TRANSPORT INFRASTRUCTURE, SPATIAL GENERAL EQUILIBRIUM AND WELFARE

Jose Melendez H., Piet Rietveld and Erik Verhoef
Free University of Amsterdam, Spatial Economics Department
jmelendezhidalgo@feweb.vu.nl

Abstract

Estimation of benefits arising from large-scale investments in transport infrastructure has been increasingly subject to debate, under assumptions of both perfect and imperfect competition in the transport- using sectors. In this paper we concentrate on the later case, complementing and extending the existing literature on transport cost-benefit analysis by comparatively evaluating the magnitude of divergence between direct benefits -those measured in the transport demand itself- and economy wide or indirect benefits- those reflected in utility levels changes-. Comparisons are undertaken under different assumptions for two versions –with and without intermediate demands- of spatial general equilibrium models with increasing returns and imperfect competition. In addition we compare results between models clarifying the implications of intermediate demands for evaluations. The renewed interest in transport improvements benefits and its consequences is an issue not only in transport economics or regional science, but has been increasingly incorporated in trade literature as traditional trade barriers (e.g. tariff and non-tariff) reductions and regional integration agreements have highlighted the role of transport costs reductions in industry location, labor migration in particular and the shape and performance of the economy in general. We link our work with this literature considering the consequences of extending cost-benefits evaluations across the borders.

Keywords: Cost benefit analysis; Core periphery model; Input-output linkages; Transport infrastructure. JEL c.c. R12, R13, D61,D63,H22.
Topic Area: E1 Assessment and Appraisal Method w.r.t. Transport Infrastructure Projects and Transport Activities

1. Introduction

The link between the transport sector and the rest of the economy has been increasingly discussed in economics for a number of reasons. In one hand, an economy without spatial dimension has been shown to be a too restrictive simplification sustained mainly on the basis of technical difficulties within economic analysis (Fujita et. al. 1999)[1]. Recent theoretical contributions in this direction have put in closer communication subjects such as international, regional and transport economics, previously characterized by following almost unconnected ways (Rietveld and Vickerman, 2004; Krugman, 1991). This tendency is reinforced by a markedly decrease in transport costs over the last fifty years with spatial consequences relevant for all these subjects. On the other hand, the transport sector involves almost inevitably government resources and consequently issues of efficiency and equity are especially at stake. Aschauer (1989) study on the effects of public infrastructure investment on

[1] For a discussion on this argument see Martin (2003).

private sector productivity initiated a long debate at an empirical level more than two decades ago, as his results gave a special role to core-infrastructure –including roads, ports and railways-[2].

In addition to this latest interest in the link between transport and the economy, concern on this topic in early contributions in economics is documented in Martin (2003). Moreover in the second half of the last century the interest revives in development and growth theorist. Since the classical works of Rosenstein-Rodan (1943) and Hirschman (1958), development economists have considered infrastructure –transport included- as an indispensable precondition of industrialization with the connection arising mainly from pecuniary externalities. With a more classical character the pioneering analysis of transport infrastructure investment in Tinbergen (1957), introduced the use of the adjustment multipliers for transportation cost-benefit analysis results. Tinbergen work started with a reduction in transport costs which immediate benefit is the fall in unit cost for each type of traffic. The ultimate consequence on output in the economy (i.e. GDP) is a growth effect arising from the cost saving in existing users calculated as the product of this cost reduction by the volume of use of the infrastructure (i.e. traffic).

Notwithstanding this interest other fields of economics, the transport economics literature experienced its own and independent discussion on the topic during 1970's, although referred as *user's benefits in transportation*. The debate was initiated with the issue of demand interaction when several transport modes are available, both in partial and general equilibrium, but subsequently turned to the divergence between transportation's consumer surplus and the benefits to the entire economy generated by changes in transport costs. Mohring (1976), Jara-Diaz and Friesz (1982) are early contributions and in this debate. Jara-Diaz (1986) revisited the issue and analytically shows that there is no divergence when competitive markets are assumed but the opposite result arose when he considers two extremes of imperfect competition: monopoly and a simple version of oligopoly.

Our aim in this paper is to complement and extend this literature. At the same time we intend to strengthen the previously recognized improving communication amongst regional, international and transport economics emphasizing the spatial consequences of transport infrastructure improvements leading to transport cost reductions. The rest of the paper is organized as follows. In the second section a brief discussion on traditional cost-benefit analysis for large-scale infrastructure projects is carried out and a need for a general equilibrium framework in the analysis is emphasized. The description of the basic model and some extensions both on the demand and supply side are discussed as a second part of this section. In section three simulations based on different parameters values are discussed. Both symmetric and asymmetric conditions between regions are taken into consideration. Section forth elaborates over possible extensions and finally conclusions are discussed in a final section.

2. Cost-benefit analysis for transport projects: partial and general equilibrium

Transport projects usually require important amounts of public funds, thus determining whether the project is worth implementing involves some sort of social cost-benefit analysis[3].

---

[2] A burgeoning literature on the subject was initiated with this contribution (see Rietveld and Bruinsma, 1998 for an overview) as well as a proliferation of a large variety of methods to estimate these effects (Rietveld and Nijkamp, 2000; Lakshmanan and Anderson, 2002). Recent work by Canning (1999) has explored the link between transport infrastructure and economic growth in a number of countries.

Eventually, improvements in transportation infrastructure reduce transport costs thus its benefits are primarily evaluated through reduced travel time. The benefits which are taken into account when evaluating infrastructure investments are in general reduced transportation costs, savings in transportation time, improved safety of delivering together with profit reallocated from other transporting sectors. The idea of cost-benefit analysis (CBA) is to compare all the benefits of an investment with all its costs. Except for the investment cost all negative externalities that affect the rest of the society should be included. However, according to Weisbrod and Treyz (1998), such methods underestimate the total benefits of transportation investment since they ignore effects outside the transport market and especially those related with transport using sectors.

The purpose of our study is to evaluate differences in benefits measures, so we ignore for now on the cost side. Transport CBA involves the application of the basic principles of CBA to *networks*. Nevertheless, the analysis can begin at the level of a single connection in the network, between origin i and destination j by mode m. Consumer surplus for the individual is the difference between willingness-to-pay and price (generalized cost). Total consumer surplus (CS_0) for a particular ijm market within the network, is shown diagrammatically in Figure 1. User benefit, CS_{ijm}, as a result of a change in supply conditions (due to a transport initiative) is shown by the shaded area. In general, CS for an ijm market is defined as the integral of the demand function with respect to generalized cost. User benefit (CS) is therefore the integral between P_0 and P_1, provided that the demand curve does not shift. If demand curves do shift, a line integral is required (Hotelling, 1938), but the calculations are still feasible. In Figure the dark green area shows benefits arising from new traffic while light green area corresponds to "pure" transport costs reduction benefits experienced by old traffic.

This way of proceeding for benefits evaluations has been subject recently to criticism amongst other things because can be ignore extra benefits arising in an imperfect regional economy (Hussain and Westin, 1999). Jara-Diaz (1986) showed that under perfect competition conditions both the transport sector effects or directs benefits and the economy-wide effects or indirect benefits coincide in magnitude and sign. This is not necessarily true when monopoly or other imperfect competition assumptions are allowed (Mohring and Harwitz, 1962). To evaluate the magnitude and sign of this difference we use alternative measures of economy-wide welfare and compare them with the change in demand surplus (measure from a derived transport demand).

