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Modelling transport in an interregional General Equilibrium Model with externalities

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Abstract

In this working paper the regional impacts of road pricing on cars are analysed taking into account externality effects from transportation on wages and productivity. In the paper the direct impacts from changes in transport costs on level of wages and productivity (=direct externality effects) have been estimated.

The direct and derived impacts of road pricing have been analysed with AKF's local economic model LINE and include the impacts on regional production, income and employment. LINE is an interregional general equilibrium model, which uses an interregional social accounting matrix (SAM-K) and a regional transport satellite account as the basis for modelling. Additionally, data from a GIS-system (Technical University of Copenhagen) on transport costs have been included to estimate the demand for transport commodities and increase in transport demand and costs due to road pricing.

The direct effects on level of wages and productivity have been included into the model together with all the direct effects on commodity prices from road pricing. In the working paper the total impacts of road pricing have been subdivided into 2 components: 1) The wage effects of reducing income net of commuting of increasing transport cost by introduction of road pricing, 2) the labour contraction effect from increasing wages through increase in commuting cost and 3) the negative productivity effects of introducing road pricing.

In total the impacts of road pricing are substantial. Regions with high level of average commuting cost (suburban areas in Greater Copenhagen) suffers most, whereas the centre of Copenhagen suffers least because of short commuting distances. In rural areas impacts are on or just below average because low level of road pricing.

1. Introduction

It is customary to model transport in an Interregional General Equilibrium model without including the effects of both positive and negative externalities. In such a simplified model focus is usually directed at the price effects of direct changes in transport costs, as the transport system is modified.

The inclusion of negative externalities such as congestion and environmental damage can usually be incorporated either as a pre-model extension where transport costs include impacts from congestion or as a post-model where environmental damage is modelled as a function of level of economic activity and a set of emission coefficients. This is normally straightforward, as the pre- and post models are usually linked in a loosely coupled system. In such a system by definition feedback effects from the economic model to the pre-model (from the economic system to congestion, for example) and from the post-model to the economic model (from environmental system to economic system, for example) are not incorporated.

The inclusion of positive externalities is a more difficult task because it usually involves integration of the externality into consumption and production behaviour. This is because positive externalities normally have both impacts on economic activity and are influenced by level of economic activity.

For small and medium size firms (SMEs) this means that increasing concentration (both number and density of firms) increases their productivity. On the other hand, increasing productivity reduces prices, increases competitiveness and thereby export and economic activity. These feedback mechanisms imply that modelling positive externalities involves the application of an interregional general equilibrium model with productivity as a fully integrated sub-model.

In the paper first a general presentation of the theory of positive externalities is made. This is followed by an examination of the effects of transport system changes on economic activity, through an econometric study of Danish regions. In order to illustrate the redistributional impacts on economic activity by positive externalities, an Interregional General Equilibrium model for Denmark is presented and results from a study using this model of the spillover and feedback effects of positive externalities are examined.

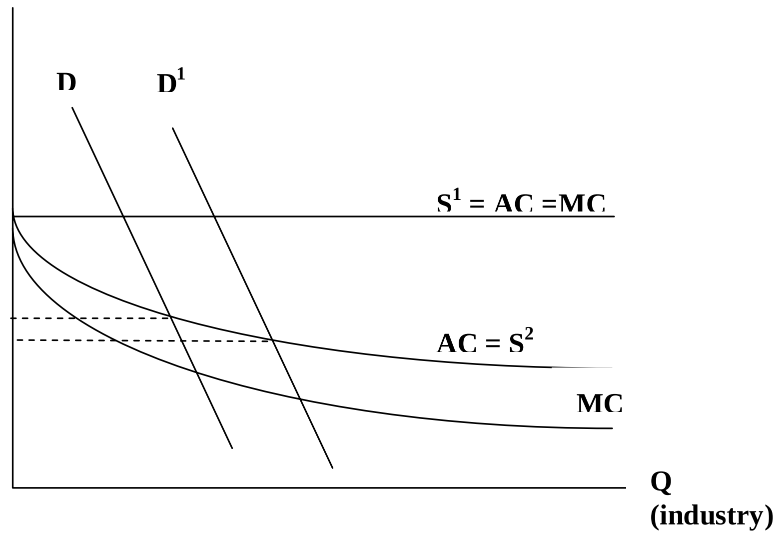
2. Positive externalities

Agglomeration economies are positive externalities associated with the spatial concentration of economic activity, resulting in lower marginal and average costs and increases in productivity. These are scale economies which do not apply at the level of the individual firm, but at the level of the industry. It is therefore possible to retain the assumption of perfect competition whilst analysing the effects of externalities.

In the literature it is customary to distinguish between locational economies, which arise from agglomeration of firms within the same industry and agglomeration or urban economies, which arise when firms in different industries agglomerate in the same (urban) area.

Externalities can be best understood by examining the case of locational economies in relation to the industry supply curve. A constant cost industry has a horizontal supply curve, which is derived from the minimum point on the long-run average cost (LRAC) curve of (identical) small firms in the industry. As the industry expands, new firms are added and the supply curve remains horizontal. If, however, there are scale economies which are external to the firm but internal to the industry, then the arrival of each additional firm will mean that the minimum point on the LRAC curves will be lower and the industry LRAC and marginal cost curves slope down to the right, as shown in figure 1. The supply curve of a declining cost industry becomes the LRAC curve rather than the marginal cost curve, as when price equals marginal cost, firms will make a loss. A further consequence is that an increase in demand (from D to D^1) for this type of industry will result in both lower prices and increased output, as shown in figure 1. This is a prime reason for policymakers' interest in external scale economies. The theory of economies of agglomeration builds upon the assumption that spatial proximity magnifies these effects and in many cases is a condition for their operation.

Figure 1
Industry supply curves for a constant cost industry (S^1) and a declining cost industry (S^2)



Marshall's (1890) writings represent a first attempt to examine the concept of economies of agglomeration, identifying four types of advantage. His original formulation includes the advantages of a thick market for specialised skills in the labour force, the development of specialized firms with backward and forward linkages associated with large markets (Fujita, Krugman & Venables, 1999) and the existence of ancillary trades. The fourth factor, 'mysteries of the trade... in the air' , relates to what now can be termed spillover effects, which are dynamic external economies.

The labour market advantage arises mainly because of efficiency gains from a pooled labour market (Krugman 1991). The linkage gains are straightforward, resting partly on assumptions of scale economies in supplying firms (which are pecuniary external economies), as well as transport cost savings.

A distinction can be made between pecuniary and technological externalities Scitovsky (1952). A pecuniary externality (which can be either positive or negative) affects the price of inputs as the size of an industry grows. If supplying firms enjoy scale economies as the industry grows, unit costs of the production of inputs will fall. Economic theory tends not to regard this as a market distorting externality, as the benefit is generally available to competitive firms. However, pecuniary externalities may be distortionary as they frequently have a regional component, being limited by transport costs, depending upon the spatial configuration of the supply chain. They may also be subject to institutional factors, such as regional brand loyalty.

As noted above, there are a number of reasons for the occurrence of localisation economies, which can occur when firms in the same industry concentrate in a region. These include the presence of a local pool of skilled labour, pecuniary external economies arising from specialisation and from economies of scale in supplying firms, non-traded local inputs, such as infrastructure and, as argued below, knowledge spillovers, which are pure technological externalities. Urbanisation economies accrue to firms in different industrial sectors, which cluster together in urban areas. These economies arise from the existence of a large and varied labour market, economies of scale in provision of infrastructure and public services, a variety of business services and again, knowledge spillovers, this time between different industries.

The literature presents conflicting evidence concerning the relative importance of localisation and urbanisation economies. One reason for the difficulty is that urban areas will typically exhibit the effects arising from both types of economy. Henderson (1986) found some evidence for the existence of localisation economies for some US manufacturing sectors, using wage levels as a surrogate for productivity data and McCann & Fingleton (1996) provided evidence for the existence of localisation economies in Scotland's Silicon Glen. Glaeser et al (1992) found evidence that local competition and urban variety promote employment growth in US cities, rejecting the hypothesis of the existence of localisation economies in cities, and presenting evidence for the existence of knowledge transfers between industrial sectors, supporting the hypothesis of Jacobs (1969) on the role of urbanization in innovation. Henderson et al. (1995) found evidence of urban externalities for high-tech industries, consistent with the role of exchange of ideas in cities. They also found that mature capital goods industries seemed to promote and benefit from localisation economies. In addition, endogenous growth theory (Romer 1990) has provided a further theoretical foundation for the existence of localisation economies.

