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Abstract

Can subsidies to domestic producers, de facto, be subsidies to foreign producers? If so, state aid may distort competition to the advantage of the foreign producers. At the same time, governments often oppose subsidies elsewhere, claiming that their industry is hurt. The possibility that governments fight subsidies on these grounds, although the effects are to the contrary, constitutes what is called ‘the state aid paradox’ that is discussed throughout the paper. The dispute over regionally differentiated payroll tax rates between Norway and the surveillance authority of the European Free Trade Association (ESA) is used as a motivating example. The dispute is analysed by means of a simple general equilibrium model. The approach is partly analytical and partly numerical. There are three regions represented in the model: the assisted periphery, the assisting core, and the world outside, interpreted here as the European Union (EU). It will be demonstrated that although the assisted periphery will be losing market shares if state aid is ended, so will possibly EU in all markets.

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1. Introduction

Under the rules governing international trade, domestic subsidies may be challenged if they cause injury to the industry of a foreign country (Article VI, GATT). Subsidies are often considered to constitute unfair trade and disturb the level-playing field. I will not discuss the economic rationale of the fairness argument here, but rather accept as a fact that countries seem to act on these grounds in trade disputes and that the rules and institutions indeed let them do so. What I would like to question is the presumption that domestic subsidies tilt the level-playing field in favour of domestic producers on the expense of their foreign rivals. In many circumstances, it is arguable the other way around. In aggregate, subsidies to domestic producers are often, de facto, subsidies to foreign producers. State aid may therefore indeed distort competition, not to the advantage of the domestic producers but to the advantage of the foreign producers whose governments make complaints about foul play. This constitutes what we may call ‘the state aid paradox’. The motivating example for investigating the intuition behind the state aid paradox is the dispute over regionally differentiated payroll tax rates between Norway and the surveillance authority of the European Free Trade Association (ESA) that has been going on for years. A brief description of the dispute is presented in Section 2. The rest of the paper is organized in 6 sections. The conceptual model is introduced in Section 3, followed by a more formal presentation in Section 4. The Norwegian position is analysed in Section 5 under the heading “The Norwegian regime” whereas the ESA position is treated in Section 6, “The ESA regime”. There is a summary of results and sensitivity analysis in Section 7, and Section 8 contains a concluding discussion. The microeconomic foundations for the model employed, is relegated to Appendix.

2. Description of the case

ESA decided July 2 1998 (Decision No. 165/98/COL) that the Norwegian system of regionally differentiated social security contributions involved state aid incompatible with the Agreement on the European Economic Area (the EEA Agreement). The decision was fully supported by the European Commission (Commission’s observations in Case E-6/98 and Dec. No. 165/98/COL p. 3). The Norwegian Government contested the decision and applied for

annulment to the EFTA Court. May 20 1999 the Court dismissed the application.¹ An amended system, accepted by ESA, was in force until the end of 2002. A more restrictive prolongation was negotiated after the EU Commission interfered and asked for a more restrictive practice (COMP/G1/DV/D(01)202). Interestingly, from press releases it appears that the initiative by the Commission was a result of Swedish complaints (NTB, April 11 2002). This arrangement only lasted for one year. At time of writing, the old system is formally abandoned, but a transition period for several years have been accepted. Moreover, the Norwegian Parliament has instructed the Government to prepare a report on how the old system can be preserved to the greatest extent possible within the European rules.