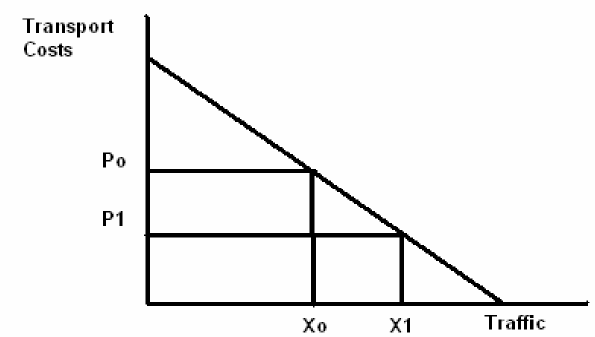


Figure 1: Change in consumer surplus due to reduced travel costs

[3] In recent years a new wave of private involvement in large-scale projects has been seen in many countries. In general, this does not rule out the need to carry out social cost-benefit analysis.

At a theoretical level the so-called new economic geography has initiated the use of general equilibrium models based on increasing returns, product differentiation and monopolistic competition to analyze the spatial dimension in economics. The trade-off between dispersal and agglomeration -or centrifugal and centripetal- forces that arise when increasing returns to scale characterize a proportion of economic activity is central in this kind of models, providing an economic explanation of the spatial structure of the economy. The link between this kind of modeling and large-scale investment in transport infrastructure seems to arise from the combination of the role of transport cost on the spatial distribution of economic activity under economies of scale and the obvious link between transport infrastructure improvements and transport costs reductions (Fernandez-Texeira, 2002). Nowadays, the use of NEG modeling in location and agglomeration analysis is widespread in theoretical literature, unless is not so in empirical work (Oosterhaven and Knaap 2002; Venables and Gasoriek, 1999). Despite that, there is significant lack of work concerning the analysis of efficiency of agglomeration outcomes in general and welfare issues within this modeling approach in particular[4]. In order to clarify the implications of transport improvements on the economy at theoretical level, in this paper we depart from the canonical NEG model to analysis the implications of traditional transport cost-benefit analysis.

Core-periphery model

This is basically the canonical core-periphery model (Fujita et. al 2000, Baldwin et. al 2003). The discussion is carried out for the general case of r regions. For simulations we consider a 2 x 2 x 2 setting, that is, the economy space is composed of two regions, it has two sectors of production (modern and traditional sectors) and there are two production factors (qualified and non-qualified labor). In a second stage of research we would consider extensions concerning firm location and network effects within models of more than two regions.

Consumers

In the general case, we consider an economy of n-regions with two sectors of production, one producing traditional goods under constant returns and the other producing manufactures (n_r-varieties in each region) under increasing returns to scale. Production is carried out only based on labor, but this factor can be of a qualified or non-qualified nature. All workers are also final consumers and share the same basic Cobb-Douglas preferences for the two basic types of goods a la Dixit-Stiglitz:

$$U_r = M_r^{\mu} T_r^{1-\mu}, \qquad (1)$$

where M represents the composite index of manufacture goods, T is the consumption of traditional good (e.g. agricultural), and μ represents the expenditure share of manufactured good in consumption. The subscript r reflex the fact that utility is measure at a regional level aggregating all consumers without distinguish between qualified and non-qualified workers. The consumption of manufactures is described by a constant elasticity of substitution sub-utility function defined over a continuum of varieties of manufactured goods, m(i), with a

[4] For the former see Charlot et. al (2003).

range of varieties described by n. The preference for variety in manufacturing goods is represented by ρ.

$$M_r = \left[\int_0^n m(i)_r{}^{\rho} di \right]^{\frac{1}{\rho}} \qquad \text{with} \quad 0 > \rho > 1 \qquad (2)$$

For convenience we use ρ to define the elasticity of substitution between a pair of varieties as σ. Whenever σ increases the substitution between a pair of manufactured goods is greater, meaning that the demand conditions for this pair approaches perfect competitive conditions[5].

$$\sigma \equiv \frac{1}{1-\rho} \quad , \qquad \rho \equiv \frac{\sigma - 1}{\sigma}$$

In each region consumers maximize utility subject to the budget constraint. Since all consumers are identical in preferences final demand will be the same for all of them differing only in terms of sources of income. We then assume that there is a representative consumer in each region meaning that the relevant income includes all sources of wages in a region, that is, manufacture or traditional production based wages[6]. If preferences were quasi-linear aggregation is not a problem but with CES preferences well-behaved aggregation is not assured to hold. Defining income in a region by Y we have that this can be assigned to traditional goods or different varieties of manufactures:

$$Y_r = p_r^T + \int_0^n p(i)_r m(i)_r di \qquad (3)$$

The utility maximization problem can be solved in two steps. First, for any value of the composite M, each m(i) have to be chosen so as to minimize the cost of attaining it. This is achieved solving the following problem,

$$\min \int_0^n p_r(i) m_r(i) di \qquad \text{subject to} \qquad M_r = \left[\int_0^n m_r(i)^{\rho} di \right]^{\frac{1}{\rho}} \qquad (4)$$

The first order condition for this expenditure minimization problem establish the equality of marginal rates of substitution to price ratios for any pair of varieties and consequently implies an expression for the consumption of a particular variety (e.g. m(j)), that replaced in the constraint in (4) finally brings an expression for the compensated demand of this particular variety as in (5),

---

[5] We assume that this elasticity is the same in all regions. Additionally we rule out for the moment the possibility of strategic interaction between firms.
[6] See Mas-Colell et al (1997) Ch. 4 for a discussion on aggregation.

$$m_r(j) = \frac{p_r(j)^{\frac{1}{(\rho-1)}}}{\left[\int_0^n p(i)_r^{\frac{\rho}{(\rho-1)}} di\right]^{\frac{1}{\rho}}} M_r \qquad (5)$$

The term in the denominator in normally regarded as a price index for the manufactured products consumed in r, denoted here by G in (6). This index measures the minimum cost of purchasing a unit of the composite index M of manufacturing goods.

$$G_r \equiv \left[\int_0^n p(i)_r^{\frac{\rho}{(\rho-1)}} di\right]^{\frac{(\rho-1)}{\rho}} = \left[\int_0^n p(i)_r^{1-\sigma} di\right]^{\frac{1}{(1-\sigma)}} \qquad (6)$$

Using (6) the equation for the demand of a particular variety can be simplified to:

$$m_r(j) = \left(\frac{p_r(j)}{G_r}\right)^{\frac{1}{(\rho-1)}} M_r = \left(\frac{p_r(j)}{G_r}\right)^{-\sigma} M_r \qquad (7)$$

In a second stage we can solve the original problem of utility maximization, where consumers divide total income between traditional and composite manufactures. This is a typical Cobb-Douglas maximization problem leading to uncompensated demands in the form of income over price times the expenditure share of the good in total consumption, as in (9).

$$\max U_r = M_r^{\mu} T_r^{1-\mu} \quad \text{subject to} \quad G_r M_r + p_T^T T_r = Y_r \qquad (8)$$

$$T_r = \frac{(1-\mu)Y_r}{p_r^T}; \qquad M_r = \frac{\mu Y_r}{G_r} \qquad (9)$$

For each variety of manufactures in the region the demand can be derived as (10), in which the elasticity of demand for every variety is σ.