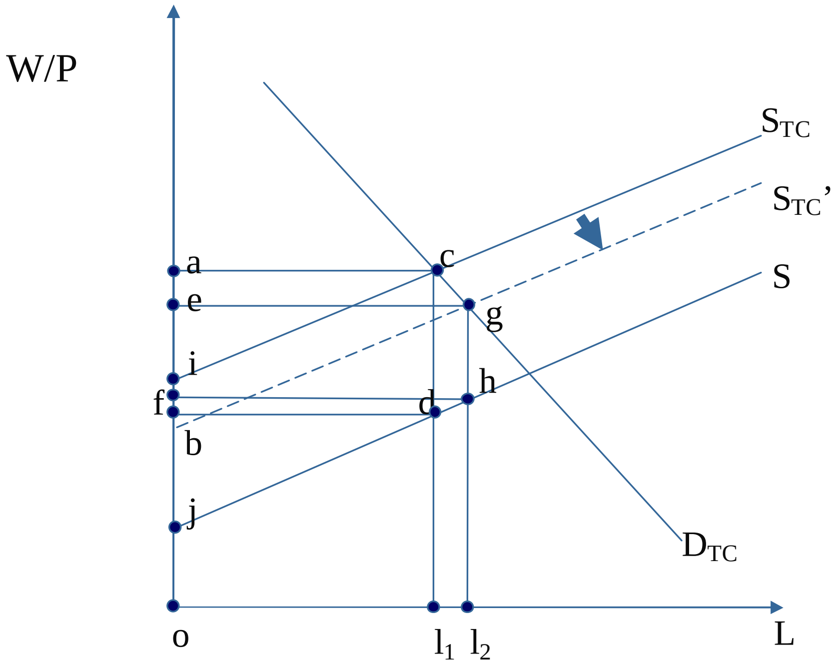
Distinction is made between static and dynamic agglomeration economies. Static economies result in a one-off downward shift in industry LRAC as shown in figure 1. Dynamic economies imply a continuous downward shift over time of the LRAC as localised industry output increases cumulatively. Whilst it seems that local pecuniary external economies related to input supply for a (localised) industry could be one cause of dynamic economies, the principal explanation for these economies is related to the production and use of knowledge, in particular the effects of knowledge spillovers, there being a public good element in the production of knowledge. The effects of knowledge spillovers on innovation and technical change, economic growth, employment and productivity in clusters, have become the central policy issue (OECD 1999, 2001) .

2.1 Pecuniary and technological externalities

It is important to distinguish between the two types of externality, pecuniary and technological. These differences are illustrated by the case of a change in the transport system involving changes in transport costs. Pecuniary externalities arising from changes in transport costs have their origins in both the commodity and factor markets. Technological externalities have their origins in direct interactions, outside the market, between producers (p) and consumers (c), giving in all four different combinations (p-p, c-c, p-c and c-p).

Pecuniary externalities can be illustrated in relation to the factor market in figure 2.

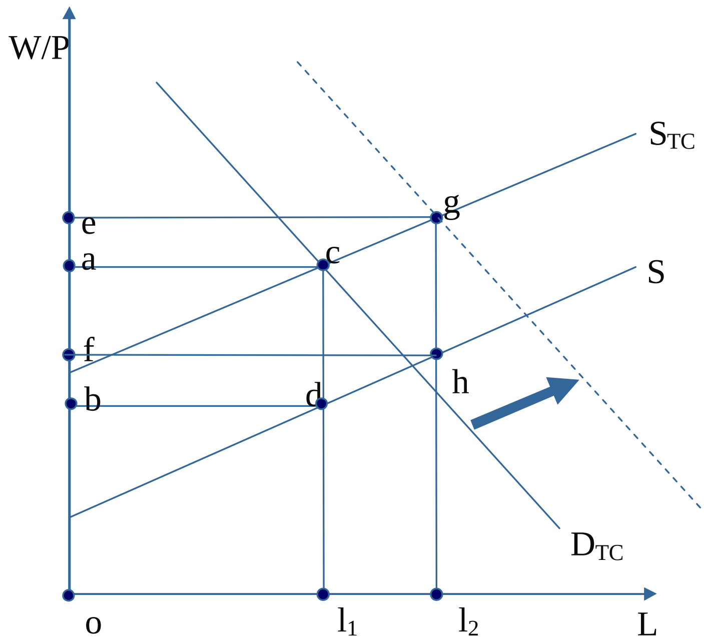
Figure 2 Pecuniary externalities associated with transport system improvements



Demand (D_{TC}) for and supply (S_{TC}) of labour are the standard curves which cross at equilibrium, c. Real wages both with and without transport costs, TC are shown in figure 2. Seen from the viewpoint of the producer and the place of production, the demand for labour includes transport costs, D_{TC}. There are two supply curves for labour, S_{TC} which shows labour supply in relation to the real wage (W/P) including transport costs (from the point of view of place of production) and S which shows labour supply in relation to the real wage (W/P from a place of residence point of view), net of transport costs from place of residence point of view. It can be assumed, that S is fixed in the long run, whereas S_{TC}, which includes transport costs, will shift with changes in these costs. In the case of transport system improvement the S_{TC} curve shifts to the right (S_{TC}'). This leads to a fall in equilibrium wage from a to e, a change in total wage bill from acl_1o to egl_2o and a change in expenditure on transport for commuting from acdb to eghf. Whether demand for transport increases or decreases depends on the price elasticity of demand for transport. The pecuniary externality for the produces is acge and for labour fhdb.

Corresponding externalities from the market for transport appear in the market for commodities, which can be illustrated in a figure similar to figure 3. Equilibrium in the commodity market is established in market prices, including the cost of transport of commodities. The demand curve for commodities intersects with the supply curve at market prices. From the viewpoint of the producer, supply is determined in basic prices, net of transport costs. Supply in market prices is determined by the use of an adding-on principle. A transport system improvement will reduce transport costs and will shift the supply curve in market prices to the right. Equilibrium prices fall, which affects the real wage (w/p). Thus, a change in transport costs will affect both w and p as shown on the vertical axis of figure 3. However, it is reasonable to assume that for any given decrease in transport costs, w will fall more rapidly than p because commuting costs are more important for labour than transport costs for commodity prices. In addition, the labour force is inherently regional, whilst commodities typically are produced in other regions or abroad, implying that the effect of local transport system improvements are greater for w than for p.

Figur 3 Technological externalities associated with transport system improvements



In the case of technological externalities, shown in figure 3, demand for labour at a given real wage increases because of non-market interaction effects arising from transactions undertaken by other agents. In this case of technological change, the demand curve for labour including transport costs (D_{TC}) shifts to the right, creating a new labour market equilibrium, as shown in figure 3, moving from c to g. This means that demand for labour increases from l_1 to l_2 and the real wage increases from a to e. The wage bill increases from acl_1o to egl_2o. The change in total expenditure on transport is shown by cghd.

3. Proximity, income and externalities in Denmark

The previous section outlined a priori expectations concerning the relationship between changes in the transport system and externality effects in relation to the labour market. First, that there is a positive relationship between changes in transport costs and the level of real wages in the case of changes in accessibility in the labour and commodity markets, this being the effect of pecuniary externalities. Second, there is a negative relationship between changes in transport costs and changes in the level of real wages in the case of changes in accessibility to urban centres. This is the effect of urban (technological) externalities. The analysis also revealed that it is important to distinguish between the direct effects of externalities (which appear at the place of production and in the unit of production) and the end user effects, which appear in the units of institutions, including the rest of the world and the place of residence of these institutions.

In this section, the results of an econometric study of real wages and externality effects in the Danish urban system are presented. In section 5 an analysis of the redistribution of these effects to end users is presented, using the subregional model LINE, presented in section 4.

3.1 Estimating urban and pecuniary externality effects: the two approaches

Two different approaches to analysis of the relationships between proximity, incomes and externalities are dealt with in the following. In order to estimate the effects of urban externalities the key spatial unit is the place of production, as the type of externality is production-production. In the case of pecuniary externalities, the spatial units of interest are both place of production and place of residence because demand and supply in the labour market involves these two components.

The first approach is based upon the hypothesis *that there is a positive externality affecting production associated with proximity to the urban centre* and that the externality is affected by distance decay. Here distance is measured from place of production to an urban centre. The externality is on the production side and producers are able to pay higher wages because workers are more productive near the urban centre because of knowledge spillovers. Firms located near the centre also benefit from the externality. An important question concerns the definition of a centre. In this study, three different measures are employed: distance from place of production (defined at the level of the municipal authority) to i) the urban centre in the (statistically defined) Danish labour market areas, ii) the capital Copenhagen, and iii) the nearest of the five large university towns: Copenhagen, Århus, Odense, Aalborg, and Esbjerg.

The second approach is based upon the hypothesis *that commuting distance is positively related to wage levels*. Commuting distance is from place of residence to place of production. It can be interpreted as a workplace disamenity and therefore workers require a higher wage if they have a longer commuting distance.

3.2 Explanations of differences in wage levels, not involving externality effects

In addition to distance, factors such as gender, age, education, and industry are often significant. Research confirms in the Danich case relationships between wage levels on the one hand and age, education and sex on the other (Albæk et al. 1999, Trigg and Madden 1995, and Berndt, 1991). If industry enters into the explanation, different sectors have different proportions of factor inputs (capital and labour) and may have better opportunities to exploit proximity advantages (cluster effects). The fact that wage levels are normally higher in the private sector (Berndt1991), indicates that political decisions concerning production levels in the public sector are not based upon the wage equals the value of the marginal product principle.

3.3 The data

The Social Accounting Matrix for Danish Municipalities (SAM-K) is the main data source in this study, and a complete description of the data is presented in Madsen et al. (2001b) and Madsen & Jensen-Butler (2005). Two main sub-sets of SAM-K are used, originating in register-based data at individual level, which are then grouped by variable.

Data used to estimate the *urban externality effects* has the following structure. The dependent variable is mean value of wages and salaries per person defined in relation to the categories used to group the individual values of the independent variables. Grouped data was used as data at individual level was not available. The independent variables are principally category variables, representing, for each of the 275 municipalities, where place of production is located grouped data. These data comprise age (3 groups), sex (2), educational qualification (5), industry (132), year (4) (to remove the effect of inflation on incomes). This gives 1,034,000 cells for each of the 4 years (275 x 3 x 2 x 5 x 132), in all 4,356.000 cells. 20,8% of these cells have non zero content with an average of 9.9 employees per observation In addition, there is a variable containing unemployment percentages for each age by sex by qualification by year for each municipality category (275 x 3 x 2 x 5 = 8.250 for each of the 4 years 33,000 possible different values). Finally, there is a distance variable, based upon location of the municipality, which has 275 possible different values. These distances are expressed as monetary values. Three distance measures are used: i) to the urban centre in the (statistically defined) Danish labour market areas, ii) to the capital Copenhagen, and iii) to the nearest of the five large university towns: Copenhagen, Århus, Odense, Aalborg, and Esbjerg. The dependent variable is mean value of wages and salaries per person (Full-time equivalent) for each of the 66.000 cells for each of the 4 years.