The system of regionally differentiated social security contributions paid by employers is an implementation of implicit regional labour subsidies. To appreciate what is on stakes here, it is necessary to understand that labour subsidies have been representing the main instrument of Norwegian regional policy. According to estimates from a study commissioned by ESA, total benefits in 1994 were 4473 million 1994-NOK or approximately 534 million 1994-ECU (Hervik, 1997).²

Compulsory social security contributions levied on employers were introduced in 1966 (Act of 17 June 1966 no. 12) and regionally differentiated in 1975 (Ot. Prp. No. 12, 1974-75). When the system was first implemented in January 1976, there were 3 tax zones with tax rates ranging from 14 to 17 per cent, replacing the previous flat rate of 16.7 per cent. The system has gradually been extended to 5 zones with tax rates ranging from zero to 14.1 per cent. In 1998, it was estimated that a flat rate of 12.6 per cent would generate the same revenues as the differentiated rate (Application for annulment to the EFTA Court, the Government of Norway, September 2 1998, p. 3). For practical reasons, differentiation was linked to place of residence of the employee, not the location of work place. The tax base was the gross salary or the payroll. The income from the payroll tax should not change as a consequence of the new system. Hence, if the tax rate was lowered somewhere, it had to go up elsewhere. It is

¹ For details on the judgement, see <http://www.efra.int/structure/main/index.html>.

² This amounts to more than 123 ECU per capita. The estimate exaggerates the cost savings to the firm for two reasons, however. First, all firms are assumed to pay the highest rate instead of the more relevant revenue neutral flat rate. This way, the two situations are not comparable since the average tax burden is increased substantially along with the change in rates. It is difficult to understand why the widely accepted conventional methodology of comparative studies on tax systems has not been followed here (see, e.g., Hamilton, 1999). Second, it is assumed that the subsidy is not shifted on to the employees at all as if labour supply were perfectly

interesting to note that ESA has never contested this principle and we will assume throughout that it will continue to apply. This is also convenient from an analytical point of view, since we may preserve a constant tax burden when comparing different tax regimes without introducing additional taxes. If payroll tax rates in assisted areas must be raised, the rates in assisting areas must fall so that the average tax burden is unaltered.

The principal view of the Norwegian Government has been that the differentiated payroll tax system is part of the overall tax system and central to labour market policy. Since the State retains the power of exercising both taxation and labour policy under the EEA Agreement, the payroll tax system is outside the competence of both ESA and the Commission.

The principal position of ESA has been that if the system should be accepted, the principle of industry neutrality had to go, i.e, certain sectors would have to pay the highest rate regardless of location. Most notably, subsidies should in principle no longer be granted to firms with no alternative location. “No alternative location” was identified as natural resource based sectors like extractive industries and hydroelectric power stations. Specifically ESA listed the following sectors (Dec. No. 165/98/COL, p.29):

- “- enterprises engaged in Production and distribution of electricity (NACE 40.1)
- enterprises engaged in Extraction of crude petroleum and gas (NACE 11.10)
- enterprises engaged in Service activities incidental to oil and gas extraction excluding surveying (NACE 11.20)
- enterprises engaged in Mining of metal ores (NACE 13)
- enterprises engaged in relation to the extraction of the industrial minerals Nefeline syenite (HS 2529.3000) and Olivine (HS 2517.49100)”

In the regional science literature, we find the idea that economic activities in a region can be divided into an economic base sector exporting its output to the world outside, and a non-basic sector serving the region.³ For peripheral regions the world outside is often far away in a literal sense. Studies on accessibility for different modes of transport in Europe, e.g. rail (Vickerman et al., 1999) and road (SPESP 2000), clearly show that peripheral regions on the

elastic. The real magnitude of the benefit is therefore more modest than the estimate suggests, although probably still important enough to merit attention.

³ For another view on what constitutes the economic base, see Venables, 1996.

physical map have transport disadvantages in terms of cost and time. In the standard Weber-Lösch model of location, firms choose location in order to economise on transport costs. Hence, the location of an economic base sector in a peripheral region, far from the output market, reveals that distance to the market is of minor importance. There may be two reasons for this. Either transport costs of a locally available input are so high that the relative cost of transporting output to the market is small, or distance to the market is irrelevant for transport costs. The “no alternative location” criterion was obviously designed to prevent subsidies to firms of the first kind, but the ESA position is in effect covering the latter possibility as well, since apart from the industry groups referred to above, the following groups were also requested to pay the highest rate (Ibid. pp.29-30):

- “- enterprises with more than 50 employees engaged in Freight transport by road (NACE 60.24)
- enterprises engaged in the Telecommunication sector (NACE 64.20)
- enterprises having branch offices established abroad or otherwise being engaged in cross-border activities related to the following sectors, namely, Financial intermediation (NACE 65), Insurance and pension funding (NACE 66), and services auxiliary to financial intermediation (NACE 67), with the exception of branch offices only providing local services.”

