generally more evenly spread over locations in the Netherlands than in the US, and perhaps also at a higher level, this explanation seems less relevant in the context of our analysis.

¹⁰ This information is provided by Statistics Netherlands in the “Bodemstatistiek 2000”.

¹¹ In particular, these land use statistics make it difficult to understand why the region of Flevoland has grown so dramatically over the past decades, if it were not for the reason of spatial planning. Founded on land reclaimed from the sea, the new town of Almere had very little to offer in terms of job opportunities or cultural amenities in its early years. Even in 2002, houses were about 40 percent more expensive in Amsterdam than in Almere, controlled for a broad range of quality characteristics, suggesting that people still consider the city of Amsterdam as a more attractive residential location nowadays. Sufficient agricultural land was available at locations closer to the main employment centres near Amsterdam. However, the shares of houses and people in Flevoland have steadily increased from essentially zero to almost 2% of the national total. The only plausible explanation appears to be a sustained policy effort to boost the population in Almere, in combination with strong restrictions on growth at many other locations near Amsterdam.

conversions, at the municipal level. These data have been put together in consistent regional time series by the consultancy ABF Research.¹³ Municipalities are obliged by law to administer all births, deaths and migrations in their territory. Statistics Netherlands gathers this information, and transforms it into regional demographic time series. This source also contains information on the age and gender composition of the regional population. In our analyses, we will focus on developments in the regional population aged between 15 and 64, as this group constitutes the potential labour force.¹⁴ Finally, regional employment is derived from regional accounts. These data stem from Statistics Netherlands as well, which collects them as a part of the national accounting process.¹⁵ A limited number of industries are distinguished, and the data also contain an estimate of the regional value added. However, only employment of employees is observed, measured in the number of person-years. This means that regional variation in self employment and hours per worker are ignored in our analysis.

Please insert Table 1 somewhere around here.

The housing stock $HOU_{r,t}$ in region r and year t is measured as the number of housing units. Note that we do not distinguish a (regulated) rental sector and an owner-occupier sector, nor are new construction and demolitions treated separately in our analysis. As Table 1 indicates, the variation in the regional housing stock is substantial, ranging from 17,000 to 600,000 dwellings. Clearly, the larger part of this variation exists between regions, but the average variation in the time series within regions appears to be substantial too. The regional housing stock has been growing with less than 2% annually on average. The larger part of the variation in this growth rate occurs in the time series dimension.

Our demographic information consists of regional population and migration, disaggregated to age and gender. The empirical analysis focuses on $POP_{r,t}$, the population in the age group 15 - 64, which approximately covers the potential labour force. The average regional population in this age group is about 250,000 persons and

¹² Note in particular that we do not have to rely on estimates based on decennial censuses, such as in the US. This should allow us to infer short-run dynamics in a more accurate way.

¹³ We kindly thank ABF Research for providing us with these data.

¹⁴ The reason is that the interactions between population and employment appear to be driven primarily by the labour market, as will be verified in Section 5.

its average growth rate is about 0.8% per year. The municipal records include information on internal and foreign migration. Hence, we can decompose population growth into the rate of net incoming internal migration $NIM_{r,t}/POP_{r,t-1}$, the rate of natural population increase $NPI_{r,t}/POP_{r,t-1}$, and in foreign migration, which is further ignored in this paper.¹⁶ One major advantage of this decomposition is that the population growth that results from natural population increase is likely to be exogenous to changes in housing supply and labour demand, so that it is a useful instrument.¹⁷ The number of net internal migrants is smaller than 1% of the regional population in 95% of all observations. The average regional population growth through natural population increase, which results solely from births, deaths and ageing, is about 0.6% per year.¹⁸

Regional employment $EMP_{r,t}$ is measured as the number of person-years of employees. Its average is about 120,000 full time equivalents, and the average regional growth rate is about 1% per year. As for the regional number of houses and people, the largest part of the variation in levels for this variable occurs at the regional level, while most variation in growth rates is found at the time series level. Note also that the temporal variation in employment growth is much larger than the variation in growth rates of the housing stock and the population, presumably reflecting a larger sensitivity to the business cycle.

As a consequence of our choice to analyse annual time series spanning three decades at the regional level, we have only a limited number of explanatory variables at our disposal. In particular, regional house prices and wages are not available for our period of observation. However, we may exploit fairly detailed demographic information to construct determinants of housing demand and labour supply. It is common in the housing markets literature to predict shifts in housing demand that result from demographic changes by multiplying shifts in the age composition of the population with age-specific headship rates in a given base year (cf. DiPasquale and

¹⁵ Consistent regional time series for eight industries have been derived from these data by CPB Netherlands Bureau for Economic Policy Analysis.

¹⁶ Foreign migration rates are small relative to internal migration rates. Furthermore, we would expect this latter variable to be more responsive to local housing and labour market conditions. For foreign migrants, other aspects such as proximity to relatives or people of the same cultural background may be more important.

¹⁷ It may be argued that natural population increase is endogenous because the size and composition of the current population is the result of past migration decisions, but net migration is small relative to the size of the average regional population, so this is unlikely to be relevant empirically.

Wheaton, 1996). We adapt this approach in order to obtain estimates of the regional demand for housing units on the basis of the age composition of the regional population. We observe h_t^k , the share of people in age group k and period t that are household head, at the national level.¹⁹ The expected number of households is obtained by multiplying these headship rates by the regional age-specific population size, and summing over age groups. We scale this variable to the total regional population $TPOP_{r,t}$, including the age groups (0 - 14) and (75 and older), to obtain the *expected regional headship rate* $EHR_{r,t} = \sum_k h_t^k POP_{r,t}^k / TPOP_{r,t}$. As each household will generally demand one house, this variable is likely to be an important determinant of regional housing demand. Table 1 indicates that on average, 37% of the regional population is household head, so that the average regional household size in our sample is 2.7 persons.

Changes in the regional population are partly driven by internal migration. Since migrants are on average younger than the indigenous population, changes in the age composition of the population in a region may be endogenous in our model. This issue is avoided by considering only the changes in the age composition that are driven by natural population increase. The variable $GEHR_{r,t}$, referred to as the *growth rate of the expected regional headship rate based on natural population increase*, is obtained by evaluating the growth rate of $EHR_{r,t}$, while substituting $POP_{r,t-1}^k + NPI_{r,t}^k$ for $POP_{r,t}^k$. After some rewriting, this yields:

$$GEHR_{r,t} = \frac{\sum_k h_t^k (POP_{r,t-1}^k + NPI_{r,t}^k)}{\sum_k h_{t-1}^k POP_{r,t-1}^k} \frac{TPOP_{r,t-1}}{TPOP_{r,t-1} + TNPI_{r,t}} - 1. \quad (1)$$

The average growth rate of the expected regional headship rate thus computed equals about 1.2%. This reflects a substantial decrease in the average household size, from a regional average of 3.4 persons in 1973 to 2.4 persons in 2002. The variation in this variable is somewhat smaller than the variation in the housing stock and population, both in the regional and the temporal dimension.

¹⁸ There are a few kinks in the demographic time series because of shifts in municipal boundaries, which explain the outliers in the rate of population growth and natural population increase. In the empirical analysis, we control for these kinks through dummies.

¹⁹ This information, provided by Statistics Netherlands, is based on a survey that is held about every four years. We thank Carel Harmsen of Statistics Netherlands for providing us with these data. Age-specific headship rates were interpolated for years in which no survey was held.