Data used to estimate the *pecuniary externality effects* has the following structure. The dependent variable is mean value of wages and salaries per person defined in relation to the categories used to define the values of the independent variables. Grouped data was used as data at individual level was available. The independent variables are principally category variables, representing, for each combination of the 275 municipalities where place of production is located and each of the same municipalities where place of residence is located. In the data set used to estimate pecuniary externalities, it should be noted that basic data relates to groups of individual data by place of residence. These data comprise age (3 groups), sex (2), qualification (5), year (4) (to remove the effect of inflation on incomes). This gives 2,268,750 cells for each of the 4 years (275 x 275 x 3 x 2 x 5), in all 9,075,000 cells over the 4 years. This contrast with data used to estimate urban externalities, where the basic data refers to individuals grouped by industry and there is no information concerning place of residence in this data set. In addition, there is a variable containing unemployment percentages by place of residence for each age by sex by qualification by year category (275 x 3 x 2 x 5 = 8250 cells for each of the 4 years. Finally, there is a distance variable, based upon the 275 x 275 inter-municipality distance matrix. The dependent variable is mean value of wages and salaries per person (Full-time equivalent) for each of the 2,268,750 observations per year (= 275 x 275 x 3 x 2 x 5).

The number of observations is of course much lower than the number of cells: Firstly, especially in the data set on pecuniary externalities the majority of cells are empty. Second, a number of observations have been eliminated for different reasons.

The following observations have eliminated from the data set used for the analysis of urban externalities: If place of work is abroad, not available, or located on the small island of Christiansø, and if age is below 15 or above 59. Furthermore, some extreme observations are removed, if the average wage is above 2 mill. DKK, and if total employment is under 5 working days the year concerned. This all reduces the number of observations to 277,237 per year in the 4-year-period with an average of 9.0 employees per observation and a standard deviation of about 35 workers. About 1 per cent of the observations contain more than 100 employees. The highest number of employees in an observation is around 2,200. Similar reductions have been made for the data set used to analyse pecuniary externalities. The total number of observations here is 205,680 per year with an average of 9.9 employees per observation and a larger standard deviation of about 89 employees.

Different measures of distance are applied in the regressions, but the source is the same. Distances are at municipal level. The distance from one municipality to another is the number of kilometres between the main post office in every pair of municipalities. An intra-municipality distance is calculated including elements such as size and shape of the municipality. When crossing water, kilometres are not an appropriate measure because there would usually be higher costs connected with crossing water. Therefore the kilometres are transformed into Danish kroner using the assumption that one kilometre on land equals one krone. When crossing water the price of a ferry ticket is applied instead of kilometres. The distances are from 1996. The distances could be defined in other ways taking other factors into account such as congestion, speed limits, time values, etc., but more accurate distances will not be used in this paper.

3.4 The effects of urban externalities

First, a real wage model with gender, education, sector, and unemployment as explanatory variables is set up and compared with a model which also includes municipalities as fixed effects. An F-test[1] cannot reject that the constant terms are all equal and therefore fixed effects are left out. In the fixed effects model with time dummies, unemployment is insignificant which corresponds to the results in Albæk et al. (1999).

Three measures of the centre are applied now in a model with gender, time, education, sector, and unemployment as explanatory variables. Fundamentally, more than one measure could enter into the model, but here it is assumed that there is only one type of centre in which one positive externality is present. The logarithmic transformation of all three measures describes the data better. Distance to the commuting centre is the worst measure comparing with the two others because the adjusted is smallest comparing the three models which only differ with respect to the distance measure. It might be because a definition of 35 commuting centres is chosen where some of the centres are small islands where no positive externality in production would be expected. The second best measure is the distance to Copenhagen. Given the geography of Denmark one would expect that it could be difficult to identify some distances because of the many belts, seas, sounds, and straits.

Table A.1 in appendix A contains the variable »distance5« this being the best of the three proposed measures. »Distance5« is the distance to five university towns: Copenhagen, Århus, Odense, Aalborg, and Esbjerg. Whether or not to interpret it as distance to an economic centre or distance to a university city is a matter of choice.

The test described regarding heteroscedasticity[2] rejects the hypothesis that there is no heteroscedasticity in all three models with the explanatory variables of table A.1 in appendix A. The results of the FGLS regression are preferred to WLS and OLS because the t-value of β is numerically smaller in the heteroscedasticity test.

Because both the average wage and distances are in logarithmic form the estimated parameters are elasticities. However, the elasticity is small: -0.04. If an improvement in infrastructure could be interpreted as a shorter distance then a10% improvement in infrastructure would result in a 0.4% higher wage. In the context of the theoretical setup of this paper it is also a welfare gain because the higher wages are due to a positive externality.

Even though the elasticity is small the total welfare gain is worth calculating. In 1999 1.5 million workers had a place of work outside the 5 centres and their average wage was 260,000 DKK. If all distances outside the centres were improved by 10% there would on average per worker be a welfare gain of 1040 DKK. The total welfare gain would be 1.5 million workers times 1040 DKK; a total of 1.560 billion DKK.

1 See appendix B, I).

2 See appendix C, I).

When dealing with infrastructure investment the positive externality associated with a centre is not the only benefit. Therefore the total welfare gain of the positive externality could be worth calculating as one of the benefits.

When comparing the size of the estimates in the regression the most important contributions to the average wages are gender, education, some sectors, and age. As mentioned the fixed effects model is rejected, which means that regional unemployment has a small but significant estimated parameter. An interpretation could be that higher unemployment lowers wages because of competition for vacancies.

3.5 Pecuniary externalities: Wage differentials and commuting distance

The second hypothesis of this paper is *that commuting distance affects wages*. To test this, a regression analysis on data set 2 is carried out.

We recall that data set 2 has information about both place of residence and place of work. Both place of residence and place of work could be used as a fixed effect, but when comparing adjusted R^2, place of work is chosen. However, an F-test[3] does not support the municipalities as fixed effects and because of that they are abandoned.

The same problems concerning grouped data are present in this regression as well. The test described rejects the hypothesis that there is no heteroscedasticity[4] in all three models with the explanatory variables of table A.2 in appendix A. Again, the results of the FGLS regression are preferred to WLS and OLS because the t-value of β is numerically smaller in the heteroscedasticity test.

Gender, education, age, year, unemployment by place of residence and commuting distances are all significant in the model using FGLS, WLS, and OLS. Estimates and standard deviations are presented in appendix A, table A.2. Comparing the estimated parameter with the regression using data set 1, the estimated parameters of gender have increased by 17% (using FGLS) and other changes have also occurred. The estimated parameter of unemployment is still small, though it has increased. An explanation could be that unemployment by place of residence is used and in the regression using the first data set unemployment by place of work is used.

Commuting distance has a positive effect on wages. The estimated parameter is around 0.03 (using FGLS), which means that if commuting distance doubles the average wage would increase by 3%.

4. The LINE-model - Modelling externalities and transport

Transport system changes have a direct impact on the costs of transportation, either by reducing transport costs as in the case of transport system improvements or by increasing transport costs as in the case of taxes on transport activities such as road pricing. Changes in transport costs have in turn direct effects on commodity prices and income: Transport cost changes influence directly the prices of commodities, because transport cost is a gross margin added to commodity trade. Transport costs are an addition to the price when shopping for commodities or when comsuming as a tourist. In both cases changes in transport costs are added to the price of the commodity after transportation to the buyer. Changes in transport costs also have a direct impact on disposable income net of commuting costs.

3 See appendix B, II).

4 See appendix C, II).

In addition as discussed above, transport costs also have an influence on wage levels and productivity through the effects of pecuniary and technological externalities. These effects derived from externalities add to the direct effects on the regional economy of changes in transport costs.

These direct effects on commodity prices and income, which include the effects derived from externalities, lead to a number of derived effects on the regional economy. The distribution and size of the total effects are, however, not the same as the distribution and size of the direct effects (including the externality effects). The direct effects on commodity prices and income are redistributed through the interregional markets for commodities and production factors, through intra- and interregional trade, shopping and tourism, and through commuting and disposable income, assuming that price changes are transferred directly to the consumer. When prices and income change, the end user reacts by adjusting demand, which influences real economic activity. Therefore the indirect and induced effects should be added to the direct effects (including the externality effects) in order to estimate the total effects on regional economic activity.

In order to estimate the total effects, it is necessary to construct an interregional/subregional general equilibrium model. A subregional general equilibrium model must include the effects of changes in commodity prices and income arising from transport cost changes, including the externality effects, and must also include the real economic reactions to changes in prices and income. In this section, an interregional/subregional general equilibrium model for Denmark, LINE, is briefly described. First, the real circle in LINE is presented. This includes modelling the impacts of commodity price changes and changes in wages on real economic activity. This is followed by a presentation of the cost-price circle, which include modelling of the changes in regional commodity prices and income. Finally, the inclusion of both pecuniary and technological externalities in LINE is considered.

4.1 LINE – an interregional general equilibrium model for modelling redistribution of productivity changes

Here a brief graphical presentation of LINE is made. The full model and its equations are described in detail in Madsen et al. (2001a) and Madsen & Jensen-Butler (2004). The data used in the model, together with the interregional SAM, are described in Madsen & Jensen-Butler (2005) and Madsen et al (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. Figure 4 shows the general model structure, based upon the real circle employed in LINE.