$$m_r(j) = \mu Y_r \frac{p_r(j)^{-\sigma}}{G_r^{-(\sigma-1)}} \quad \text{for} \quad j \in [0, n_r] \qquad (10)$$

Under these conditions an expression for the indirect utility function can be obtained. This expression is the base for welfare analysis within this model. Since all consumers share the same preference structure, this expression is valid for all workers in a region as well.

$$V_r(p_r^T, G_{r,} Y_r) = \mu^{\mu}(1-\mu)^{(1-\mu)} Y_r G_r^{-\mu} (p_r^T)^{-(1-\mu)} \qquad (11)$$

Producers

Before describing producer behavior we introduce the spatial dimension in the model explicitly through transport cost. The explicit modeling of a transport sector -with or without distinguishing between different modes- is ruled out at this stage and we stick to the usual indirect way of modeling assuming iceberg type cost of transportation *a la* Samuelson, in which in order to put one unit of a manufactured good from region r in region s, τ^{Drs} units of the good should be send, implying that only $1/\tau^{Drs}$ will actually arrive after traveling D_{rs} units of distance[7]. In a model of only two regions the price of a variety produced in region r and consumed in s will be:

$$p_{rs} = p_r \tau_{rs}$$

In the case of multiple regions, we can specify in more details the price index for manufactures as:

$$G_r = \left[\int_0^{n_s} \left(p_{rr}^{1-\sigma} \right) di + \int_{n_r}^{n_s} \left(p_{sr}^{1-\sigma} \right) di \right]^{\frac{1}{(1-\sigma)}} \tag{12}$$

Further more, to simplify computations –without compromising results- we can assume that in each region the price for each variety is the same, then (12) become easier to handle:

$$G_r = \left[n_r p_r^{1-\sigma} + n_s (p_s \tau_{rs})^{1-\sigma} \right]^{\frac{1}{(1-\sigma)}} \qquad r = 1, 2 \text{ and } s \neq r$$

Then, aggregate consumption demanded by consumers in location s for a product produced in r now follows from (10):

$$m(j)_s = \mu Y_s (p_r \tau_{rs})^{-\sigma} G_s^{(\sigma-1)} \tag{13}$$

From the point of view of producers, providing this amount of manufacture for consumption, a greater amount has to be shipped, exactly τ_{rs} times the amount to be consumed[8].

$$q_r = \mu \sum_{s=1}^{R} Y_s (p_r \tau_{rs})^{-\sigma} G_s^{\sigma-1} \tau_{rs} \tag{14}$$

In a two region model the market demand for variety i for producer in region r is given:

$$q(i)_r = m(i)_r + m(i)_s \tau_{rs} \tag{15}$$

---

[7] In a network economy with more than two regions it must be recognized that increasing returns to scale are normally present in the transport of goods, as was pointed out by Marshall in the case of maritime transport (McConville, 1999).

[8] We are assuming here that no transport cost have to be incurred for trade within regions but this can be modified to incorporated in-region transport infrastructure improvements.

Now we can turn to the specific modeling of producer behavior. The production of the quantities in (16) requires C_r units of labor, where $F_r > 0$ and $c_r > 0$ are respectively the fixed and the marginal labor requirements. Production of any variety exhibits increasing returns to scale *internal* to the firm[9].

$$C_r = F_r + c_r q_r \qquad r = 1, 2 \qquad (16)$$

The profit function of each firm located in region r is therefore:

$$\Pi_r = p_r q_r - w_r (F_r + c_r q_r) \qquad (17)$$

Where the demand faced is taken from (15). From (16) the equilibrium price can be determined using first order conditions, which in this case give the classic result:

$$p_r (1 - \frac{1}{\varepsilon_r}) = c_r w_r \qquad (18)$$

In (17) the price elasticity of demand for variety i is represented by ε_r, defined as,

$$\varepsilon_r = -\frac{\partial q_r}{\partial p_r} \frac{p_r}{q_r}$$

In the particular case of Dixit-Stiglitz monopolistic competition assumption, the “large group” assumption concerning competitors is assumed, and then ε_r corresponds to σ. In this version of our model we rule out strategic interaction between producers when $\varepsilon_r = \sigma$. This assumption implies that price for variety i is above marginal cost just by a constant mark-up, as in (18).

$$p_r^* = \frac{\sigma}{\sigma - 1} c_r w_r ; \qquad \sigma = \frac{p_r^* - c_r w_r}{p_r^*} \qquad (18)$$

Assuming free-entry of competitor’s profits will go to zero and we can derive an expression for the equilibrium level of production for each variety in (19):

$$\frac{c_r}{\sigma - 1} q_r - F_r = 0$$

$$q_r^* = \frac{F_r (\sigma - 1)}{c_r} \qquad (19)$$

Using (19) we can derive the cost incurred in equilibrium, and use this to find the total demand of labor in each region as in (20)

$$C_r^* = F_r + c_r q_r^* = F_r \sigma$$

[9] It is also possible to model increasing returns to scale external to the firm.

$$L_r^* = nC_r^* = n(F_r + c_r q^*) \qquad (20)$$

The total number of varieties in equilibrium is,

$$n^* = \frac{L_r}{F_r \sigma} \qquad (21)$$

Some normalization in parameters can be taken in order to simplify the model and its solution for simulation purposes. Following Baldwin et al (2003),

$$F_r \equiv \frac{1}{\sigma}, \qquad c_r \equiv \frac{(\sigma - 1)}{\sigma}$$

Using the zero profit condition, this implies that:

$$p_r = w_r \qquad \mathrm{r} = 1,2; \qquad q_r = 1 \qquad \mathrm{r} = 1,2$$

As mentioned before in this model nominal wages adjust until no firm enters or exits the market, meaning that profits are zero in equilibrium. After some manipulations we arrive to:

$$w_r = w_r^{1-\sigma} \frac{\mu Y_r}{n_r w_r^{1-\sigma} + \tau^{1-\sigma} n_s w_s^{1-\sigma}} + \tau^{1-\sigma} w_r^{1-\sigma} \frac{\mu Y_s}{\tau^{1-\sigma} n_r w_r^{1-\sigma} + n_s w_s^{1-\sigma}}$$

This is nonlinear in w_r, meaning that no analytical solutions can be obtained then numerical solutions are the rule in this model. A spatial equilibrium in this case is the final result of the interplay between agglomeration and dispersion forces and is characterized in the literature as the situation where skilled worker have no additional incentives to change location. The equilibrium depends heavily on the transport cost level (Krugman, 1991) and can be formally denoted by an "excess" indirect utility a skilled worker enjoy in region i = 1,2, a spatial equilibrium arises at λ between (0,1) when,

$$\Delta V(\lambda) \equiv V_1(\lambda) - V_2(\lambda) = 0 \qquad (21)$$

Welfare Analysis[10]

Since we are interested in a CBA analysis comparison based traditional evaluation approach and a more general approach that uses broad welfare measures that take care of general equilibrium effects, we should first derived a transport demand to compute the first CBA type and afterwards decide which welfare measure use to compute CBA of the second type.