In a similar way, we compute the *expected regional participation rate* $ERP_{r,t}$ based on the demographic composition, using national age and gender-specific participation rates. This variable may be an important determinant of regional labour supply. Let $p_t^{k,g}$ denote the national participation rate in age group k , gender g and year t , which is measured by Statistics Netherlands. We then define $ERP_{r,t} = \sum_{k,g} p_t^{k,g} POP_{r,t}^{k,g} / POP_{r,t}$, where we sum over age groups between 15 and 64 and scale to the regional potential labour force. The average expected regional participation rate in our sample is 62%. Like changes in the expected headship rate, changes in this variable may be endogenous in our model. Hence, we define $GEPR_{r,t}$, the *growth rate of the expected regional participation rate based on natural population increase*, as:

$$GEPR_{r,t} = \frac{\sum_k p_t^k (POP_{r,t-1}^k + NPI_{r,t}^k)}{\sum_k p_{t-1}^k POP_{r,t-1}^k} \frac{POP_{r,t-1}}{POP_{r,t-1} + NPI_{r,t}} - 1. \quad (2)$$

The average growth rate of the expected regional participation rate thus computed equals about 0.3%, which predominantly reflects a rise in female labour participation over the past decades.

Changes in the regional demand for labour are identified by two variables. Information on the industrial composition of regional employment and on industry-specific national employment growth rates g_t^i is combined to predict regional employment growth with the so-called *share* $SHA_{r,t} = \sum_i g_t^i EMP_{r,t-1}^i / EMP_{r,t-1}$ (cf. Bartik, 1991).²⁰ Table 1 indicates that its variation is significantly smaller than the variation in regional employment growth. Furthermore, the regional accounting data include value added for the same industrial breakdown as for employment. This information is used to construct *productivity* $PRO_{r,t}$ as the ratio of value added to employment. This variable is a crude proxy for labour productivity, although it reflects the average regional human capital and returns to other factors as well. Under *ceteris paribus* conditions, labour demand should be higher in regions where labour

²⁰ The share variable is based on a slightly finer industrial division than the 8 industries observed throughout our period observation, but different divisions were used for the period until 1987 and the period after.

productivity is higher. The average productivity is 44,000 Euros in current prices per full-time equivalent, and it varies predominantly in the longitudinal dimension.

Unfortunately, we have no obvious exogenous determinants of housing supply, because housing supply in the Netherlands appears to be predominantly a policy outcome, rather than a market outcome. One would ideally like to use proxies for policies that affect regional housing supply, but we have not been able to obtain such variables. However, lags in growth of the housing stock may arguably capture some of these supply side considerations. In the first place, certain features of land use regulation in the Netherlands, such as the preservation of the “Green Heart” area and “clustered deconcentration” policies, have been highly persistent over the past decades. Secondly, the procedures for changing land use plans and obtaining permission for new construction are quite lengthy, which may translate into high autocorrelation in a time series of regional growth of the housing stock as well.

4 Econometric analysis

In empirical work on the interdependency of local population and employment growth in the spirit of Carlino and Mills (1987), it is generally assumed that population and employment in a region converge to their equilibrium values according to a lagged adjustment process. This restricts the dynamics of the interdependency, implying in particular that such specifications cannot distinguish between short-run and equilibrium adjustment effects. While this assumption may be appropriate when changes in regional population and employment over a decade are considered, it is less innocuous in analyses of annual regional time series. In earlier work on regional population and employment growth in the Netherlands (Vermeulen and Van Ommeren, 2004), we have tested the lagged adjustment specification against a more general econometric model and it was strongly rejected. The Figures 2 to 4 in our present paper are also suggestive of interesting differences in the dynamics of adjustment processes. Notably, while the regional share of houses and people develop more or less in line, employment appears to adjust to these variables with a certain lag. Therefore, we do not impose lagged adjustment dynamics on our model, but more general dynamic specifications are estimated instead. As a consequence, we cannot identify our model on exclusion restrictions that follow from lagged adjustment and in each equation, we have to pay

careful attention to identification with the use of other instruments.²¹ In the remainder of this section, we will present results for each equation separately.

4.1 Housing supply

Next to fixed effects for each region and period, our econometric model for the growth rate of the regional housing stock contains mainly demand shifters. Both population and employment growth push up local housing demand, whereas the expected regional headship rate accounts for composition effects with respect to age (see Section 3). These variables appear in first differences and lagged levels in order to allow for the identification of short and long-run effects respectively. Employment growth $\overline{\Delta emp}_{r,t}$ is weighted with a spatial weight matrix because labour demand in neighbouring regions may affect the regional demand for housing. This approach essentially follows Boarnet (1994). The weight matrix is estimated on interregional commuting flows, as explained in more details in the Appendix. Furthermore, the lagged level of the housing stock is included, because a large regional housing stock relative to the population is likely to reduce new supply. It may also reduce supply because of a long-run upward sloping supply curve of residential land, as predicted by urban economic theory (cf. Fujita, 1989). This yields the following equation, where lower case variables are in logarithms:

$$\begin{aligned} \Delta hou_{r,t} = & a_r + b_t + \alpha_1 \Delta pop_{r,t} + \alpha_2 \overline{\Delta emp}_{r,t} + \alpha_3 GEHR_{r,t} + \alpha_4 ehr_{r,t-1} \\ & + \alpha_5 hou_{r,t-1} + \alpha_6 pop_{r,t-1} + \alpha_7 emp_{r,t-1} + u_{r,t} \end{aligned} \quad (3)$$

The growth rates of population and employment are endogenous in this equation if regions with a high supply of housing attract people and jobs.²² The variable $\Delta pop_{r,t}$ is therefore instrumented with $NPI_{r,t}/POP_{r,t-1}$, the population growth rate due to natural increase, which is plausibly exogenous to local housing market conditions. The

²¹ While the validity of identification on the assumption of lagged adjustment dynamics is seldom tested, Boarnet (1994) reports an overidentifying restrictions test that rejects his exclusion restrictions. This suggests that identification of simultaneous models of local population and employment growth may be a more troublesome issue than is generally acknowledged in the literature.

²² We treat all variables in lagged levels as exogenous. This assumption may be challenged when using fixed effects estimation, because it requires the explanatory variables to be strictly exogenous. However, the bias that results from estimating a dynamic panel data model with fixed effects is inversely proportional to the number of periods observed, approximately 30 in our case. We assume that this number is large, so that the bias is ignored.

variable $\overline{\Delta emp}_{r,t}$ is instrumented with the spatially weighted shifters of regional labour demand, $\overline{SHA}_{r,t}$, and $\overline{pro}_{r,t-1}$, and supply, $\overline{GEPR}_{r,t}$. We estimate Equation (3) under various exogeneity assumptions, while weighting all observations with the average regional size of the housing stock.²³ Results are shown in Table 2, where the reported standard errors are robust to heteroskedasticity and autocorrelation up to the second order.²⁴

Please insert Table 2 somewhere around here.

The first specification in this table contains estimation results of Equation (3) by Ordinary Least Squares (OLS), hence ignoring potential endogeneity issues. However, using $NPI_{r,t}/POP_{r,t-1}$, $\overline{GEPR}_{r,t}$, $\overline{SHA}_{r,t}$, and $\overline{pro}_{r,t-1}$ as instruments, a *C* statistic wildly rejects orthogonality of $\Delta pop_{r,t}$ and $\Delta emp_{r,t}$ to the error term, so these estimates reflect conditional correlations rather than causal effects. The second specification instruments both population growth and employment growth using a two-stage least square (TSLS) estimator. The *F* tests of joint significance of the instruments in the first stage equations indicate that they predict these variables reasonably well and an overidentifying restrictions test suggests that they are valid. Regional employment growth is assumed to be exogenous in Specification 3, but the *p* value associated with a *C* test of orthogonality of $\overline{\Delta emp}_{r,t}$ to the error term is 0.06. In Section 3, we have argued that although our housing supply equation does not include clear exogenous supply shifters, lags of the dependent variable are likely to pick up supply side considerations to some extent. Therefore, Specification (4) includes $\Delta hou_{r,t-1}$ as an explanatory variable, while $\Delta pop_{r,t}$ is instrumented as in Specification (3). The *p* value associated with a *C* test of orthogonality of employment growth on the error term is now 0.19, so that treating it as exogenous seems justified.