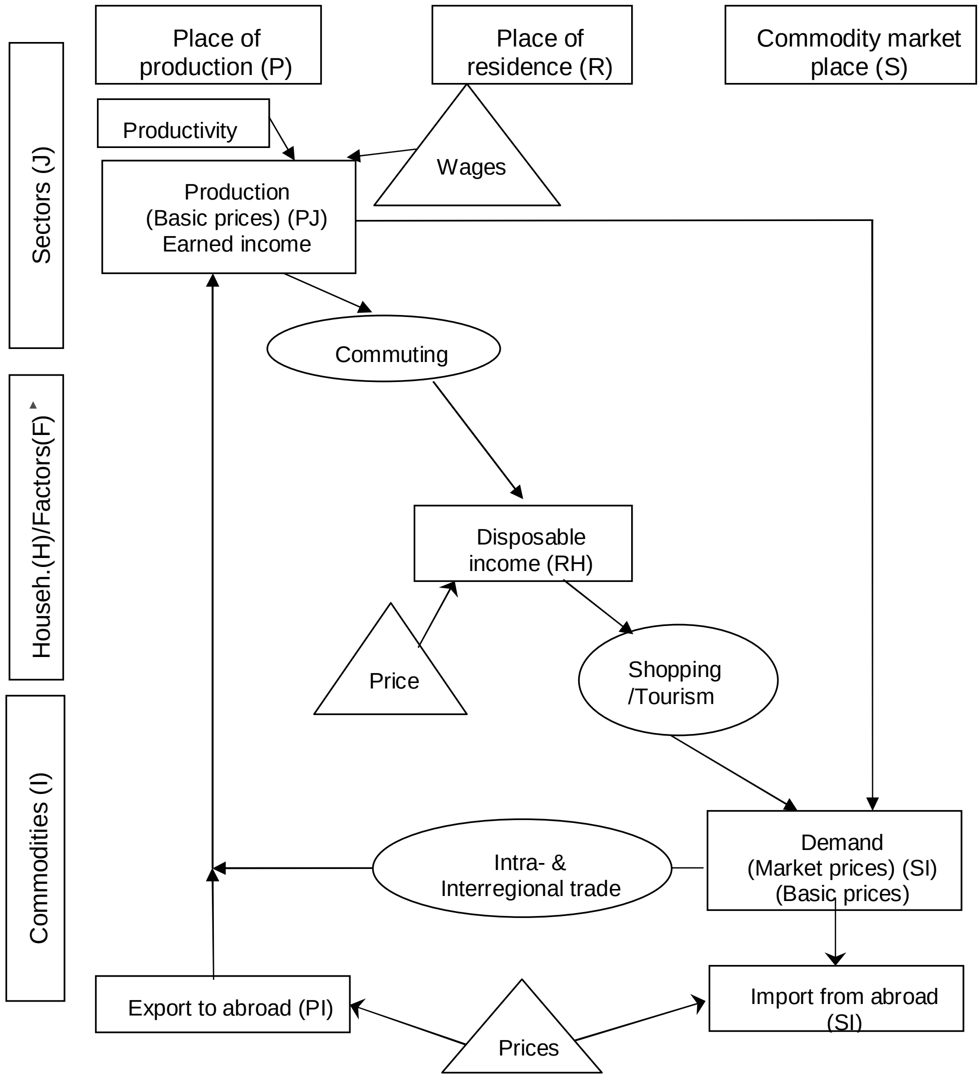
The horizontal dimension is spatial: place of production (P), place of residence (R) and place of commodity market (S). Production activity is related to place of production. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of commodity market. The vertical dimension follows with its three-fold division the general structure of a SAM model. Production is related to activities (J); factor incomes are related to factors of production with labour by sex, age and education (G) and type of households (H) commodities are related to the supply and demand for commodities (I).

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in figure 4. Starting in the upper left corner (PJ), production generates factor incomes in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors (J) to sex, age and educational groups and households (H) and from place of production (P) to place of residence (R) through a commuting model. Employment follows the same path. Employment and unemployment are determined at place of residence (R). In addition to other adjustments, taxes are deducted from factor income and transfers added, giving disposable income, which by definition is related to place of residence (RH).

Disposable income is the basis for determination of private consumption in market prices, by place of residence (RH). Private consumption is divided into tourism (domestic and international) and local private consumption and assigned to place of commodity market (SI) using a shopping model for local private consumption and a travel model for domestic tourism. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities in market prices (SI). The market price variables are transformed into basic prices through a use matrix, including information on the commodity composition of demand and commodity tax rates and trade margin shares. In this transformation from market prices to basic prices commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production (SI). Through a trade model exports to other regions and production for the region itself is determined (PI). Adding export abroad, gross output by commodity is determined (PI). Through a reverse make matrix the cycle returns to production by sector (PJ).

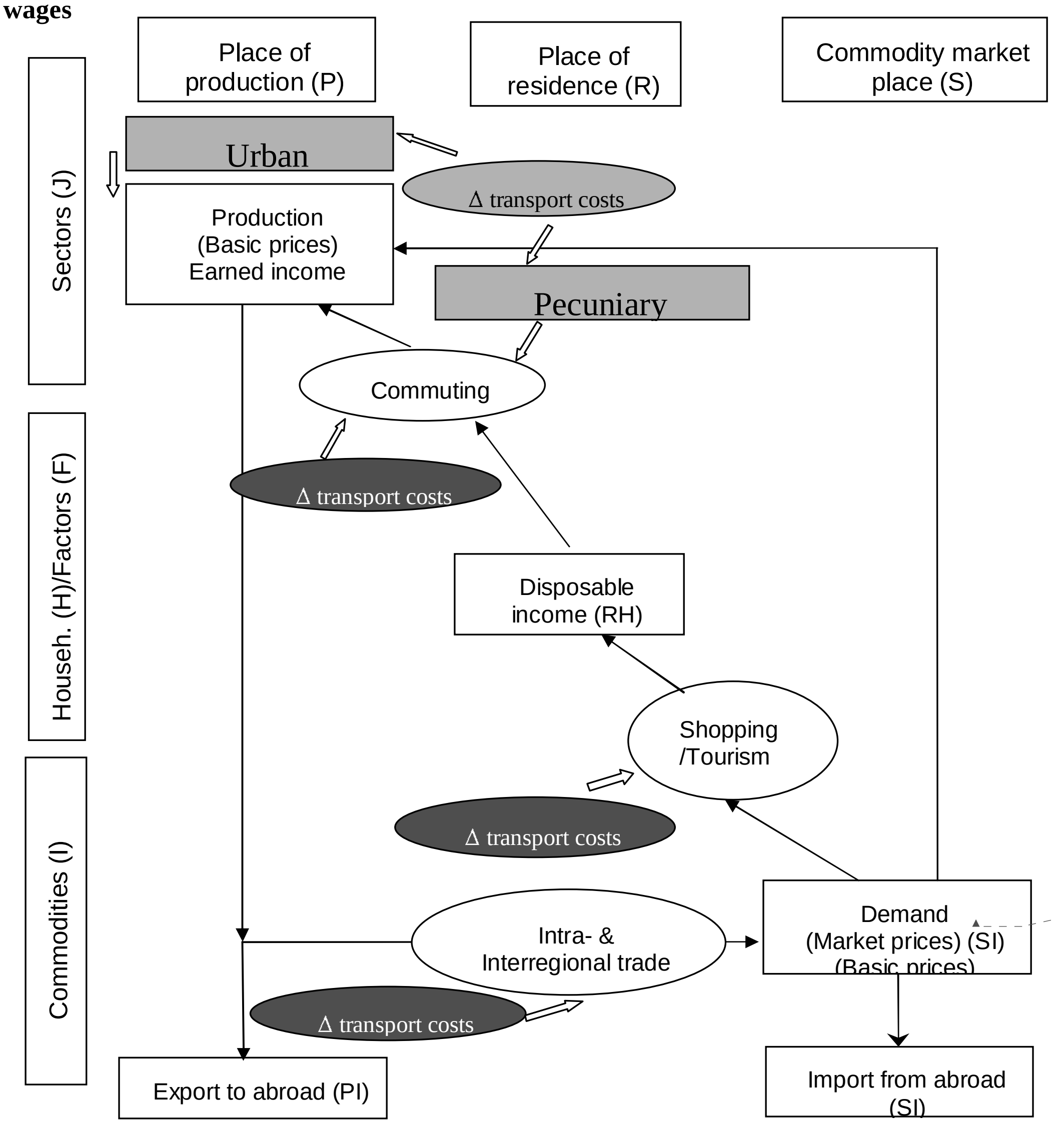
Economic activity in the real circle is affected by changes in prices and wages: wages and productivity affect prices of the local production (PJ), which through relative changes in local competitiveness affects exports (PI) and imports (SI) which in turn affects private consumption through changes in real disposable income (RH). The anticlockwise cost/price circuit shown in figure 5 corresponds to this dual problem. In the cost-price circle, production and demand are calculated in current prices, which in turn are transformed into relevant price indices. In the upper left corner production in current prices (in basic prices) is determined by costs (intermediate consumption, value added and indirect taxes, net in relation to production - PJ). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (PI). These are then transformed from place of production to place of demand (SI) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes. This transformation takes place using a reverse use matrix. Commodities for intermediate consumption enter into the next step in the production chain, determining prices of production and these prices are spread further in a round-by-round distribution process. Finally, private consumption is transformed from place of commodity market (SI) to place of residence in market prices (RI).

Figure 4
Real circle in LINE – the impacts of price and wage changes on economic activity and behaviour



Formateret: Engelsk (Storbritannien)

Figure 5
The cost-price circle in LINE. The impacts of transport cost changes on prices and wages



4.2 LINE: configuration
In this version of LINE the model configuration is the following.
Sectors (J):
21 sectors aggregated from the 133 sectors used in the national accounts.
Factors (G):
7 age, 2 sex and 5 education groups.
Households (H):

4 types, based upon household composition

Needs:

For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.