Expression (22) can be seen as a *derived* demand for transport services corresponding to variety i . The valid range of values for τ in this derived demand is obtained as the range in

---

[10] A more extensive explanation of the approach followed to measure welfare change and to compare it to traditional CBA is given in an appendix.

which the general equilibrium of the model sustains dispersion equilibriums[11]. To account for the total welfare effect in the transport using consumption, we have to multiply the change in consumer surplus by the proportion of varieties consumed in the corresponding region meaning the analysis can be equivalently be carried out over the aggregate derived transport demand for variety i in region r.

$$q(j)_{rs} = \mu Y_s (p_r \tau_{rs})^{-\sigma} G_s^{(\sigma-1)} \tag{22}$$

For the second type of CBA analysis mentioned we make use of Hicksians measures of welfare (e.g equivalent and compensate variations). Corresponding expressions can be derived starting with the indirect utility function in (11). The following two relations implicitly define an expression for the equivalent (EV) and compensate (CV) variations,

$$V(\tau^0,\ Y + EV) = U^1$$

$$V(\tau^1,\ Y - CV) = U^0$$

where U^i indicate the level of utility depending on the stage, that is, in the original situation before the change in transport cost and in the final situation after the change respectively. Combining these conditions with (11) a pair of explicit expressions for the EV and CV can be derived, for instance, for the equivalent variation,

$$U^1 = \mu^{\mu}(1-\mu)^{(1-\mu)}(Y_r + EV)\ G_r^{-\mu}(p_r^T)^{-(1-\mu)}$$

$$\mu^{\mu}(1-\mu)^{(1-\mu)} Y_1 G_1^{-\mu} = \mu^{\mu}(1-\mu)^{(1-\mu)}(Y_0 + EV)\ G_0^{-\mu}$$

$$(Y_0 + EV) = \frac{Y_1 G_1^{-\mu}}{G_0^{-\mu}}$$

$$EV = Y_1 \left[\frac{G_1}{G_0}\right]^{-\mu} - Y_0 \tag{28}$$

and applying a similar procedure we will obtain,

$$CV = Y_r^1 - Y_r^0 \left[\frac{G_0}{G_1}\right]^{-\mu} \tag{29}$$

The welfare analysis is completed when these two measures of economy-wide welfare are compared with the traditional consumer surplus change arising from a cost-benefit analysis. This comparison is conducted by calculating the ratio of EV over CS. This ratio should be equal or greater than one when considering a reduction in transport costs (by a reduction in τ).

---

[11] A discussion regarding type and number of equilibriums in core-periphery type models can be found in Baldwin et al (2003).

A ration greater than one implies the presence of indirect effects not taken into account in traditional CBA.

3. Simulations

As a first set of simulations we run the two region version of the model under two different schemes[12]. The first one is characterized by symmetry between regions, that is, both regions are exactly the same then trade arise just as a consequence of the 'love of variety' nature of the model whenever transport cost are high or low enough to generate a dispersion equilibrium. The second type is characterized by the presence of asymmetry between regions arising from a different endowment of non-mobile workers. This can be interpreted as an exogenous differentiation of regions between a core (urban) and a periphery (rural) as compared to an endogenous one arising from equilibrium.

Symmetry

Under symmetry several simulations where carried out changing two main parameters in the model, that is, elasticity of substitution between manufactured varieties and the share of expenditure in manufactures per region[13]. Figures 1 shows the typical derived transport demand curves for manufactures in region i for production in region j. The implicit assumption here is that when a core-periphery structure is present, region 1 is assumed to be the core. If both a core-periphery and dispersion structures are possible, the assumption is that dispersion dominates. The benchmark case shown in Fig. 1 involves a high level for the elasticity of substitution between manufactured varieties (σ=7). Under this conditions the difference between economy-wide welfare change measures and traditional CBA, arising from a 10% reduction in transport costs, are quite close to zero.

One particular feature of this exercise is the extreme behavior of economy-wide measures of welfare when a regime change in the model is in place (a bifurcation in the model equilibrium). The analysis of this situation is carried out in more detail below. The point to emphasize here is that the ratio between EV and CS is very close to one and that a slightly different result for small values of transport costs arises when a change in regime occurs mainly because the increased competition experience in a specialized region 1.

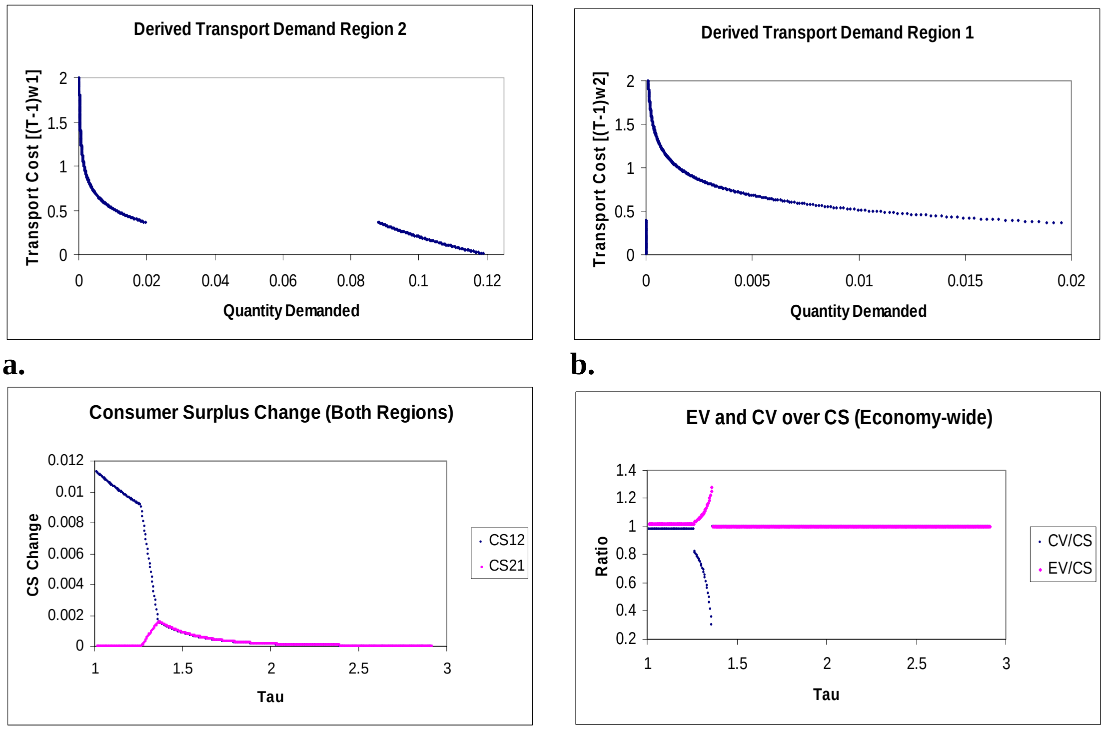
As a second case we consider an economy where imperfect competition is more conspicuous, shown in Fig.2. In this case $\sigma = 4$ and $\mu = 0.4$. The difference in welfare change measures is shown Fig. 2b with ratios of EV and CV over CS[14], reflecting the magnitude of indirect effects. Results are shown for all the range of transport costs but are especially relevant between T-break (1.94) and T-sustain (2.33). Fig. 2b shows that welfare impacts arising from small reductions in transport costs are still well captured by a traditional CBA for high values of transport costs as well as for low values. The difference between welfare measures is smaller but shows a sudden increase (respectively decrease) in the multiple equilibrium range for the EV (respect. CV). Results show that under an idealized setting such as symmetric economy, CBA practice is still giving an appropriate measure of welfare change in the economy.

---

[12] All simulations are carried out using Mathematica ®

[13] We assume at this point symmetry in all these parameters.