Consistent with the low price elasticity of housing supply reported in Vermeulen and Rouwendal (2007), the estimation results suggest that growth of the regional

²³ All estimation and testing in this section has been carried out with the IVREG2 command in STATA. See Baum et al. (2003) for a thorough explanation of these procedures.

²⁴ Throughout the analyses in this section, we exclude Flevoland from our observations (see Footnote 6), and a number of dummies are included in the model to account for administrative shifts in boundaries of the COROP regions.

housing stock accommodates demand-side variables at most to a limited extent. While the first specification points to a strong conditional correlation between $\Delta pop_{r,t}$ and $\Delta hou_{r,t}$, a 10% increase in the regional population being associated with a 3.5% increase in the housing stock, this effect disappears once we account for the endogeneity of population growth. Notably, no economically or statistically significant impact of this variable exists in the final specification. Since in the next subsection, internal migration will appear to be highly sensitive to regional housing supply, the bias in the OLS estimates is likely to be due to simultaneity. Furthermore, the effect of $\overline{\Delta emp}_{r,t}$ appears to be negligible, except perhaps in the second specification, although there it is only significant at the 10% level. While the estimated effect of $\overline{GEPR}_{r,t}$ and $ehr_{r,t-1}$ is positive in the first specification, these variables appear mostly with a negative sign in the other specifications. This runs counter to what one would expect if housing supply were demand driven as well.

In the long run, housing supply is negatively affected by the regional density of housing. A 10% increase in $hou_{r,t-1}$ reduces the dependent variable by about 0.4% annually in all specifications. This effect appears to be counterbalanced by a small positive effect of $\overline{emp}_{r,t-1}$ and, in the fourth specification, $pop_{r,t-1}$. Hence, there may be a limited demand-induced effect in the long run. Furthermore, the results point to substantial autocorrelation in growth of the regional housing stock. The large coefficient for the first lag of this variable in Specification 4 is consistent with the view of housing supply as being determined by long-running planning processes rather than by short-run variations in demand.

4.2 *Net internal migration*

Next to the inherent attractiveness of regions, for which we control through fixed effects, net internal migration is assumed to be driven by conditions on local labour and housing markets. Both housing supply and spatially weighted employment enter in levels and first differences in the migration equation, where the latter variable proxies labour demand in regions on an acceptable commuting distance. Furthermore, we include the lagged level of the regional population in this equation. A large regional population relative to the housing stock and the level of employment is likely to put

pressure on local labour and housing markets, and hence reduce net incoming migration. Furthermore, a large population density may make residing in a region more or less attractive, depending on (dis)economies of scale such as social interactions or congestion externalities. This yields the following econometric model for net internal migration in the age group 15 - 64:

$$\begin{aligned}
NIM_{r,t}/POP_{r,t-1} = & c_r + d_t + \beta_1 \Delta hou_{r,t} + \beta_2 \overline{\Delta emp}_{r,t} \\
& + \beta_3 hou_{r,t-1} + \beta_4 pop_{r,t-1} + \beta_5 \overline{emp}_{r,t-1} + v_{r,t}
\end{aligned} \tag{4}$$

Growth of the regional housing stock is endogenous in this equation to the extent that housing supply is responsive to demand. We instrument $\Delta hou_{r,t}$ with $NPI_{r,t}/POP_{r,t-1}$ and $GEHR_{r,t}$, although the analysis of housing supply has pointed out that this variable is not so responsive to these demand shifters. Hence, we also use $\Delta hou_{r,t-2}$ as an instrument. Taking the second lag should reduce concerns about endogeneity of this variable, while evidence of the autocorrelation in regional housing supply suggests that it is still a sufficiently strong instrument. Regional employment growth is endogenous in Equation (4) to the extent that labour demand responds elastically in the short run to regional shifts in supply. We instrument this variable with the same labour demand and supply shifters as in the housing supply equation. Estimation results for various specifications are shown in Table 3, where all observations have been weighted with the regional average of the population.

Please insert Table 3 somewhere around here.

The first specification of this table shows estimates of Equation (4) by OLS, but as a C statistic strongly rejects orthogonality of $\Delta hou_{r,t}$ and $\overline{\Delta emp}_{r,t}$ on the error term, these results do not allow for a causal interpretation. The variable $\Delta hou_{r,t}$ is instrumented with $NPI_{r,t}/POP_{r,t-1}$ and $GEHR_{r,t}$ in Specification 2, and with $\Delta hou_{r,t-2}$ in Specification 3, while $\overline{\Delta emp}_{r,t}$ is instrumented with $\overline{SHA}_{r,t}$, $\overline{pro}_{r,t-1}$, and $\overline{GEPR}_{r,t}$ in both specifications. As expected, the instruments for $\Delta hou_{r,t}$ in Specification (2) appear to be rather weak, witness the F statistic on joint significance in a first stage regression.

Overidentifying restrictions tests do not reject the exclusion restrictions in either specification. In Specification 4 we instrument $\Delta hou_{r,t}$ with $\Delta hou_{r,t-2}$, while treating $\overline{\Delta emp_{r,t}}$ as exogenous. A C test of orthogonality of $\overline{\Delta emp_{r,t}}$ on the error term does not reject this assumption ($p = 0.26$).

Irrespective of the way in which we treat $\Delta hou_{r,t}$, the results point to a particularly strong short-run relationship between housing supply and internal migration. In the first specification, a 10% increase of the housing stock is associated with a 6.5% increase of the regional population in the age group 15 - 64 through internal migration, conditional on the other explanatory variables. Although a lack of clear supply shifters makes identification of this effect somewhat troublesome, the other specifications suggest that if anything, the OLS estimates have underestimated the impact of $\Delta hou_{r,t}$.²⁵ In particular, the estimates in Specifications (3) and (4) indicate a unit short-run elasticity of the regional migration rate with respect to housing supply. Furthermore, there is evidence of a modest long-run effect through $hou_{r,t-1}$, as well as a negative impact of population density of about the same magnitude. This suggests that a long-run relationship between these two variables may exist, which is characterised by a unit elasticity, and that internal migration responds to deviations from this relationship. In contrast, the short-run effect of employment is estimated to be small and statistically insignificant in all specifications, while it is even negative in the long-run.

4.3 *Employment growth*

The model for regional employment growth contains both demand and supply shifters. Labour demand is expected to be higher in regions with a more favourable industry mix and in regions in which the value added per employee is higher. Supply is incorporated through levels and first difference of the regional population aged between 15 and 64, which constitutes the potential labour force, and of the expected regional participation rate based on demographic composition (see Section 3). These supply variables are spatially weighted because the availability of labour in regions on an acceptable commuting distance may affect regional employment too. We use a slightly different spatial weight matrix than in the housing supply and migration equations, see again the

²⁵ The sign of this bias does not point to simultaneity, suggesting that omitted variables play a role.