Commodities (I):

27 commodities, aggregated from 131 commodities used in the national accounts.

Regions:

277 municipalities, including one state-owned island and one unit for extra-regional activities, this being the lowest level of spatial disaggregation. Regions are defined either as place of production, place of residence or as place of commodity market. In this version of LINE the 277 municipalities have been aggregated into 16 regional units including one unit for extra-regional activities (see figure 6).

Figure 6
Danish regions

Note: Danish regions are counties and two municipalities with county status, Copenhagen M and Frederiksberg M. Three fixed links: A: Oresund, to Malmo, Sweden, B: Great Belt, C: Femer Belt to Germany. Four ferry routes: D : Spodsbjerg-Taars, E: Odden-Aarhus (Mols Line), F: Odden-Ebeltoft (Mols Line), G: Frederikshavn-Gothenburg (Sweden). Other very local and international ferry routes are not shown

4.3 Direct wage and price effects in LINE

As described above, wages and prices will change as transport costs change. There are two direct effects, one which is truly direct, and one which arises through creation or reinforcement of externalities which in turn has an impact on prices. In figure 5 the two types of direct effect on wages and prices are shown. The true direct effect is shown by ellipses with dark shading, whilst the effects which operate through externalities are shown by ellipses with lighter shading. The first effect enters directly into the price circle as an addition to costs and prices: In figure 5 an increase in commuting costs implies that disposable income is reduced directly. In addition, commodity prices increase due to changes in transport costs for regional and interregional trade and also for changes in transport costs for shopping and tourism. The second effect works through externalities, both technological and pecuniary, which influence equilibrium wages and prices. In figure 5 a change in transport costs changes the size of the labour market and thereby the equilibrium wage. Changes in wages lead to changes in prices of production and in prices of commodities, following the logic of the cost-price circle. A change in transport costs will also affect the level of urban externalities and thereby wages and prices. This in turn changes the prices of commodities following the logic of the cost-price circle.

It should be noted that this discussion and illustration of the effect of externalities is limited to the consequences of changes in transport costs for wages, as shown in figure 5. Similar effects could be illustrated in relation to the commodity market.

The indirect and induced effects of wage and price changes depend in the medium term on exchange rate regimes. If the economy is based upon fixed exchange rates, it matters whether or not a change in real wages leads to changes in nominal wages or changes in prices or a combination of these two. If wages change, assuming sticky prices, then competitiveness of domestic production is unchanged and the wage change will only have a minor impact on economic activity. On the other hand, if prices change, assuming sticky wages, then competitiveness of domestic production and international export and import will react with corresponding more substantial effects on economic activity.

If the economy is based upon floating exchange rates, then changes in competitiveness due to changing prices will be more moderate as price changes will tend to be neutralised by exchange rate fluctuations.

5. Modelling the redistribution of the relative productivity decline associated with road pricing – the case of Denmark

The main aim of this part of the analysis is to examine the consequences of including externalities in an analysis of the effects of a change in transport costs on regional economic activity. To demonstrate these effects, the hypothetical case of the introduction of road pricing in Denmark is examined. First, the road pricing scheme is presented, followed by a description of the way in which transport costs are affected. Second, the effects without externalities are presented, followed by an examination of the impacts of including externality effects in the analysis. Finally, the total effects, divided into direct price effects and externality effects are estimated.

5.1 Road pricing and changes in transport costs

The design of road pricing systems relates to general issues concerning transport policy and technical constraints and possibilities, in concrete institutional and cultural contexts. Road pricing systems are discussed in Jensen-Butler et al. (2005) and Madsen et al (2005). In this study it is assumed that a GPS-based/vehicle metered road pricing system is introduced throughout Denmark permitting precise identification of the location of a vehicle and thereby its road use, related in turn to toll level for the road. A range of different toll levels could be chosen, depending on type of vehicle, time of day, type of road, location, level of congestion etc. Here a simple assumption is made that tolls are set for cars only at DKK 0.6 per kilometre in urban areas and DKK 0.3 per kilometre in rural areas, on a 24 hour basis and irrespective of which type of road, car or level of congestion is involved.

Changes in transport costs are calculated using a) an interregional satellite account for transport used to determine *levels* of transport costs and b) exogenously given interregional transport costs, based on a digital road map**, Vejnet DK**, used to calculate *changes* in transport costs.

The data in the interregional satellite accounts are estimated in four steps:

a1) Taking the national make and use tables, national transport activity is determined by i) transport mode ii) subdivided by transport costs related to intermediate consumption (by sector) and to private consumption (by component) and iii) by external (transport firm based) and internal (own transport, within a non-transport producing firm or a household) costs. Six different modes of transport activity are used in the interregional satellite accounts, four for passenger transport and two for goods. Passenger transport is divided into car, rail, aeroplane and other and freight is divided into lorry and rail.

a2) In the second step national transport activity related to passenger transport is subdivided (using data from the National Travel Survey) by trip purpose: i) commuting ii) shopping, iii) tourism iv) business travel and v) recreation.

a3) National transport activity is then divided by origin and destination using data on intra and inter-regional trade (freight and business trip transport activity) and interregional shopping, tourism and commuting (personal trip transport activity)

a4) Regional transport activity is then corrected (using regionalised National Travel Survey data) to ensure that the data reflect regional transport activity by mode.

Changes in interregional transport activity for car transportation are estimated using the digital road map **Vejnet DK.** Transport costs in Vejnet DK are based upon both time and distance where the generalised cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. In addition, costs are calculated both with and without road pricing. The calculations are based on assumptions shown in Table 1.

Table 1
Maximum speeds, distance and time costs, road pricing tariffs (DKK) (DKK 7.50=ca 1 Euro=ca 1$US)

	Car	**Lorry**
Motorway	110 km/t	80 km/h
Non-urban highway	80 km/t	70 km/h
Urban	50 km/t or local restrictions taken from VejnetDK	Max 50 km/h or local restrictions if under 50 km/hour
Distance cost per kilometre	1.82 DKK	2.60 DKK
Time cost pr. hour	0.75	2.78 DKK.
Road pricing – Urban	0.60	-
Road pricing – Rural	0.30	-

The estimation of level of transport activity by region, mode, purpose and by type of consumption described above reflects a basic assumption that data on transport activity obtained from National (transport satellite) Accounts used in a top down procedure, are superior to data on transport activity obtained from different statistical sources, used in a bottom-up approach.

In this paper, only results based upon road pricing for private cars is presented.

Table 2 shows the consequences of introducing road pricing. It is assumed that all ferry routes and fixed links will continue with unchanged ticket prices. The table shows that transport costs in general increase from 2% to 13%, outside the main cities of Copenhagen and Arhus least in the interregional links where use of rural roads is important and/or where a significant part of the journey uses ferries. In Copenhagen and Aarhus transport costs decline as road pricing results in a reduction of congestion, and thus, transport costs.

Table 2
Changes in total transport costs (index: 1.00 =unchanged) for transport between Danish regions after road pricing for cars

(%)	**Cp & FrbM**	**CpC**	**FrC**	**RoC**	**VsC**	**SsC**	**BhC**	**FyC**	**SjC**	**RbC**	**VjC**	**RkC**	**ÅrC**	**ViC**	**NjC**
Copenhagen & Frederiksberg M	0.91	0.96	1.02	1.01	1.06	1.07	1.00	1.05	1.07	1.07	1.07	1.05	1.01	1.04	1.04
Copenhagen C	0.96	1.13	1.13	1.13	1.13	1.12	1.00	1.08	1.09	1.09	1.09	1.05	1.02	1.05	1.05
Frederiksborg C	1.02	1.13	1.10	1.12	1.11	1.12	1.00	1.08	1.09	1.09	1.08	1.04	1.02	1.05	1.05
Roskilde C	1.01	1.13	1.12	1.08	1.13	1.11	1.00	1.07	1.09	1.09	1.08	1.09	1.02	1.05	1.05
Vestsjællands C	1.06	1.13	1.11	1.13	1.12	1.11	1.01	1.05	1.08	1.08	1.07	1.08	1.00	1.04	1.04
Storstrøms C	1.07	1.12	1.12	1.11	1.11	1.13	1.02	1.07	1.09	1.09	1.08	1.09	1.03	1.06	1.05
Bornholms C	1.00	1.00	1.00	1.00	1.01	1.02	1.09	1.02	1.03	1.03	1.03	1.03	1.01	1.02	1.02
Fyns C	1.05	1.08	1.08	1.07	1.05	1.07	1.02	1.12	1.12	1.12	1.12	1.12	1.10	1.11	1.12
SønderjyllandsC	1.07	1.09	1.09	1.09	1.08	1.09	1.03	1.12	1.15	1.12	1.12	1.11	1.10	1.11	1.12
Ribe C	1.07	1.09	1.09	1.09	1.08	1.09	1.03	1.12	1.12	1.12	1.12	1.11	1.10	1.11	1.11
Vejle C	1.07	1.09	1.08	1.08	1.07	1.08	1.03	1.12	1.12	1.12	1.12	1.11	1.07	1.11	1.11
Ringkøbing C	1.05	1.05	1.04	1.09	1.08	1.09	1.03	1.12	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Århus C	1.01	1.02	1.02	1.02	1.00	1.03	1.01	1.10	1.10	1.10	1.07	1.11	0.97	1.10	1.09
Viborg C	1.04	1.05	1.05	1.05	1.04	1.06	1.02	1.11	1.11	1.11	1.11	1.11	1.10	1.11	1.09
Nordjyllands C	1.04	1.05	1.05	1.05	1.04	1.05	1.02	1.12	1.12	1.11	1.11	1.11	1.09	1.09	1.12

5.2 Effects of transport costs on prices and costs, with and without externalities

In this section the results of the changes in transport costs on costs and prices are presented. First the results of a calculation without externality effects are shown in table 3a. Then the consequences of including pecuniary externalities (table 3b) and urban externalities (table 3c) are presented.