[14] Consumer surplus can be calculated numerically from an interpolation of the derived transport demand points or using a well known procedure in CBA for transport, the rule of a half.

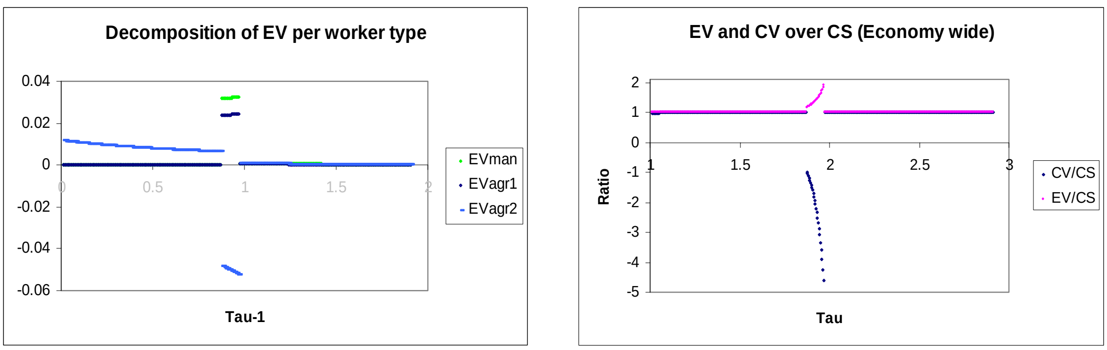


a. b.

c. d.

Figure. 1. Benchmark case characterized by a high elasticity of substitution

In the range of multiple equilibriums traditional CBA against consumer welfare measures can not be appropriately evaluated since the composition of consumers in each region is changing and consequently a decrease in 10% in transport cost can lead to a sudden change in the economy structure. In order the have a closer look at what is behind this behavior we show a decomposition of welfare change in Fig.2a. As is clear from this figure, the significant divergence between welfare change measures is due to the change in the structure of the economy that generates a totally different distribution of manufacture workers and as a consequence a change in the shape of derived transport demand.



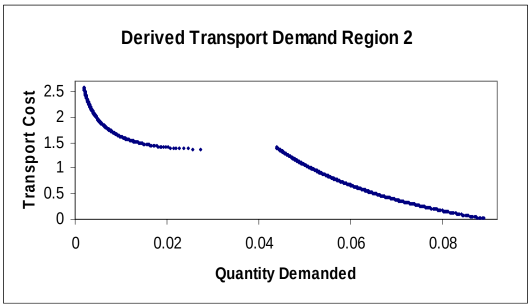
a. b.

Figure 2. Economy with low elasticity of substitution between manufactures

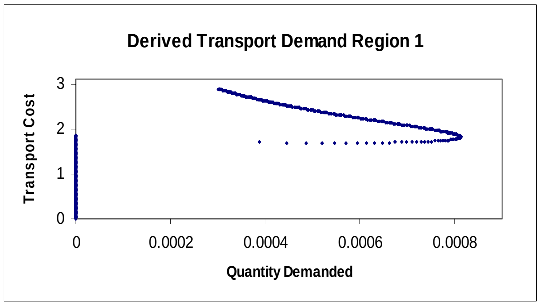
The change in consumer welfare measured as EV experiment a sudden increase both for agriculture workers in region 1 and manufacture workers in general that know migrate completely to region 1. They now can buy all their manufactures need in its own region without incurring in transport cost expenses. For the agricultural workers in region 2 the situation is the opposite since from now on they will face decreasing transport cost. Comparing this situation with a traditional CBA in which the shape of transport demand is explicitly accounted for, explain a transitory divergence between welfare measures. This situation is in some sense artificial and mainly drive by extreme simplifying assumptions in this type of models.

Asymmetry

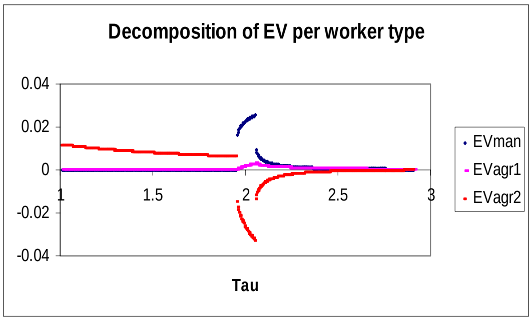
A region's economic size depends on how much qualified and non-qualified labor it has. Since non-qualified labor is mobile and its interregional division is endogenous, intrinsic size asymmetries must come from different endowments of the immobile factor or different distribution of a given total amount within regions. To this end, we assume either that the two regions are endowed with different stocks of this factor and further more, one region – eventually the core- is 'bigger' in the sense that L*=L+ε with ε>0, or that this factor is distributed differently than evenly (phi not 0,5). Fig. 3 and 4 show derived transport demands under an small and big asymmetry of region 1 with respect to region 2.



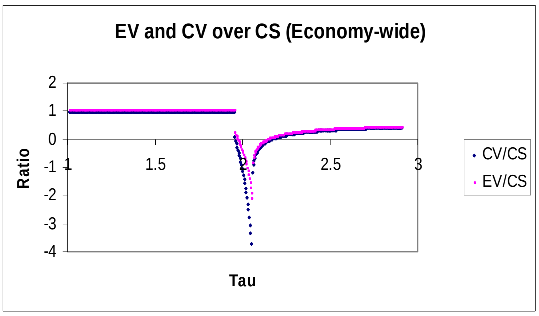
a.



b.



c.



d.

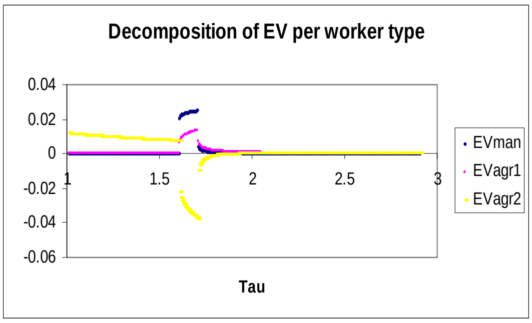
Figure 3. Asymmetric endowment of agricultural labor between regions

In this case, transport demand in region 1 shows a backward bending behavior near the change in structure from dispersion to agglomeration[15]. This is due to a divergence behavior in

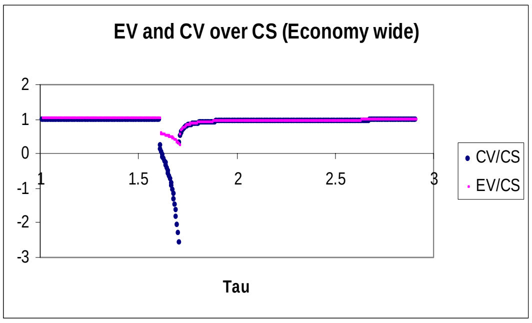
[15] A demand with positive slope in some range of prices implies that consumer surplus measures does not make much sense for that region.

transport cost as compared to iceberg costs. Concretely, the level of manufacture wage in region two goes down when iceberg transport costs are going up, and for a small range of these costs it compensate the increasing iceberg cost. The main issue in this asymmetry case is that the transition from a dispersion equilibrium when transport cost are going down is smother than in the previous case and this is the root of all the results that we have here. When transport costs are going down, the dispersion equilibrium is disappearing gradually as region 1 is increasing its participation in agricultural workers from 0.5 to 0.69 (with our parameters), after that a sudden change in the structure of the economy transform region 1 in the new core.