Appendix for details. Although new construction may generate some employment directly, we do not include this variable in our econometric model, because the residential construction industry is small relative to total employment. The lagged level of employment is included because it may reduce employment growth if it is large relative to the regional population. Furthermore, the density of employment may affect growth through (dis)economies of agglomeration. Under these assumptions, the following equation obtains:

$$\begin{aligned} \Delta emp_{r,t} = e_r + f_t + \delta_1 \overline{\Delta pop}_{r,t} + \delta_2 \overline{GEPR}_{r,t} + \delta_3 \overline{ep}_{r,t-1} + \delta_4 \overline{SHA}_{r,t} + \delta_5 \overline{pro}_{r,t-1} \\ + \delta_6 \overline{pop}_{r,t-1} + \delta_7 \overline{emp}_{r,t-1} + w_{r,t} \end{aligned} \quad (5)$$

Our analysis of internal migration suggests that the endogeneity issue of $\overline{\Delta pop}_{r,t}$ is likely to be limited, as a reverse impact of employment growth on population growth appears to be virtually absent. Nevertheless, we instrument this variable with both $\overline{NPI}_{r,t}/\overline{POP}_{r,t-1}$ and $\overline{\Delta hou}_{r,t}$. Estimation results are shown in Table 4, where the observations have been weighted by the average regional employment.

Please insert Table 4 somewhere around here.

The first specification in this table has been estimated by OLS and as expected, a *C* test that uses $\overline{NPI}_{r,t}/\overline{POP}_{r,t-1}$ and $\overline{\Delta hou}_{r,t}$ as instruments does not reject orthogonality of $\overline{\Delta pop}_{r,t}$ to the error term ($p = 0.60$). Hence, the relationships in Specification 1 may be interpreted in a causal way. Nevertheless, we present TSLS results for Equation (5), instrumenting with both $\overline{NPI}_{r,t}/\overline{POP}_{r,t-1}$ and $\overline{\Delta hou}_{r,t}$ in Specification (2), and with $\overline{NPI}_{r,t}/\overline{POP}_{r,t-1}$ only in Specification (3). An *F* test indicates that $\overline{\Delta pop}_{r,t}$ is well identified in both specifications. Furthermore, the Hansen *J* test does not reject our exclusion restrictions in the second specification, which justifies in particular our exclusion of housing supply in the employment growth model.

The impact of population growth on employment growth appears to be negative in the short run, although the coefficient of $\overline{\Delta pop}_{r,t}$ is estimated rather imprecisely. However, a 10% higher lagged level of the population is associated with a 1.7% higher

annual growth rate of employment. The impact of the lagged level of employment is negative with about the same magnitude. This suggests that a long-run relationship exists between these variables that is characterised by a unit elasticity, and that any deviation from it is reduced by almost 20% annually through employment growth.

Our other shifter of labour supply, the age composition of the regional population, appears to have a large and statistically significant impact in the short run. Furthermore, the two labour demand shifters have a positive effect as expected. A 10% increase in employment growth expected on the basis of industrial composition is associated with a 5% increase of actual employment. Nevertheless, the impact of these variables is only statistically significant at the 10% level. Thus, labour demand considerations feature less prominently in the equation than supply side variables.

5 Labour supply or local consumer demand?

The previous section has indicated that employment adjusts to the regional distribution of the population. Throughout this paper, we have assumed that this adjustment process was driven by the labour market. However, regional population growth may also attract jobs because of increased demand for products that are not traded between regions, such as certain retail products and local services. In this section, we perform a rudimentary check of whether it is labour supply that attracts employment, or local consumer demand. Using information about the industrial composition of regional employment, we are able to make a rough distinction between employment in a sector that exports to other regions or countries, and a sector that produces for local consumption.²⁶ If it is consumer demand that causes employment to adjust, then only the latter sector should respond to population changes. On the other hand, if employment in the export sector adjusts to population in the same way, it is more likely that labour supply has been the main reason for equilibrium adjustment.

Descriptive statics for employment in the export sector $EMP_{r,t}^{EX}$, and employment in the local sector $EMP_{r,t}^{LO}$, are given in Table 1. They indicate that the latter sector is somewhat larger, and that it also has a larger temporal variation than employment in the export sector. Figure 5 shows the number of people and the number

of jobs in the export and local sector as a share of the national total for the Intermediate zone, where population and employment have grown strongest (see Section 2). The figure indicates that the share of employment in both sectors has grown to a similar extent as the population share, which would suggest that labour supply has driven employment growth.²⁷

Please insert Figure 5 somewhere around here.

Our equations for $\Delta emp_{r,t}^{EX}$ and $\Delta emp_{r,t}^{LO}$ are derived from the model for total regional employment growth in Equation (5). The labour supply variables in these equations remain unchanged, but the demand shifters $\overline{SHA}_{r,t}$ and $\overline{pro}_{r,t-1}$ are calculated for each sector separately. Furthermore, we enter employment growth in the other sector, in order to account for interactions through crowding out and linkage effects (cf. Thurston and Yezer, 1994). Finally, the lagged level of employment now distinguishes $emp_{r,t-1}^{EX}$ and $emp_{r,t-1}^{LO}$. This yields the following equations:

$$\begin{aligned} \Delta emp_{r,t}^{EX} = & e_r^{EX} + f_t^{EX} + \delta_1^{EX} \overline{\Delta pop}_{r,t} + \delta_2^{EX} \Delta emp_{r,t}^{LO} + \delta_3^{EX} \overline{GEPR}_{r,t} + \delta_4^{EX} \overline{epr}_{r,t-1} \\ & + \delta_5^{EX} \overline{SHA}_{r,t} + \delta_6^{EX} \overline{pro}_{r,t-1} + \delta_7^{EX} \overline{pop}_{r,t-1} + \delta_8^{EX} emp_{r,t-1}^{EX} + \delta_9^{EX} emp_{r,t-1}^{LO} + w_{r,t}^{EX}, \end{aligned} \quad (6)$$

$$\begin{aligned} \Delta emp_{r,t}^{LO} = & e_r^{LO} + f_t^{LO} + \delta_1^{LO} \overline{\Delta pop}_{r,t} + \delta_2^{LO} \Delta emp_{r,t}^{EX} + \delta_3^{LO} \overline{GEPR}_{r,t} + \delta_4^{LO} \overline{epr}_{r,t-1} \\ & + \delta_5^{LO} \overline{SHA}_{r,t} + \delta_6^{LO} \overline{pro}_{r,t-1} + \delta_7^{LO} \overline{pop}_{r,t-1} + \delta_8^{LO} emp_{r,t-1}^{EX} + \delta_9^{LO} emp_{r,t-1}^{LO} + w_{r,t}^{LO}. \end{aligned} \quad (7)$$

Although the previous section has indicated that $\overline{\Delta pop}_{r,t}$ may be treated as exogenous in the equation for total employment growth, we instrument it with $\overline{NPI}_{r,t}/\overline{POP}_{r,t-1}$ in these sector-specific models. Furthermore, $\Delta emp_{r,t}^{LO}$ may be endogenous in the equation for $\Delta emp_{r,t}^{EX}$ and $\Delta emp_{r,t}^{EX}$ may be endogenous in the equation for $\Delta emp_{r,t}^{LO}$. Hence, these variables are instrumented with the sector specific

²⁶ The export sector consists of the industries *agriculture and fishery, manufacturing, construction, transport and communications and banks and insurance*, and the local sector consists of *merchandise, catering and repair, real estate, other services in the tertiary sector and health care and government*.

²⁷ It is noteworthy though, that the share of employment in the local sector has grown steadily with the population share, whereas employment in the export sector has started picking up only in the 1980s.

labour demand shifters. Estimation results are shown in Table 5, where the observations have been weighted by the average total regional employment. Specifications 1 and 3 show OLS results for the export and the local sector respectively, while Specifications 2 and 4 have been estimated by TSLS.

Please insert Table 5 somewhere around here.