The analyses, which do not include externality effects, begin in the interaction components of the cost price circle shown in figure 5. Starting with the demand for commodities at the place of commodity market the prices on commodities increase in total by 0.05% (column 8), distributed regionally as indicated in the table. Prices increase most in rural areas of the country, whilst prices actually decline in Greater Copenhagen because of declining congestion.

Given the point at which the analysis commences, the presentation follows the cost-price circle: private consumption at the place of commodity market (column 9) and private consumption at the place of residence (column 10). Price increases are still moderate at the place of commodity market (at national level 0.04%), but markedly higher at the place of residence (at national level 0.42). This reflects the fact, that impact from cost increases on cars in trade is limited, because most transport on intra- and interregional trade typically is on lorry. But for the shopping the transport cost increases from road pricing on cars are much higher, because private cars are used much more frequent.

Looking at intermediate consumption price increases are again moderate (column 2) reflecting the fact that most transportation related to intermediate consumption is on lorry, both in trade and in shopping (intermediate consumption from the wholesaling to the place of production). Therefore the impact on the gross output deflator (column 3) and in turn on foreign export (column 5) are low. The regional distribution of changes in costs and prices are similar, for each column/regional economic variable, reflecting the fact that the direct impact of changes in transport costs reflect the decreasing costs and prices in urban areas and increases in rural areas.

Now, looking at the impacts from externalities these are generated in a completely different way (see table 3b and 3c): Here the impacts originate from changes in the Gross Value Added deflator (column 1) and then commence through the cost-price circle (column 2-10). Here the consequences for the price of production of all type of commodities are influenced through the wage impact. GVA In the case of pecuniary externalities (table 3b, column 1) GVA-deflator increases with 0.21% at the national level but only with 0.03% in the case of urban externalities (table 3c, column 1). The regional pattern follows the one from changes in transport costs (table 2). As a consequence all prices change accordingly. In this case there is no difference between the impacts on private consumption at the place of commodity market and the place of residence.

Table 3a
Cost and price changes for production, demand, export, import and private consumption - without externalities

	(1) Supply: Gross Value Added	(2) Intermediate consumption	(3) Gross output	(4) Gross output	(5) Foreign export	(6) Demand: Domestic production	(7) Foreign Import	(8) Demand	(9) Private consumption Place of market place	(10) Private consumption Place of residence
	(PJ)	(PJ)	(PJ)	(PI)	(PI)	(SI)	(SI)	(SI)	(SI)	(RH)
Copenhagen & Frederiksberg M	0.00	0.00	0.02	0.01	0.04	-0.02	0.00	-0.01	0.01	-0.13
Copenhagen C	0.00	0.00	0.04	0.02	0.10	-0.01	-0.01	-0.01	0.00	0.48
Frederiksborg C	0.00	0.05	0.06	0.06	0.14	0.07	-0.03	0.05	0.04	0.54
Roskilde C	0.00	0.05	0.06	0.05	0.14	0.06	-0.02	0.04	0.04	0.47
Vestsjællands C	0.00	0.08	0.11	0.10	0.25	0.10	-0.01	0.08	0.06	0.60
Storstrøms C	0.00	0.08	0.09	0.08	0.18	0.11	-0.01	0.09	0.07	0.64
Bornholms C	0.00	0.03	0.05	0.04	0.12	0.03	0.00	0.03	0.02	0.37
Fyns C	0.00	0.08	0.09	0.08	0.16	0.10	-0.02	0.08	0.06	0.60
Sønderjyllands C	0.00	0.10	0.12	0.10	0.18	0.13	-0.01	0.10	0.08	0.77
Ribe C	0.00	0.11	0.13	0.11	0.21	0.13	-0.01	0.11	0.08	0.67
Vejle C	0.00	0.10	0.13	0.11	0.21	0.13	-0.01	0.11	0.08	0.68
Ringkøbing C	0.00	0.08	0.12	0.09	0.18	0.10	-0.01	0.08	0.07	0.59
Århus C	0.00	0.05	0.06	0.04	0.11	0.05	0.01	0.04	0.03	-0.04
Viborg C	0.00	0.07	0.10	0.09	0.18	0.09	-0.01	0.07	0.06	0.55
Nordjyllands C	0.00	0.07	0.09	0.08	0.17	0.09	-0.01	0.07	0.06	0.58
Outside regions	0.00	0.03	0.05	0.01	0.01	0.03	0.00	0.03	-	-
Total	0.00	0.05	0.08	0.06	0.14	0.06	0.00	0.05	0.04	0.42

Table 3b
Cost and price changes for production, demand, export, import and private consumption labour market negotiations (Pecuniary externalities)

	(1) Supply: Gross Value Added (RJ)	(2) Inter-mediate consump-tion (RJ)	(3) Gross Output (RJ)	(4) Gross Output (RI)	(5) Foreign Export (RI)	(6) Demand: Domestic Production (SI)	(7) Foreign Import (SI)	(8) Demand (SI)	(9) Private consump-tion Place of Market place (SI)	(10) Private consump-tion Place of Residence (RH)
Copenhagen & Frederiksberg M	-0.15	0.01	-0.05	-0.06	-0.01	-0.02	-0.01	-0.02	-0.02	0.00
Copenhagen C	0.29	0.19	0.29	0.27	0.45	0.25	-0.01	0.21	0.18	0.15
Frederiksborg C	0.32	0.19	0.30	0.29	0.44	0.26	0.00	0.21	0.17	0.16
Roskilde C	0.27	0.17	0.27	0.25	0.40	0.22	0.00	0.18	0.15	0.14
Vestsjællands C	0.37	0.19	0.35	0.32	0.47	0.27	-0.01	0.22	0.19	0.19
Storstrøms C	0.39	0.21	0.36	0.33	0.39	0.30	-0.01	0.25	0.22	0.21
Bornholms C	0.29	0.17	0.28	0.26	0.33	0.23	-0.01	0.20	0.17	0.17
Fyns C	0.36	0.20	0.34	0.31	0.37	0.29	-0.01	0.24	0.20	0.20
Sønderjyllands C	0.46	0.23	0.42	0.38	0.40	0.33	-0.01	0.28	0.24	0.24
Ribe C	0.39	0.22	0.39	0.35	0.47	0.30	-0.01	0.25	0.22	0.22
Vejle C	0.38	0.21	0.38	0.34	0.44	0.30	-0.01	0.25	0.22	0.21
Ringkøbing C	0.35	0.20	0.37	0.33	0.45	0.28	-0.01	0.23	0.20	0.20
Århus C	-0.05	0.05	0.04	0.01	0.06	0.03	-0.01	0.03	0.01	0.02
Viborg C	0.34	0.19	0.34	0.30	0.38	0.27	-0.01	0.22	0.20	0.19
Nordjyllands C	0.36	0.20	0.36	0.32	0.39	0.28	-0.01	0.24	0.21	0.21
Outside regions	0.00	0.08	0.08	0.03	0.01	0.11	-0.01	0.08	–	–
Total	0.21	0.15	0.24	0.21	0.31	0.20	0.00	0.16	0.15	0.15

Table 3c
Cost and price changes for production, demand, export, import and private consumption Urban agglomeration (urban externalities)

	(1) Supply: Gross Value Added (PJ)	(2) Inter-mediate consump-tion (PJ)	(3) Gross Output (PJ)	(4) Gross output (PI)	(5) Foreign export (PI)	(6) Demand: Domestic production (SI)	(7) Foreign Import (SI)	(8) Demand (SI)	(9) Private consump-tion Place of market place (SI)	(10) Private consump-tion Place of residence (RH)
Copenhagen & Frederiksberg M	-0.16	-0.04	-0.09	-0.09	0.08	-0.08	0.00	-0.07	-0.04	-0.03
Copenhagen C	-0.08	-0.02	-0.04	-0.04	0.28	-0.04	0.00	-0.03	-0.02	-0.02
Frederiksborg C	0.05	0.03	0.06	0.05	-0.05	0.04	0.00	0.03	0.02	0.01
Roskilde C	0.03	0.03	0.05	0.04	-0.01	0.03	0.00	0.02	0.02	0.01
Vestsjællands C	0.14	0.06	0.15	0.11	-0.28	0.08	0.00	0.06	0.04	0.03
Storstrøms C	0.15	0.07	0.14	0.12	-0.14	0.09	0.00	0.08	0.05	0.04
Bornholms C	0.00	0.01	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00
Fyns C	0.12	0.06	0.12	0.10	-0.09	0.08	0.00	0.07	0.05	0.04
Sønderjyllands C	0.17	0.08	0.17	0.13	-0.09	0.10	0.00	0.09	0.06	0.05
Ribe C	0.18	0.09	0.20	0.15	-0.26	0.12	-0.01	0.10	0.07	0.06
Vejle C	0.15	0.08	0.18	0.13	-0.20	0.11	0.00	0.09	0.05	0.05
Ringkøbing C	0.12	0.06	0.16	0.11	-0.20	0.09	0.00	0.07	0.04	0.04
Århus C	0.02	0.03	0.05	0.04	0.04	0.03	0.00	0.03	0.02	0.02
Viborg C	0.09	0.05	0.12	0.09	-0.08	0.07	0.00	0.06	0.03	0.03
Nordjyllands C	0.09	0.05	0.11	0.09	-0.07	0.07	0.00	0.06	0.04	0.04
Outside regions	0.00	0.02	0.02	0.01	0.01	0.02	-0.01	0.01	–	–
Total	0.03	0.03	0.06	0.04	-0.03	0.03	0.00	0.03	0.02	0.02

5.3 Effects on real economic activity from changes in cost and prices, with and without externalities

Real economic activity is influenced by the changes in prices. In addition, the way the revenues from the road pricing is recycled for example either through reduction in taxation or through increases in public consumption, will influence the level of economic activity. In this study only the gross impacts of cost and price changes are presented as the focus of the study is the multiplier effects of inclusion of externalities in the analysis. For a treatment of the public sector see Madsen et al (2005).