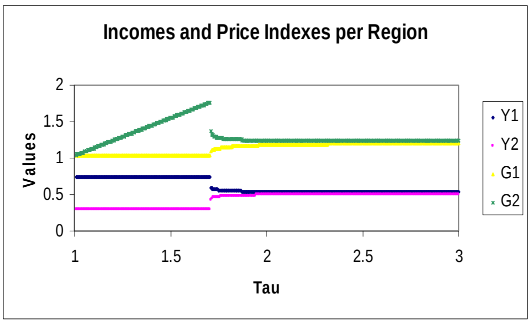
Under the same parameter values results change considerably. After the T-break when the economy becomes disperse the CS is always overestimating economy-wide welfare impacts. Results are also sensitive to the conditions of competition in the market (measured by σ) and the proportion of expenses in manufacturing goods. This result is in line with Martin (1999) results –despite a three region environment is considered there- since suggest that an improved transport link can harm an already disadvantaged region.



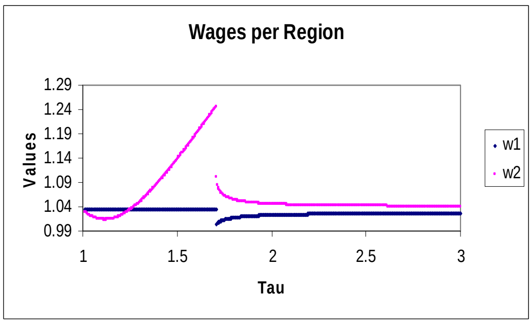
a.



b.



c.



d.

Figure 4. Small asymmetry in endowments of labor between regions

In Fig. 3 a similar pattern as in Fig. 4 is shown, only that with a small asymmetry result in a significant divergence in welfare measures and even in a reversing sign on the effects in the case of the equivalent variation in agricultural workers in region 2 before reaching the T-break point.

4. Industry input demand

When effects arising from transport infrastructure improvements between countries as compared to effects within countries are the main issue, the assumptions of free-movement of workers as in the canonical core-periphery model is no longer valid. A more suitable version of the model is the one developed in Krugman and Venables (1995). Following Dixit and Stiglitz (1977), production of a quantity x(k) of any variety k requires the same fixed (α) and variable (βx(k)) quantities of the production input in any region. As in Venables(1996) the production input in manufacturing can be modeled as a Cobb-Douglas composite of labor and an aggregate of intermediaries. Following Either(1982), all industrial goods enter symmetrically into the intermediate aggregate with a constant elasticity of substitution across varieties σ (>1). The price index of the aggregate of industrial goods used by firms is region-specific, and is defined by

$$q_i = \left[\int_{h \in N} (p_i(h))^{(1-\sigma)} dh + \int_{h \in N} (\tau \ p_j(h))^{(1-\sigma)} dh \right]^{1/(1-\sigma)} \qquad (30)$$

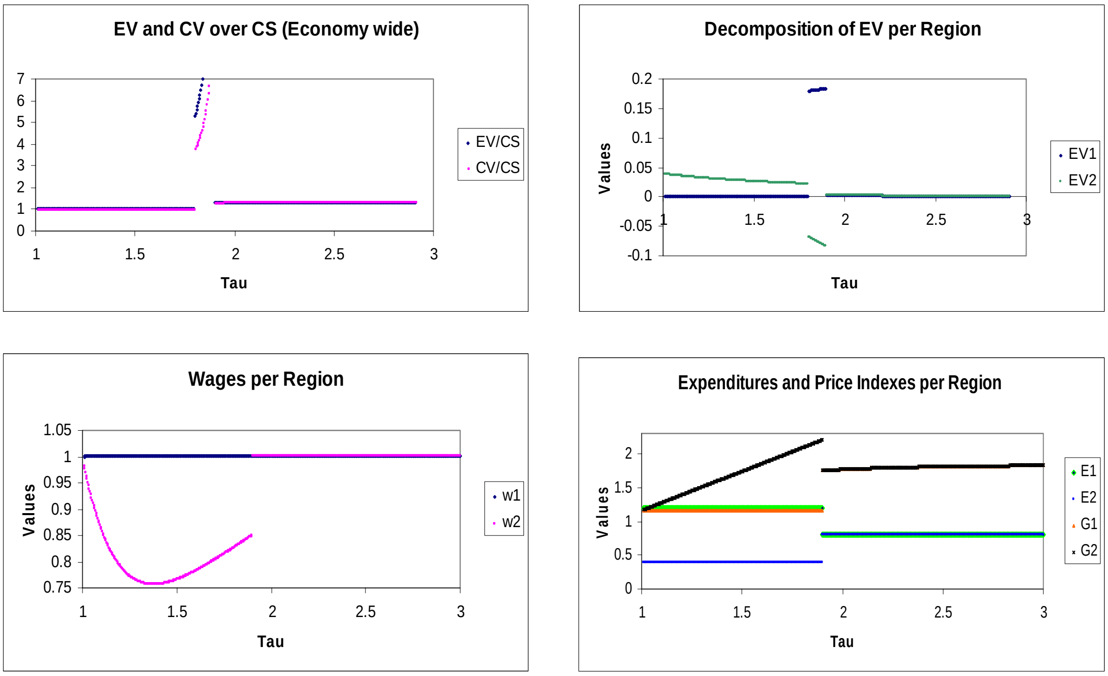
where $p_i(h)$ is the producer price of variety h in region i. Shipments of the industrial goods incur in 'iceberg' trade costs: τ (>1) units must be shipped in order that one unit arrives in the other region. An industrial firm producing quantity x(h) of variety h in region i have a minimum cost function:

$$C(h) = q_i^{\mu} w_i^{(1-\mu)} (\alpha + \beta x(h)) \qquad (31)$$

where μ (with 0≤μ<1) is the share of intermediaries in firms' costs. Demands for individual firms are derived by using Shepard's lemma on expression (31). Using these we can construct as before transport services derived demands and similar comparison between effects within the transport sector and effects on the whole economy can be carried out.

Figure 5 shows the corresponding welfare effects when industrial linkages are added to the previous models and migration between regions –in this case possible countries- is not allowed. As is clear from the figures the shape of transport demands is not very different from previous cases.

In Figure5 the significance of indirect effects in this type of model is shown. Since here the comparison is between a final consumption based measure of welfare (for workers in each region) and a derived transport demand measure of welfare change, an increase in the magnitude of effects is clearly expected, but the shape of the curve is quite close to Fig.4 where no industrial linkages are recognized. Accompanying this magnitude effect a significant divergence between welfare measures exists for high levels of transport costs. The ratio between EV and CS for levels of transport cost above 1.902 is in the range of 1.28 to 1.31. For levels of transport cost where a core-periphery structure arises CBA performs as well as EV and CV.



a. **b.**

Figure 5 Industrial Demand added to the model

5. Conclusions and policy recommendations

In this paper we tried to fill a gap in research concerning cost-benefit analysis for transport infrastructure projects. Our focus is on the measure of benefits, mainly on the divergence of economy-wide measures of welfare and traditional transport market based measures of welfare change. Departing from the canonical core-periphery modeling we construct measures of welfare and linked them with the practice of CBA. Simulations based on symmetry and asymmetry conditions in this model show that a difference exists in both measures and that this measure is negative and increases significantly in the case of asymmetry and more particularly when more realistic features are included in the model. This evidence support the interest in more detailed research on indirect and strategic effects arising from infrastructure projects in the debate that originated studies such as SACTRA (1999) and CPB(2000).