We focus first on the labour supply variables, which should have no role in the export sector if local consumer demand would drive employment growth. Most importantly, a 10% higher regional population increases $\Delta emp_{r,t}^{EX}$ by about 2%, and $\Delta emp_{r,t}^{LO}$ by 1 to 1.5%, depending on the estimation method. The elasticity with respect to $\overline{GEHR}_{r,t}$ is also larger in the export sector, although this is at least partially offset by a negative impact of the lagged level of this variable. These findings appear to be at odds with the hypothesis that jobs have followed people because of markets for local consumption goods, at least at our spatial level of aggregation. Furthermore, we find that employment growth in the other sector has a negative effect once we take account of its endogeneity, and that sector specific share variables appear to be stronger predictors in these models than the aggregate share in Equation (5). These two observations are consistent with the view that employment in one sector may grow at the expense of the other sector, but that aggregate employment is determined by the regional supply of labour. It should be noted, however, that the overidentifying restrictions tests cast doubt on the validity of our instruments, so that these results should be interpreted with caution.

6 Conclusions and discussion

Our empirical analysis identifies housing supply as a driving force behind regional development in the Netherlands. Although a strong correlation exists between regional growth of the number of houses and residents, housing supply does not turn out to be responsive to either population or employment growth once the endogeneity of these variables is taken into account. In contrast, net internal migration appears to be highly sensitive to changes in the regional housing stock, while a growing number of jobs has a negligible impact. We find that the long-run relationship between the number of people

and jobs in a region is mainly restored through changes in employment growth. So regional housing supply induces population growth and in the long run, this increase in labour supply is matched by demand.

The prominence of housing supply in our findings may appear surprising as, with the notable exception of Greenwood (1980) and Greenwood and Stock (1990), it is ignored in most of the empirical literature on the interdependency of local population and employment growth. However, as recently observed by Glaeser et al. (2006), the response of local labour supply to shifts in demand depends crucially on the price elasticity of housing supply. These authors show that in US cities where new construction is restricted by severe land use controls, shifts in labour demand push up house prices and wages, but employment is largely unaffected. It follows that in such cities, employment is basically determined by the size of the housing stock. Since housing supply conditions are highly restrictive in the Netherlands as well, our findings are perfectly in line with this work.

Our results are also consistent with strands of the literature on internal migration and regional labour markets. Notably, the importance of housing market conditions for internal migration has been reported in various earlier studies (cf. Gabriel et al., 1992, for the US, Jackman and Savouri, 1992, Cameron et al., 2006, for the UK, and Antolin and Bover, 1997, for Spain). The absence of any significant effect of employment growth on internal migration in our analysis is in line with the mixed performance of regional wage and unemployment variables in the literature (cf. Greenwood, 1993). Furthermore, labour is known to be rather immobile between regions, in particular in most European countries (cf. Eichengreen, 1993, Decressin and Fatas, 1995, OECD, 2005). To the extent that regional labour supply adjusts to demand through internal migration, such findings suggest that the wage elasticity of regional labour supply is limited. On the other hand, the regional demand for labour should be elastic with respect to wages, in particular in a small and open economy such as the Netherlands. Although short-run elasticities are generally found to be below unity (cf. Bartik, 1991), it seems plausible that the long-run employment response to a shift in wages is substantially larger (cf. Muth, 1990). If regional labour demand is much more sensitive to wages than supply, one should expect to find that employment adjusts to the regional distribution of people rather than the other way around.

Unfortunately, the demand and supply elasticities in labour and housing markets that enable us to interpret the results in terms of underlying economic behaviour could

not be estimated, because regional house prices and wages were not available.²⁸ As a consequence of our choice to analyse annual time series spanning three decades at the regional level, the range of other explanatory variables at our disposal was also limited. While this has made the identification of causal relationships challenging, this disadvantage of our empirical strategy has been traded off against the possibility to study analyse both short and long-run effects in the interdependency of our endogenous variables. Furthermore, the regional panel structure of the data has allowed us to control fully for national trends as well as for all time-invariant regional determinants of growth rates of housing, population and employment.

In interpreting our results, a few other caveats should also be born in mind. In the first place, labour demand and supply are heterogeneous. Although aggregate employment has been found to adjust to the regional supply of labour, the inclination to follow jobs is likely to rise with educational attainment. If housing supply restricts the total number of workers in a booming region, higher educated workers may outbid the lower educated for housing. The existence of significant differences in educational attainment between regions in the Netherlands supports this view. In the second place, it should be realised that our results have been obtained in a setting which is characterised by restrictive land use regulation and generally tight housing market conditions. It makes sense to expect that new construction attracts workers and jobs in a region where housing supply is highly restricted. However, this finding should not be taken as a recipe for growth enhancement in lagging peripheral regions, where the size of the housing stock by and large reflects demand conditions.

So why has job growth over the past decades been weaker in the Dutch Randstad area than in surrounding regions? While our analysis points to the role of lagging housing supply, it does not provide explicit evidence of the role of land use planning. However, there is ample evidence that policies such as preservation of the “Green

²⁸ However, since housing supply in the Netherlands is almost fully inelastic with respect to prices, adding house prices to the housing supply equation in our analysis would not add a lot of explanatory power in all likelihood. Wage bargaining at the national level reduces regional wage differentials, which are therefore believed to be rather small. Hence, the consequences of omitting wages in the equations for net internal migration and employment growth may be limited as well. The most unfortunate omission in our analysis is probably the absence of house prices in the migration equation. Nevertheless, this loss may also be limited because about half of the housing stock is rental housing, to which various regulations apply. The regional variation in controlled rents is particularly small in the social sector, where rationing is the dominant allocation mechanism. Moreover, it should be realised that house prices and wages are endogenous to regional housing and labour market outcomes. Including these variables would require an extension of the system of three equations with another two equations, thus rendering identification even more complicated.

Heart” area and other green buffer zones between the four large Dutch cities have imposed significant and binding restrictions on new residential development (cf. Vermeulen and Rouwendal, 2007). Thus, land use planning has altered the spatial pattern of economic activity in the Netherlands and through economies of agglomeration, it has probably left its marks on productivity too. In other words, there may be substance to the OECD claim that housing market institutions partly explain lagging labour productivity in the Randstad area.

Appendix: Accounting for interregional commuting

In the empirical analysis in Section 4, we use weight matrices in order to account for interregional commuting. The matrix W^1 applied to employment related variables in the equations for housing supply and internal migration, whereas W^2 is applied to population related variables in the model for employment growth.

For the housing supply and internal migration equations, we compute $\overline{EMP}_{i,t} = \sum_j w_{ij}^1 EMP_{j,t}$, where w_{ij}^1 may be interpreted as the probability that someone working in region j lives in region i . Multiplying this probability by employment in region j we get the expected number of people working in j that live in region i , and summing over employment regions yields the expected working labour force in region i . For the employment growth equation, we compute $\overline{POP}_{i,t} = \sum_j w_{ij}^2 POP_{j,t}$, where w_{ij}^2 may be interpreted as the probability that someone living in region j would work in region i . Multiplying this probability by population in region j we get the expected number of people living in region j that potentially work in region i (the probability is also applied to people that do not participate). The sum over population regions yields weighted potential labour supply for production in region i .