In this section the results of changes in real economic activity are described. First, the results of a model calculation without externality effects are shown in table 4a. This is followed by an analysis of the consequences of inclusion of pecuniary externalities (table 4b) and then of urban externalities (table 4c).

The first step, where externality effects are not included examines the impacts on disposable income and private consumption (table 4a, column 1-4). Disposable income in current prices is reduced in average by 0.21% (column 1) because of the income reduction arising from road pricing on commuting. Second, real disposable income is reduced, because prices of private consumption increase. In total, real disposable income is reduced by 0.96% (column 2), which in turn reduces private consumption by 0.96 both at place of residence (column 3) and at place of commodity market (column 4). Demand is reduced, but proportionally less because the real impacts on other components of demand (intermediate consumption) is smaller or even unchanged (public consumption and investments).

When including the externality effects (see tables 4b and 4c) there are 2 consequences, which have opposite signs: First, increases in income arising from wage increases related to road pricing (wage compensation), which increase private consumption and demand. Second, wage increases raise export prices and domestic prices which means that exports to abroad decline and imports from abroad increase, reducing domestic production. The second effect, based upon declining competitiveness dominates. The reduction in production will be even greater when including the externality effects.

The next step is to include pecuniary and technological externalities in the direct effects. The impact of these affects real wages, as shown above. The effects going from real wages to GVA are presented in column (1) of table 4b (pecuniary externalities) and table 4c (urban externalities). The effects are transmitted through the economic system in the same way as described in relation to table 4a.

Table 4a
Consequences for demand, production and income with road pricing – without externalities

	(1) Disposable income (current prices) (RH)	(2) Real disposable income (RH)	(3) Private consump-tion Place of residence (RI)	(4) Private consump-tion Place of demand (SI)	(5) Demand (SI)	(6) Foreign imports (SI)	(7) Demand: Domestic production (SI)	(8) Foreign export (PI)	(9) Gross output (PJ)	(10) GDP at factor prices (PJ)
Copenhagen & Frederiksberg M	0.01	0.18	0.18	-0.05	-0.05	-0.05	-0.05	-0.03	-0.10	-0.08
Copenhagen C	-0.17	-0.69	-0.69	-0.66	-0.25	-0.20	-0.26	-0.12	-0.25	-0.26
Frederiksborg C	-0.27	-1.20	-1.21	-1.16	-0.50	-0.54	-0.47	-0.20	-0.40	-0.43
Roskilde C	-0.25	-1.00	-1.00	-0.95	-0.46	-0.48	-0.46	-0.21	-0.40	-0.43
Vestsjællands C	-0.29	-1.38	-1.38	-1.34	-0.56	-0.53	-0.56	-0.36	-0.49	-0.54
Storstrøms C	-0.32	-1.49	-1.50	-1.46	-0.65	-0.62	-0.65	-0.26	-0.56	-0.63
Bornholms C	-0.20	-0.95	-0.95	-0.96	-0.40	-0.37	-0.40	-0.13	-0.35	-0.40
Fyns C	-0.30	-1.39	-1.39	-1.38	-0.56	-0.52	-0.57	-0.23	-0.48	-0.53
Sønderjyllands C	-0.40	-2.00	-2.01	-1.95	-0.68	-0.55	-0.67	-0.24	-0.55	-0.64
Ribe C	-0.32	-1.52	-1.53	-1.52	-0.54	-0.44	-0.55	-0.31	-0.47	-0.52
Vejle C	-0.34	-1.40	-1.41	-1.39	-0.50	-0.42	-0.52	-0.33	-0.46	-0.49
Ringkøbing C	-0.29	-1.46	-1.47	-1.45	-0.48	-0.38	-0.50	-0.28	-0.42	-0.47
Århus C	0.00	0.06	0.06	0.00	-0.05	-0.03	-0.06	-0.15	-0.12	-0.08
Viborg C	-0.30	-1.49	-1.49	-1.47	-0.52	-0.42	-0.53	-0.24	-0.45	-0.50
Nordjyllands C	-0.29	-1.39	-1.40	-1.37	-0.51	-0.43	-0.51	-0.23	-0.44	-0.49
Outside regions	-	-	-	-	-0.02	-0.02	-0.03	0.00	-0.10	-0.08
Total	-0.21	-0.96	-0.96	-0.96	-0.36	-0.31	-0.37	-0.19	-0.33	-0.35

Table 4b
Consequences for demand, production and income with road pricing labour market negotiations (pecuniary externalities)

	(1) Dispos-able income (current prices) (RH)	(2) Real dispos-able income (RH)	(3) Private consump-tion Place of residence (RH)	(4) Private consump-tion Place of demand (SI)	(5) Demand (SI)	(6) Foreign imports (SI)	(7) Demand: Domestic produc-tion (SI)	(8) Foreign export (RI)	(9) Gross output (PJ)	(10) GDP at factor prices (PJ)
Copenhagen & Frederiksberg M	0.00	0.01	0.01	-0.01	0.00	0.04	-0.01	0.01	-0.02	0.00
Copenhagen C	0.07	-0.07	-0.07	-0.07	-0.12	-0.08	-0.13	-0.71	-0.19	-0.16
Frederiksborg C	0.11	-0.04	-0.03	-0.03	-0.10	-0.06	-0.11	-0.73	-0.19	-0.16
Roskilde C	0.11	-0.03	-0.03	-0.03	-0.08	-0.04	-0.09	-0.70	-0.15	-0.12
Vestsjællands C	0.15	-0.03	-0.03	-0.03	-0.13	-0.11	-0.14	-0.82	-0.23	-0.16
Storstrøms C	0.16	-0.04	-0.04	-0.04	-0.09	-0.05	-0.10	-0.68	-0.16	-0.11
Bornholms C	0.12	-0.04	-0.04	-0.04	-0.08	-0.05	-0.09	-0.52	-0.15	-0.11
Fyns C	0.16	-0.03	-0.03	-0.03	-0.10	-0.05	-0.11	-0.63	-0.18	-0.13
Sønderjyllands C	0.22	-0.02	-0.01	-0.01	-0.13	-0.11	-0.16	-0.63	-0.24	-0.18
Ribe C	0.18	-0.03	-0.02	-0.02	-0.17	-0.14	-0.18	-0.81	-0.28	-0.21
Vejle C	0.18	-0.02	-0.02	-0.02	-0.15	-0.11	-0.15	-0.74	-0.25	-0.17
Ringkøbing C	0.18	-0.01	0.00	0.00	-0.18	-0.15	-0.19	-0.77	-0.30	-0.20
Århus C	-0.01	-0.03	-0.03	-0.03	-0.03	0.02	-0.04	-0.09	-0.07	-0.03
Viborg C	0.16	-0.02	-0.02	-0.02	-0.13	-0.10	-0.14	-0.63	-0.23	-0.15
Nordjyllands C	0.17	-0.03	-0.02	-0.02	-0.12	-0.09	-0.13	-0.63	-0.21	-0.14
Outside regions	-	-	-	-	-0.02	0.02	-0.03	0.00	-0.12	-0.09
Total	0.11	-0.03	-0.03	-0.03	-0.09	-0.05	-0.10	-0.51	-0.17	-0.12

Table 4c

Consequences for demand, production and income with road pricing urban agglomeration (technological externalities)

	(1) Dispos-able income (current prices) (RH)	(2) Real dispos-able income (RH)	(3) Private consump-tion Place of residence (RH)	(4) Private consump-tion Place of demand (SI)	(5) Demand (SI)	(6) Foreign imports (SI)	(7) Demand: Domestic production (SI)	(8) Foreign export (PI)	(9) Gross output (PJ)	(10) GDP at factor prices (PJ)
Copenhagen & Frederiksberg M	-0.06	-0.01	-0.01	-0.01	0.01	0.02	0.01	0.02	0.02	0.02
Copenhagen C	-0.05	-0.02	-0.02	-0.02	0.02	0.04	0.01	-0.01	0.02	0.02
Frederiksborg C	-0.02	-0.04	-0.04	-0.03	-0.04	-0.02	-0.04	-0.12	-0.07	-0.06
Roskilde C	-0.02	-0.04	-0.04	-0.03	-0.03	-0.02	-0.04	-0.12	-0.06	-0.04
Vestsjællands C	0.03	-0.02	-0.02	-0.02	-0.08	-0.07	-0.08	-0.19	-0.16	-0.10
Storstrøms C	0.05	-0.01	-0.01	-0.01	-0.05	-0.03	-0.05	-0.20	-0.10	-0.06
Bornholms C	0.00	-0.01	-0.01	-0.01	-0.01	0.01	-0.01	-0.04	-0.02	-0.01
Fyns C	0.04	-0.02	-0.02	-0.02	-0.06	-0.03	-0.06	-0.18	-0.11	-0.07
Sønderjyllands C	0.05	-0.02	-0.02	-0.03	-0.09	-0.06	-0.10	-0.19	-0.16	-0.11
Ribe C	0.05	-0.04	-0.04	-0.04	-0.13	-0.10	-0.13	-0.26	-0.23	-0.15
Vejle C	0.05	-0.02	-0.02	-0.02	-0.10	-0.08	-0.11	-0.24	-0.19	-0.11
Ringkøbing C	0.04	-0.02	-0.02	-0.02	-0.11	-0.08	-0.12	-0.20	-0.20	-0.12
Århus C	0.01	-0.02	-0.02	-0.02	-0.03	0.00	-0.03	-0.11	-0.05	-0.03
Viborg C	0.03	-0.02	-0.02	-0.02	-0.07	-0.04	-0.07	-0.16	-0.12	-0.07
Nordjyllands C	0.03	-0.02	-0.02	-0.02	-0.06	-0.03	-0.06	-0.15	-0.11	-0.06
Outside regions	-	-	-	-	-0.01	0.01	-0.02	0.00	-0.05	-0.06
Total	0.01	-0.02	-0.02	-0.02	-0.04	-0.02	-0.05	-0.12	-0.08	-0.05

Table 5 shows the real economic consequences of both types of direct transport cost changes. The table shows the employment effect, which is closely related to changes in production, export, demand private consumption and disposable income. All these real effects have been derived from changes in costs and prices which influence demand: the total effect is a reduction in employment of 8423 when externalities are not included and 12654 when they are. Externalities add therefore approximately 50% to the pure direct effect on commodity prices and income.