In a future extension of this paper more realistic features are considered such as networks effects (more than two regions), imperfect and heterogeneous labor markets, government intervention, congestion effects and growth.

References

Affuso, L., Masson, J. and Newbery, D.M.G., 2000. Comparing Investments on new Transport Infrastructure: Roads vs. Railways?, Department of Applied Economics. Working Paper 0021

Aschauer, D.A., 1989. Is public expenditure productive?, Journal of Monetary Economics, 23.

Brackman, S, Garretsen, H., van Marrewijk, C., 2002. An Introduction to Geographical Economics, Cambridge University Press.

Bröcker, J., 1999. Trans-European Effects of 'Trans- European Networks': A Spatial CGE Analysis, Mimeo, Technical University of Dresden, Dresden

Bröcker, J., 1998. Operational Spatial Computable General Equilibrium Modelling', in: Ann. Regional Science, 32 367-387.

Canning, D., and Pedroni, P., 1999. Infrastructure and Long-Run Economic Growth, Queen's University of Belfast. Processed.

CPB/NEI, 2000. Evaluatie van infrastructuur projecten, Leidraad voor kosten-batenanalyse. The Hague: Centraal Planbureau/Nederlands Economisch Instituut.

Dixit, A.K., Stiglitz, J.E., 1977. Monopolistic Competition and Optimum Product Diversity, American Economic Review 67, 297-308.

Jara-Diaz, S.R., 1986, On the Relation between Users' Benefits and the Economic Effects of Transportation Activities, Journal of Regional Science, 26, 2.

Jara-Diaz, S.R., and Friesz, T., 1982. Measuring the Benefits Derived from a Transportation Investment, Transportation Research . 16B, 57-77.

Jenkins, Glenn P., and Kuo, Chun Yan, 2004. Evaluation of the Benefits of Transnational Transportation Projects (March 2004)

Knaap T. and Oosterhaven, J., 2000. The welfare effects of new infrastructure: An economic geography approach to evaluating a new Dutch railway link'. Paper presented at the North American RSAI meetings, Chicago, November 9-12.

Krugman and Venables 1995. Globalization and the Inequality of Nations. Quaterly Journal of Economics, 110 (4) 857-880.

Fujita, M., Krugman, P., and Venables, A., 1999. The Spatial Economy, MIT Press.

Hirschman, A., 1958. The Strategy of Economic Development. New Haven, Conn.

Martin, P., 2003. Putting the Economy in its Place: On Economics and Geography, paper presented at the Cambridge Journal of Economics Conference Economics for the Future: Celebrating 100 Years of Cambridge Economics 17-19 September 2003

Melendez-Hidalgo, J., Rietveld, P., and Verhoef, E., 2003. Transport Infrastructure Impacts: Direct and Indirect Effects, working paper, Vrije Universiteit Amsterdam.

Mohring, H., 1976. Transportation Economics. Cambridge, MA: Ballinger.

Mohring, H., and Harwitz, M., 1962. Highway Benefits: An Analytical Framework, Northwestern University Press, Evanston, Illinois

NEI, 2000. Vervoerswaarde Studie Zuiderzeelijn, Eindrapport, NEI Transport i.s.m. Bouwdienst Rijkswaterstaat, Rotterdam.

NERA, 1999. A framework for assessing studies of the impact of transport infrastructure projects on economic activity, London.

Oosterhaven, J., Knaap, T., Ruijgrok, C.J., Tavasszy, L.A., 2001. On the development of RAEM: the Dutch spatial general equilibrium model and its first application', 41th European Regional Science Association Conference, Zagreb

Oosterhaven, J. and Knaap, T., 2002. Spatial Economic Impacts of Transport Infrastructure Investments, in: A. Pearman, P. Mackie. J. Nellthorp and L. Giorgi (eds), Transport Projects, Programmes and Policies: Evaluation Needs and Capabilities, Ashgate (forthcoming)

Porter, M., 1990. The Competitive Advantage of Nations.

Rietveld, P. and Bruinsma, F., 1998. Is transport infrastructure effective? Transport infrastructure and accessibility: impacts on the space economy, Springer, Berlin

Rietveld, P., and Nijkamp, P., 2000. Transport Infrastructure and Regional Development. In: J.B. Polak and A. Heertje (eds.) Analytical Transport Economics, An European Perspective. Edward Elgar, UK.

Rosenstein-Rodan, P., 1943. Problems of Industrialization of Eastern and Southeastern Europe, Economic Journal 53 (June-September) 210-211

Standing Advisory Committee on Trunk Road Assessment (SACTRA), 1999. Transport and the economy, London.

Spiekermann, K., Wegener, M., Copus, A., 2002. Review of Peripherality Indices and Identification of 'Baseline Indicator': Deliverable 1 of AsPIRE – Aspatial Peripherality, Innovation, and the Rural Economy. Dortmund/Aberdeen: S&W, IRPUD, SAC.

Schürmann, C., Spiekermann, K., Wegener, M., 1997. Accessibility Indicators, Berichte aus dem Institut für Raumplanung 39, Dortmund, IRPUD

Tinbergen, J., 1957. The appraisal of road construction: two calculation schemes. Review of Economics and Statistics, 39 241-249.

Weisbrod, G. and Treyz, F., 1998. Productivity and accessibility: Bridging project-specific and macroeconomic analysis of transportation investment. Journal of Transportation and Statistics, October 1998, 65-79

Appendix

A.I. Welfare Measures

Welfare measures for comparison between a general CBA and a traditional –specific- CBA are the following:

- Consumer Surplus (CS)
- Compensate Variation (CV)
- Equivalent Variation (EV)

CS is measured in two different ways. First it can be measure using "rule of half" type procedure, which means that in both the original and final equilibrium the levels of demand in region i fulfilled with production from region j, that is manufactures goods using transport services, are computed. Next, the following formula is applied using as a measure of "prices" the level of transportation plus one (τ) cost in each equilibrium:

$$CS_{ROH} = s_{ij}(D_{ij}^0 + D_{ij}^1)(\tau^0 - \tau^1) \qquad \text{(A.1)}$$

In this formula s_i represents the proportion of manufacture workers staying in region i, or more appropriate the proportion of varieties from region j consumed in region i. It must be used as a weight in the calculation of CS for a particular region since the consumer surplus refers to the total gain in welfare arising from the consumption of transport sector using goods. In this measure no difference between agricultural or manufacture workers in done.

CS can also be measure directly from the expression of demand for variety j consumed in region i, as follows (in the case of i=1, j=2):

$$Dij = \frac{\mu E_j p_{ij}^{-\sigma}}{n_i p_{ij}^{1-\sigma} + n_j p_{jj}^{1-\sigma}} \qquad \text{(A.2)}$$

The integration of this expression over the corresponding range of levels of τ and subsequently weighted by s gives another measure of CS that should be consistent with the first one is the demand curve is not very far from the linear case. For the purpose of integration I use two numerical integration procedures that in general give close results; these are Trapezoid rule and Simpson rule. These calculations can be carried out for the symmetry case since between equilibriums only τ is changing. This occurs because of the normalizations employed requires that prices are one in equilibrium (and equal to salaries for manufacture workers) in both scenarios an as a consequence expenditure is equal in both regions and since the equilibriums analyzed are for dispersion we have $n_i = n_j = 0.5$. This means that the movement in over the demand curve and doesn't affect the position of the demand curve. This is completely different to what happen when asymmetry between regions is allowed. In this case not only τ changes, but other elements in the expression for demand change so we can not use anymore the second approach to calculate CS.