In order to avoid endogeneity of the weight matrices, the elements w_{ij}^1 and w_{ij}^2 are computed using predicted, rather than observed commuting patterns. We predict commuting flows with following gravity model:

$$COM_{ij,t} = A_i B_j F(d_{ij}) . \tag{A.1}$$

The variable $COM_{ij,t}$, the number of commuters living in region i and working in region j , is explained by origin and destination-specific effects A_i and B_j , and a distance

decay function $F(d_{ij})$. None of the parameters depends on the period t , we use the variation in commuting flows over time only to obtain more precise estimates. The distance decay function is parameterized as follows:

$$F(d_{ij}) = \exp(\alpha_i D_i^1 + \beta_i D_i^2 + \gamma_i d_{ij}). \quad (\text{A.2})$$

So we assume that the number of commuters between two regions decreases exponentially with distance. The dummy variable D_i^1 corrects for commuting within regions and the dummy variable D_i^2 measures border effects. In order to account for regional heterogeneity, we allow all coefficients to vary with the region of living. The parameters α_i , β_i and γ_i are estimated on 1992 – 2002 commuting data from the Dutch Labour Force Survey. Distance between two regions is measured by the average number of car kilometres travelled by commuters, because the largest share of interregional commuters travels by car.²⁹

The probabilities w_{ij}^1 and w_{ij}^2 are computed using the predicted commuting flows from model A.2 in the following way:

$$w_{ij}^1 = \frac{A_i F(d_{ij})}{\sum_i A_i F(d_{ij})}, \quad w_{ij}^2 = \frac{B_i F(d_{ji})}{\sum_i B_i F(d_{ji})}. \quad (\text{A.3})$$

Note that $\sum_i w_{ij}^1 = 1$ and $\sum_i w_{ij}^2 = 1$, so that these weights can indeed be interpreted as probabilities.³⁰

Finally, we remark that commuting costs have decreased over time, so that our estimates based on the period 1992 - 2002 overestimate interregional commuting in earlier years. However, as only about 20% of the work force lives and works in different COROP regions nowadays, the impact on our results of ignoring this is probably limited.

²⁹ Estimation results are available upon request.

³⁰ The matrices W^1 and W^2 differ from the spatial weight matrices that are common in spatial econometric applications (Anselin, 1988) in two perspectives. Firstly, numbers on the diagonal are smaller than one, because diagonal flows have been included in the commuting model. Secondly, computing the required probabilities amounts to column normalization, instead of the usual procedure of row normalization.

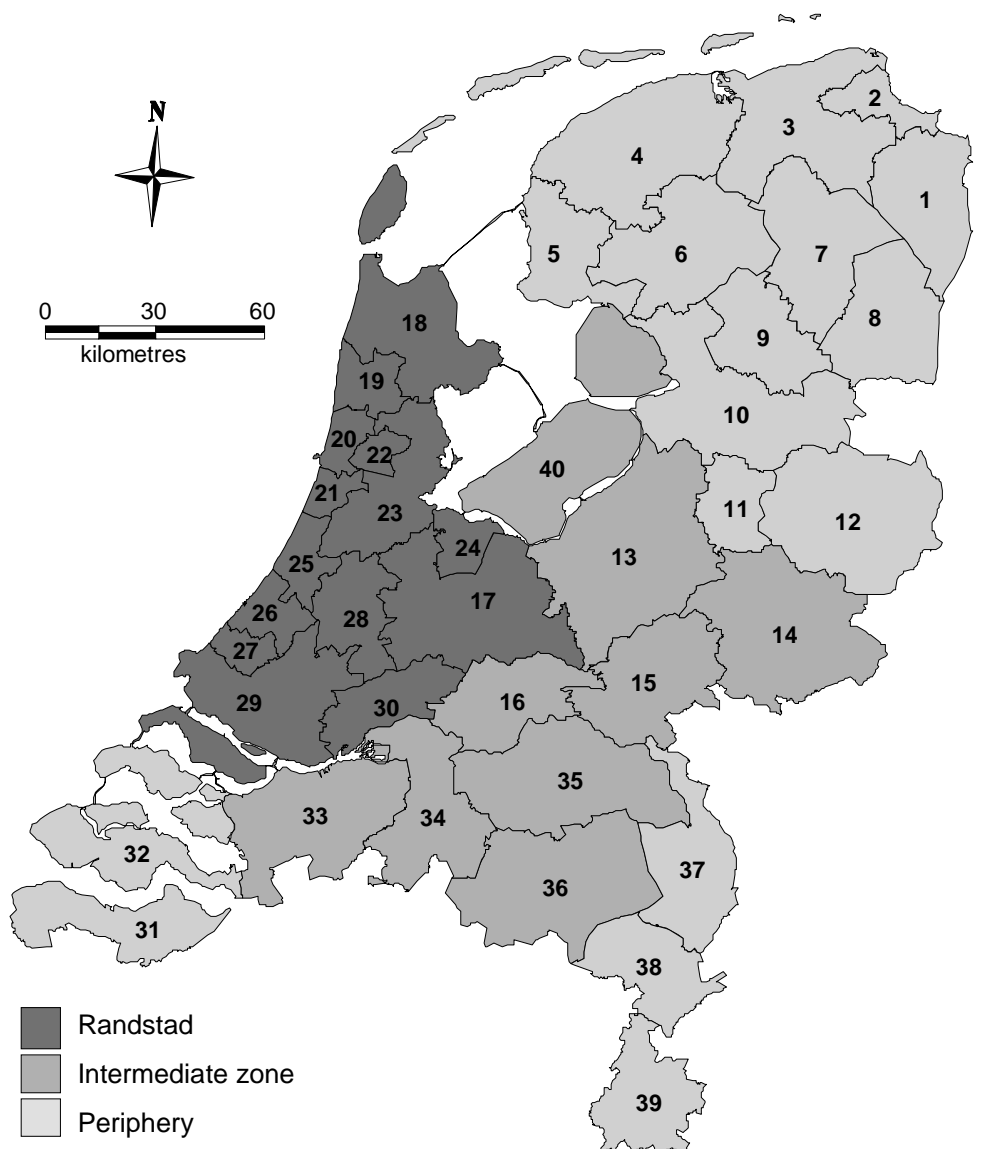
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Figure 1: Overview of the COROP regions and country parts



■ Randstad

■ Intermediate zone

■ Periphery

- | | | | |
|----|-----------------------|----|--------------------------------|
| 1 | Oost-Groningen | 21 | Agglomeratie Haarlem |
| 2 | Delfzijl en omgeving | 22 | Zaanstreek |
| 3 | Overig Groningen | 23 | Groot-Amsterdam |
| 4 | Noord-Friesland | 24 | Het Gooi en Vechtstreek |
| 5 | Zuidwest-Friesland | 25 | Agglom. Leiden en Bollenstreek |
| 6 | Zuidoost-Friesland | 26 | Agglomeratie 's-Gravenhage |
| 7 | Noord-Drenthe | 27 | Delft en Westland |
| 8 | Zuidoost-Drenthe | 28 | Oost-Zuid-Holland |
| 9 | Zuidwest-Drenthe | 29 | Groot-Rijnmond |
| 10 | Noord-Overijssel | 30 | Zuidoost-Zuid-Holland |
| 11 | Zuidwest-Overijssel | 31 | Zeeuwsch-Vlaanderen |
| 12 | Twente | 32 | Overig Zeeland |
| 13 | Veluwe | 33 | West-Noord-Brabant |
| 14 | Achterhoek | 34 | Midden-Noord-Brabant |
| 15 | Arnhem/Nijmegen | 35 | Noordoost-Noord-Brabant |
| 16 | Zuidwest-Gelderland | 36 | Zuidoost-Noord-Brabant |
| 17 | Utrecht | 37 | Noord-Limburg |
| 18 | Kop van Noord-Holland | 38 | Midden-Limburg |
| 19 | Alkmaar en omgeving | 39 | Zuid-Limburg |
| 20 | IJmond | 40 | Flevoland |