Table 5
Impacts on employment at place of production

	(1) Without externality Number	(2) Labor market negotiation Number	(3) Urban agglomeration Number	(4) With externality Number	(5) Without externality - pct -	(6) Labor market negotiation - pct -	(7) Urban agglomeration - pct -	(8) With externality - pct -
Copenhagen & Frederiksberg M	-374	-20	59	-335	-0.09	-0.01	0.01	-0.08
Copenhagen C	-828	-445	43	-1229	-0.23	-0.12	0.01	-0.34
Frederiksborg C	-560	-192	-69	-822	-0.37	-0.13	-0.05	-0.54
Roskilde C	-332	-91	-32	-455	-0.35	-0.10	-0.03	-0.49
Vestsjællands C	-565	-167	-103	-835	-0.44	-0.13	-0.08	-0.65
Storstrøms C	-530	-110	-63	-704	-0.50	-0.10	-0.06	-0.66
Bornholms C	-61	-21	-1	-84	-0.31	-0.11	-0.01	-0.42
Fyns C	-982	-265	-147	-1393	-0.44	-0.12	-0.07	-0.62
Sønderjyllands C	-623	-211	-127	-961	-0.50	-0.17	-0.10	-0.77
Ribe C	-513	-222	-160	-895	-0.43	-0.19	-0.13	-0.75
Vejle C	-750	-288	-200	-1239	-0.41	-0.16	-0.11	-0.67
Ringkøbing C	-583	-294	-174	-1052	-0.38	-0.19	-0.11	-0.69
Århus C	-259	-94	-87	-440	-0.08	-0.03	-0.03	-0.14
Viborg C	-486	-186	-91	-763	-0.39	-0.15	-0.07	-0.62
Nordjyllands C	-976	-319	-146	-1441	-0.40	-0.13	-0.06	-0.59
Outside regions	-2	-1	-1	-4	-0.04	-0.03	-0.02	-0.09
Total	-8423	-2926	-1298	-12654	-0.30	-0.11	-0.05	-0.46

6. Summary

In the paper, an analysis on the impacts of changing transportation by introducing road pricing for cars in Denmark is presented. In the analysis, the impacts from externalities have been included, generating substantially higher gross effects of changing transport costs. In the paper the direct effects of changing transport costs on labour market (pecuniary externalities or labour market enlargement effects) and on productivity (urban externalities through positive technological spill-overs) are presented. The results of an econometric study in Denmark were presented. The derived effects was modelled with an interregional general equilibrium for Denmark, LINE has been used.

The analysis shows that due to reduction in congestion the Greater Copenhagen area benefit through reduction in the transport costs, whereas rural areas suffer, because of long commuting distances. The total effects on employment is app. 8000 including the conventional commodity price and income reducing effects from road pricing and app. 4000 higher if externality effects are included. This demonstrates that conventional analysis is insufficient, because real impacts are underestimated. There is a need to include externality effects in analysis of transport system changes.

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Appendix A

Table A1
Wage differentials by place of production. Estimated parameters and standard errors

Dependent variable: ln(average wage)	FGLS	WLS	OLS
Intercept	12.04955 (0.00262)	12.07617 (0.00221)	12.0701 (0.00354)
Gender	0.17744 (0.00056923)	0.19182 (0.00042372)	0.15730 (0.00080864)
Year=1999	0.07181 (0.00086704)	0.06812 (0.00063209)	0.06648 (0.00124)
Year=1998	0.05261 (0.00083882)	0.05011 (0.00059852)	0.04885 (0.00121)
Year=1997	0.02129 (0.00078997)	0.01956 (0.00055930)	0.02116 (0.00114)
Long further and higher education	0.44529 (0.00116)	0.48476 (0.00089247)	0.38434 (0.00153)
Middle-range further and higher education.	0.32206 (0.00094904)	0.31477 (0.00069157)	0.29656 (0.00132)
Short further and hi. edu.	0.19079 (0.00102)	0.19089 (0.00084233)	0.16910 (0.00135)
Skilled worker	0.10002 (0.00065551)	0.10167 (0.00045153)	0.08367 (0.00098931)
Public and personal services	0.03522 (0.00158)	-0.00264 (0.00148)	0.08941 (0.00202)
Financial intermediation	0.19359 (0.00167)	0.19702 (0.00155)	0.19622 (0.00212)
Transport and communic.	0.09228 (0.00182)	0.11263 (0.00161)	0.08528 (0.00239)
Wholesale and retail trade	0.05271 (0.00164)	0.07839 (0.00150)	0.04573 (0.00213)
Construction	0.01555 (0.00207)	-0.00886 (0.00162)	0.03066 (0.00321)
Electricity, gas, & water.	0.15069 (0.00296)	0.10845 (0.00271)	0.17680 (0.00381)
Manufacturing	0.10046 (0.00158)	0.08810 (0.00148)	0.10430 (0.00201)
Age 45-59	0.26275 (0.00071966)	0.28820 (0.00053279)	0.22788 (0.00101)
Age 30-44	0.20693 (0.00070084)	0.22936 (0.00051082)	0.17211 (0.00099141)
ln(unemployment)	-0.02047(0.00081802)	-0.02993(0.00061965)	-0.02309 (0.00117)
ln(distance5)	-0.03893(0.00027692)	-0.04252(0.00017878)	-0.03165(0.00045022)
* Adjusted R^2	-	-	0.215

Note: All variables are significant at 10% level. If all dummy variables are zero the representation is: Year=1996, basic education, sector= Agriculture, and age 15-29 years old.

Table A2

Wage differentials and commuting distances. Estimated parameters and standard errors.

Dependent variable: ln(average wage)	FGLS	WLS	OLS
Intercept	11.99731 (0.00198)	11.96282 (0.00120)	11.95378 (0.00310)
Gender	0.20739 (0.00058077)	0.20313 (0.00032394)	0.18550 (0.00089959)
Year=1999	0.04847 (0.00088965)	0.6484 (0.00050635)	0.04807 (0.00137)
Year=1998	0.03423 (0.00086104)	0.04703 (0.00048466)	0.03470 (0.00133)
Year=1997	0.01399 (0.00081145)	0.01898 (0.00045713)	0.01323 (0.00125)
Long further and higher education.	0.46169 (0.00109)	0.49915 (0.00071247)	0.45697 (0.00158)
Middle-range further and higher education.	0.29248 (0.00090276)	0.29033 (0.00055063)	0.30186 (0.00138)
Short further and higher education.	0.17716 (0.00101)	0.17132 (0.00068469)	0.19049 (0.00150)
Skilled worker	0.10374 (0.00070002)	0.09785 (0.00036837)	0.10002 (0.00111)
Age 45-59	0.30252 (0.00074048)	0.27874 (0.00042973)	0.31246 (0.00112)
Age 30-44	0.24254 (0.00071004)	0.22502 (0.00041411)	0.24134 (0.00106)
ln(unemployment)	-0.07263(0.00082992)	-0.03924(0.00047434)	-0.06847 (0.00130)
ln(distance)	0.03071 (0.00022535)	0.03067 (0.00016048)	0.04145 (0.00036696)
* Adjusted R^2	-	-	0.2626

Note: All variables are significant at 10% level. If all dummy variables are zero the representation is: Year=1996, basic education, and age 15-29 years old.

Appendix B
F-test for fixed effects

F-test:

I) F-test in a model with wage differentials by place of production (data set 1) and explanatory variables gender, education, sector, age, and unemployment:

   As $F(4,4) = 1$ the hypothesis that all constant terms are equal could not be rejected.

II) F-test in a model with wage differentials (data set 2) and explanatory variables gender, education, age, unemployment, and commuting distance:

   As $F(4,4) = 1$ the hypothesis that all constant terms are equal could not be rejected.

Appendix C

I) A model with wage differentials by place of production (data set 1) and explanatory variables gender, time, education, sector, age, unemployment, and distance is examined. The squared residuals of the weighted regression (u^2) are estimated on the size of the group (N):

The results are:

	FGLS	WLS	OLS
$	0.01863	0.0060891	-0.00079502
t-value of $	26.89	36.53	-40.9

All of the t-values are significant and therefore a group error component could be present.

II) A model with wage differentials and explanatory variables gender, time, education, age, unemployment, and distance is examined.

The test described above gives the following results:

	FGLS	WLS	OLS
$	0.00461	0.00788	-0.00016861
t-value of $	9.84	329.21	-14.96

All of the t-values are significant and therefore a group error component could be present.