CV and EV measures are derived from the expression of indirect utility for the aggregate of consumers in a region. This expression for region r is the following:

$$V_r(p^T, G, Y) = \mu^{\mu}(1-\mu)^{(1-\mu)} Y\, G^{-\mu}(p^T)^{-(1-\mu)} \qquad \text{(A.3)}$$

The following two relations implicitly define an expression for the equivalent (EV) and compensate (CV) variations,

$$V(\tau^0,\ Y^0 + EV) = U^1$$

$$V(\tau^1,\ Y^1 - CV) = U^0$$

where U^i indicate the level of utility depending on the stage, that is, in the original situation before the change in transport cost and in the final situation after the change. Combining these conditions with (3) a pair of explicit expressions for the EV and CV can be derived, for example, for the equivalent variation,

$$U^1 = \mu^{\mu}(1-\mu)^{(1-\mu)}(Y^0 + EV)\ (G^0)^{-\mu}(p_r^T)^{-(1-\mu)}$$

$$\mu^{\mu}(1-\mu)^{(1-\mu)} Y^1 (G^1)^{-\mu} = \mu^{\mu}(1-\mu)^{(1-\mu)}(Y^0 + EV)\ (G^0)^{-\mu}$$

$$(Y^0 + EV) = \frac{Y^1 (G^1)^{-\mu}}{(G^0)^{-\mu}}$$

$$EV = Y^1 \left[\frac{G^1}{G^0}\right]^{-\mu} - Y^0 \qquad \text{(A.4)}$$

and applying a similar procedure we will obtain,

$$CV = Y^1 - Y^0 \left[\frac{G^0}{G^1}\right]^{-\mu} \qquad \text{(A.5)}$$

CV and EV measures can also be derived from the compensate demand function for variety i, which can be obtained starting from the FOC of the utility maximization faced by the consumer in this version of the core-periphery model, that is,

Maximization of $U_r = M_r{}^{\mu} T_r{}^{1-\mu}$, subject to $Y_r = p_r^T T + \int_0^n p(i)_r\, m(i)_r\, di$,

where M represents the composite index of manufacture goods, T is the consumption of traditional good (e.g. agricultural), and μ represents the expenditure share of manufactured good in consumption. The consumption of manufactures is described by a constant elasticity of substitution sub utility function defined over a continuum of varieties of manufactured goods, m(i), with a range of varieties described by n. The preference of variety in manufacturing goods is represented by ρ.

$$M_r = \left[\int_0^n m(i)_r{}^{\rho} di \right]^{\frac{\sigma}{\sigma-1}} \qquad \text{with} \quad 0 > \sigma > 1 \tag{A.6}$$

Since all consumers are identical in preferences, final demand for an specific variety will be the same for all of them differing only in terms of sources of income. We can also assume that there is a representative consumer in each region meaning that the relevant income includes all sources of wages in a region, that is, manufacture or traditional production based wages[16]. The utility maximization problem can be solved in two steps. First, for any value of the composite M, each m(i) have to be chosen so as to minimize the cost of attaining it. This is achieved solving the following problem,

$$\min \int_0^n p_r(i) m_r(i) di \qquad \text{subject to} \qquad M_r = \left[\int_0^n m_r(i)^{\rho} di \right]^{\frac{1}{\rho}} \tag{A.7}$$

The first order condition for this expenditure minimization problem establish the equality of marginal rates of substitution to price ratios for any pair of varieties and consequently implies an expression for the consumption of a particular variety (e.g. m(j)), that replaced in the constraint in (4) finally brings an expression for the *compensated demand* of this particular variety as in (5),

$$m_r(j) = \frac{p_r(j)^{\frac{1}{(\rho-1)}}}{\left[\int_0^n p(i)_r{}^{\frac{\rho}{(\rho-1)}} di \right]^{\frac{1}{\rho}}} M_r \tag{A.8}$$

The term in the denominator is normally regarded as a price index for the manufactured products, denoted here by G in (9). This index measures the minimum cost of purchasing a unit of the composite index M of manufacturing goods.

$$G_r \equiv \left[\int_0^n p(i)_r{}^{\frac{\rho}{(\rho-1)}} di \right]^{\frac{(\rho-1)}{\rho}} = \left[\int_0^n p(i)_r{}^{1-\sigma} di \right]^{\frac{1}{(1-\sigma)}} \tag{A.9}$$

Using (9) the equation for demand of a particular variety can be simplified to:

[16] See Mas-Colell et al (1997) Ch. 4 for a discussion on aggregation.*

$$m_r(j) = \left(\frac{p_r(j)}{G_r}\right)^{\frac{1}{(\rho-1)}} M_r = \left(\frac{p_r(j)}{G_r}\right)^{-\sigma} M_r \qquad \text{(A.10)}$$

In a second stage we can solve the original problem of utility maximization, where consumers divide total income between traditional and composite manufactures. This is a typical Cobb-Douglas maximization problem leading to *uncompensated demands* in the form of income over price times the expenditure share of the good in total consumption, like in (9).

$$\max U_r = M_r^{\mu} T_r^{1-\mu} \quad \text{subject to} \quad G_r M_r + p_T^T T_r = Y_r$$

$$T_r = \frac{(1-\mu)Y_r}{p_r^T}; \qquad M_r = \frac{\mu Y_r}{G_r} \qquad \text{(A.11)}$$

For each variety of manufactures *uncompensated demand* can be derived as in (2), in which the elasticity of demand for every variety is σ.

$$m_r(j) = \mu Y_r \frac{p_r(j)^{-\sigma}}{G_r^{-(\sigma-1)}} \text{ for } \quad j \in [0, n_r] \qquad \text{(A.12)}$$

To derive *compensate demand* expression for variety I, instead of using M_r we should use the corresponding *compensate demand* expression for the aggregate of manufactures, M^c. Since the original consumer maximization problem is a typical Cobb-Douglas, the expression for this type of demand is well-known,

$$M_r = \frac{\mu E_r}{G_r}$$

where E_r correspond to the expenditure function that can be derived directly from (3) as,

$$E_r(p^T, G, Y) = \mu^{-\mu}(1-\mu)^{-(1-\mu)} V G^{\mu}(p^T)^{(1-\mu)} \qquad \text{(A.13)}$$

Consequently, a final expression for compensated demand for variety i is as follows,

$$m_r^C(j) = \left(\frac{p_r(j)}{G_r}\right)^{-\sigma} M_r^C = \left(\frac{p_r(j)}{G_r}\right)^{-\sigma} \frac{\mu E_r}{G_r} = \left(\frac{\mu}{1-\mu}\right)^{(1-\mu)} V_r \frac{p_r(j)^{-\sigma}}{G_r^{-(\sigma+\mu-1)}} \qquad \text{(A.14)}$$

One important property of this function is that it coincides with (9) in the initial equilibrium if the EV is used as a reference of welfare and it coincides with the final equilibrium if CV is used instead. In the case of asymmetry this kind of measure cannot be used since from equilibrium to equilibrium variables other than τ change.