Figure 2: Housing, population and employment share of the Randstad area

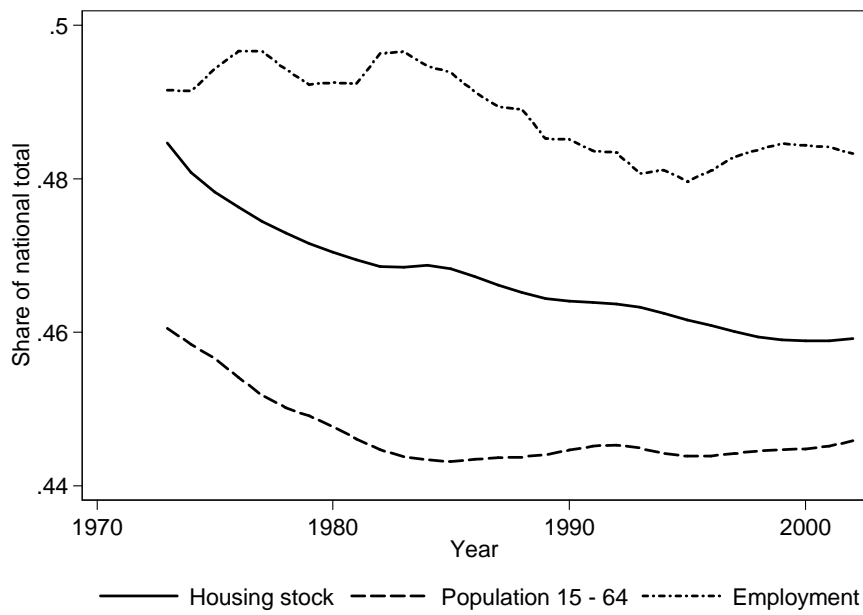


Figure 3: Housing, population and employment share of the Intermediate zone



Figure 4: Housing, population and employment share of the Periphery

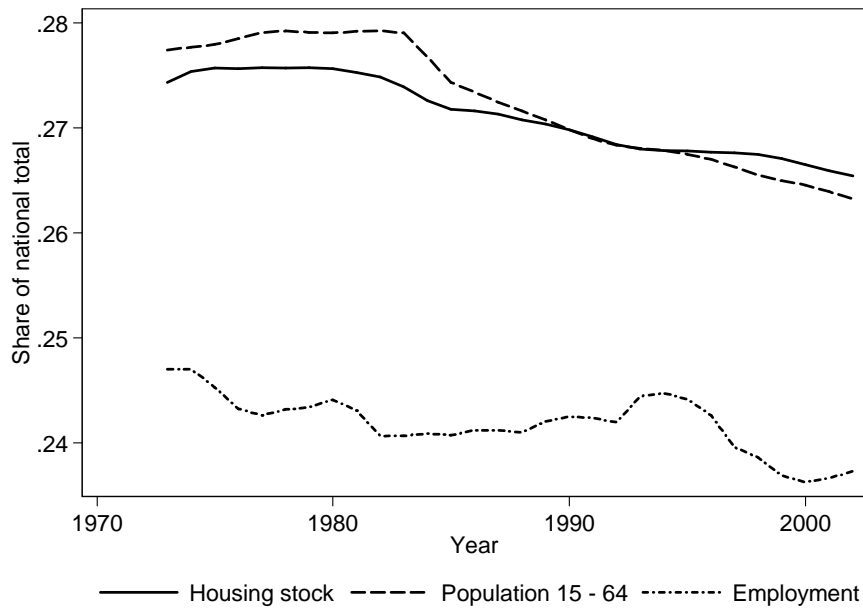


Figure 5: Share of population and employment in two sectors of Intermediate zone

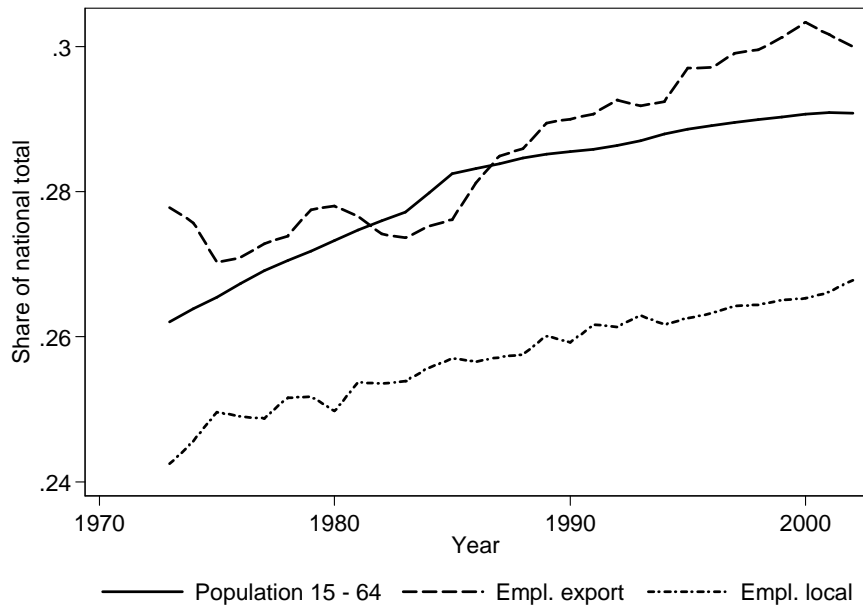


Table 1: Sample properties for all model variables

Variable	Mean	Standard deviation			Minimum	Maximum	Number of obs.	
		Overall	Between	Within			Periods	Total
$HOU_{r,t}$ (1000)	139.8	114.7	113.4	25.0	17.3	601.5	30	1170
$\Delta hou_{r,t}$ (%)	1.688	0.840	0.379	0.752	-0.720	5.683	29	1131
$POP_{r,t}$ (1000)	252.7	191.5	192.4	23.8	31.5	923.5	31	1209
$\Delta pop_{r,t}$ (%)	0.779	1.026	0.381	0.955	-7.119	4.056	30	1170
$NIM_{r,t}/POP_{r,t-1}$ (%)	-0.053	0.500	0.260	0.429	-1.785	2.965	30	1170
$NPI_{r,t}/POP_{r,t-1}$ (%)	0.593	1.189	0.284	1.156	-14.555	7.839	30	1170
$EMP_{r,t}$ (1000)	118.9	108.4	108.2	18.2	11.3	615.8	31	1209
$\Delta emp_{r,t}$ (%)	0.941	2.593	0.502	2.545	-13.236	15.128	30	1170
$EHR_{r,t}$ (%)	36.93	3.87	1.13	3.71	27.55	43.87	30	1170
$GEHR_{r,t}$ (%)	1.238	0.697	0.210	0.665	-0.194	3.633	31	1209
$EPR_{r,t}$ (%)	61.89	3.00	0.62	2.93	57.14	71.29	30	1170
$GEPR_{r,t}$ (%)	0.266	0.906	0.129	0.897	-1.485	2.750	31	1209
$SHA_{r,t}$ (%)	0.962	1.608	0.253	1.588	-3.886	4.103	29	1131
$PRO_{r,t}$ (1000)	44.21	16.56	7.73	14.69	14.19	135.66	30	1170
$EMP_{r,t}^{EX}$ (1000)	52.00	44.73	44.93	5.67	6.53	236.37	30	1170
$EMP_{r,t}^{LO}$ (1000)	67.30	67.04	65.42	17.91	4.03	408.70	30	1170

Notes: Variables in lower case are in logarithms. The housing stock is measured in 1000 units. All demographic variables are measured in 1000 persons and refer to the age group 15 - 64. All employment variables refer to employees, measured in 1000 full time equivalents. Productivity is measured in 1000 Euros in current prices per full time equivalent. The region of Flevoland was excluded when computing these descriptives, as the empirical analysis treats this observation as an outlier.

Table 2: Estimation of the housing supply equation

Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4
$\Delta pop_{r,t}$	0.350 (0.066)***	-0.151 (0.082)*	-0.127 (0.069)*	0.006 (0.036)
$\overline{\Delta emp}_{r,t}$	0.008 (0.008)	0.160 (0.084)*	0.007 (0.009)	0.013 (0.006)**
$GEHR_{r,t}$	0.138 (0.092)	-0.302 (0.146)**	-0.243 (0.123)**	-0.135 (0.081)*
$ehr_{r,t-1}$	0.003 (0.017)	-0.079 (0.022)***	-0.069 (0.020)***	0.015 (0.011)
$hou_{r,t-1}$	-0.041 (0.008)***	-0.047 (0.011)***	-0.045 (0.010)***	-0.038 (0.005)***
$pop_{r,t-1}$	-0.003 (0.005)	-0.028 (0.011)***	-0.012 (0.007)*	0.010 (0.004)***
$\overline{emp}_{r,t-1}$	0.015 (0.005)***	0.033 (0.013)**	0.011 (0.007)*	0.009 (0.004)***
$\Delta hou_{r,t-1}$				0.676 (0.032)***
region dummies (39)	incl.	incl.	incl.	incl.
time dummies (29)	incl.	incl.	incl.	incl.
Observations	1131	1131	1131	1092
R-squared	0.84			
F(instruments for $\Delta pop_{r,t}$)		5.71 $p = 0.00$	5.69 $p = 0.00$	6.37 $p = 0.00$
F(instruments for $\overline{\Delta emp}_{r,t}$)		7.48 $p = 0.00$		
Hansen J statistic		0.37 $p = 0.83$	3.84 $p = 0.28$	2.14 $p = 0.54$

Notes: Reported standard errors are robust to arbitrary heteroskedasticity and autocorrelation up to the second order, * indicates significance at 10% level, ** indicates significance at 5% level and *** indicates significance at 1% level. Observations are weighted to the regional housing stock, averaged over time. The outlier region of Flevoland is left out of our sample. The equation further includes a number of dummies that control for administrative shifts in regional borders, which are not reported in the table.

Table 3: Estimation of the equation for net internal migration

Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4
$\Delta hou_{r,t}$	0.654 (0.033)***	2.652 (0.843)***	1.165 (0.121)***	1.167 (0.110)***
$\overline{\Delta emp}_{r,t}$	0.009 (0.007)	-0.154 (0.205)	0.139 (0.088)	0.006 (0.009)
$hou_{r,t-1}$	0.023 (0.006)***	0.151 (0.056)***	0.048 (0.011)***	0.052 (0.009)***
$pop_{r,t-1}$	-0.030 (0.004)***	-0.006 (0.024)	-0.041 (0.009)***	-0.028 (0.006)***
$\overline{emp}_{r,t}$	-0.003 (0.004)	-0.052 (0.039)	0.013 (0.014)	-0.008 (0.005)
region dummies (39)	incl.	incl.	incl.	incl.
time dummies (29)	incl.	incl.	incl.	incl.
Observations	1131	1131	1053	1053
R-squared	0.69			
F(instruments for $\Delta hou_{r,t}$)		2.28 $p = 0.05$	18.06 $p = 0.00$	18.18 $p = 0.00$
F(instruments for $\overline{\Delta emp}_{r,t}$)		5.35 $p = 0.00$	6.02 $p = 0.00$	
Hansen J statistic		3.61 $p = 0.31$	3.53 $p = 0.17$	

Notes: Reported standard errors are robust to arbitrary heteroskedasticity and autocorrelation up to the second order, * indicates significance at 10% level, ** indicates significance at 5% level and *** indicates significance at 1% level. Observations are weighted to the regional population, averaged over time. The outlier region of Flevoland is left out of our sample. The equation further includes a number of dummies that control for administrative shifts in regional borders, which are not reported in the table.

Table 4: Estimation of the employment growth equation

Variable	Spec. 1	Spec. 2	Spec. 3
$\overline{\Delta pop}_{r,t}$	-0.311 (0.187)*	-0.323 (0.279)	-0.817 (0.448)*
$\overline{GEPR}_{r,t}$	0.622 (0.157)***	0.624 (0.161)***	0.685 (0.176)***
$\overline{epr}_{r,t-1}$	-0.189 (0.139)	-0.184 (0.158)	-0.004 (0.204)
$\overline{SHA}_{r,t}$	0.507 (0.297)*	0.508 (0.298)*	0.525 (0.299)*
$\overline{pro}_{r,t-1}$	0.013 (0.007)*	0.013 (0.007)*	0.013 (0.007)*
$\overline{pop}_{r,t-1}$	0.173 (0.028)***	0.173 (0.029)***	0.164 (0.030)***
$\overline{emp}_{r,t-1}$	-0.144 (0.019)***	-0.144 (0.019)***	-0.151 (0.020)***
region dummies (39)	incl.	incl.	incl.
time dummies (29)	incl.	incl.	incl.
Observations	1131	1131	1131
R-squared	0.51		
F(instruments for $\overline{\Delta pop}_{r,t}$)		119.40 $p = 0.00$	16.86 $p = 0.00$
Hansen J statistic		1.87 $p = 0.17$	

Notes: Reported standard errors are robust to arbitrary heteroskedasticity and autocorrelation up to the second order, * indicates significance at 10% level, ** indicates significance at 5% level and *** indicates significance at 1% level. Observations are weighted to regional employment, averaged over time. The outlier region of Flevoland is left out of our sample. The equation further includes a number of dummies that control for administrative shifts in regional borders, which are not reported in the table.

Table 5: Employment growth in the local and export sector

Variable	Export sector		Local sector	
	Spec. 1	Spec. 2	Spec. 3	Spec. 4
$\Delta \overline{pop}_{r,t}$	-0.038 (0.229)	-0.976 (0.598)	-0.437 (0.226)*	-0.868 (0.577)
$\Delta emp_{r,t}^{LO}$	0.138 (0.038)***	-0.236 (0.278)		
$\Delta emp_{r,t}^{EX}$			0.137 (0.049)***	-0.081 (0.199)
$\overline{GEPR}_{r,t}$	0.786 (0.225)***	1.063 (0.305)***	0.344 (0.170)**	0.580 (0.259)**
$\overline{epr}_{r,t-1}$	-0.886 (0.225)***	-0.699 (0.289)**	0.019 (0.199)	-0.044 (0.275)
$\overline{SHA}_{r,t}^{EX}$	0.895 (0.253)***	0.769 (0.278)***		
$\overline{pro}_{r,t-1}^{EX}$	0.017 (0.007)**	0.018 (0.008)**		
$\overline{SHA}_{r,t}^{LO}$			1.176 (0.280)***	1.167 (0.296)***
$\overline{pro}_{r,t-1}^{LO}$			0.019 (0.029)	0.010 (0.030)
$\overline{pop}_{r,t-1}$	0.197 (0.033)***	0.229 (0.055)***	0.101 (0.041)**	0.149 (0.074)**
$\overline{emp}_{r,t-1}^{EX}$	-0.120 (0.015)***	-0.127 (0.017)***	0.011 (0.014)	-0.019 (0.029)
$\overline{emp}_{r,t-1}^{LO}$	0.036 (0.017)**	-0.037 (0.054)	-0.184 (0.040)***	-0.187 (0.041)***
region dummies (39)	incl.	incl.	incl.	incl.
time dummies (29)	incl.	incl.	incl.	incl.
Observations	1131	1131	1131	1131
R-squared	0.50		0.32	
F(instruments for $\overline{\Delta pop}_{r,t}$)		13.81 $p = 0.00$		5.78 $p = 0.00$
F(instruments for $\Delta emp_{r,t}^{LO}$)		6.66 $p = 0.00$		
F(instruments for $\Delta emp_{r,t}^{EX}$)				8.48 $p = 0.00$
Hansen J statistic		4.18 $p = 0.04$		2.56 $p = 0.11$

Notes: Reported standard errors are robust to arbitrary heteroskedasticity and autocorrelation up to the second order, * indicates significance at 10% level, ** indicates significance at 5% level and *** indicates significance at 1% level. Observations are weighted to regional employment, averaged over time. The outlier region of Flevoland is left out of our sample. The equation further includes a number of dummies that control for administrative shifts in regional borders, which are not reported in the table.