For firms within the telecommunication industry as well as service firms relying on modern telecommunications for market access and to some extent also firms in the road haulage industry, transport costs to obtain market access do not matter much, and cheap labour may be sufficient to choose a remote location. ESA does not accept preferential tax treatment that may cause such cost advantages to arise.

On basis of this brief outline of the different positions, I think that the analytical distinction between an economic base and a non-basic sector may serve as a useful taxonomy. Although some economic base industries seem to be allowed to benefit from a lower rate, it is reasonable to argue that by and large the principal ESA position amounts to request that

economic base sectors covered by the EEA Agreement pay the full rate, whereas non-basic sectors may continue to pay the reduced rate.⁴

3. Conceptual model

The present context suggests that we need to divide the European Economic Area into at least three regions: Northern Norway (n), southern Norway (s), and the European Union (u). To a first approximation we may consider n to be the assisted area benefiting from a lower payroll tax rate than s . According to ESA, close to 70 percent of total benefits accrue to n (Dec. No. 165/98/COL, p.6). To a first order of approximation we may also ignore the small economies of Liechtenstein and Iceland, and consider the EEA to consist of Norway and the EU.

Transport costs between n and u is higher than either between n and s or s and u , because of distance and different accessibility costs. Distance is leading to a geographical disadvantage for n compared to s since higher transport costs imply higher living costs, leading to lower real wage or higher labour costs. According to ESA, transport subsidies may be allowed to compensate geographical disadvantage (Dec. No. 165/98/COL, p.30). Differentiated payroll tax rates are in fact only accepted as a substitute for regional transport aid.

Besides different accessibility between the three regions, the home markets are obviously very different in size. Measured by population, s is more than 7 times larger than n , and u is more than 95 times larger than s . This suggests that it may be reasonable to apply the small country assumption, or more accurate, the small region assumption, to trade with region u , i.e., region n and s export to u at constant prices. In the formal model to be used the three regions are treated symmetrically, but the small region assumption is used in the interpretation of the results.

In each of the three regions there is an economic base sector, the B sector, and a non-basic sector, the A sector. To simplify, I assume that the B sector produces only final goods, while the A sector only produces intermediates. Following orthodox trade theory, we abstract from

⁴ In addition to the industry groups listed, ESA also mentions production of ECSC steel and shipbuilding which have a particular status due to a long history of European over-capacity, see Schina (1987), §162.

interregional trade in intermediates so only final goods are tradables. Technology is assumed identical in the three regions.

The B sector produces by means of B skilled labour and intermediates from the A sector. The consumers distinguish the products from the B sectors of the three regions by origin only.⁵ Lack of substitution between goods made in n and s preserves status quo by acting as a centrifugal force working against centripetal forces favouring one of the two regions. The firms are price takers in the output market and use a constant to scale technology. In equilibrium no firms earn profits due to free entry. Market prices are determined by equating demand and supply. In order to abstract from currency issues, all regions are treated as if they had a common currency.

The A sector produces differentiated intermediates by means of a single input called A skilled labour. Due to fixed set up costs there are internal increasing returns to scale. The market structure is Chamberlinian monopolistic competition. Specialisation through the number of intermediate inputs is endogenous and acts as a centripetal force. The larger the A sector, the more productive is the B sector of the region.⁶

Both B skilled and A skilled labour might be mobile between n and s . Since labour is less mobile in the short run than in the medium and long run, and since low skilled labour is less mobile than high skilled, we consider several alternatives: no mobility, mobility in the A sector only, and full mobility.⁷ We do not allow retraining so there is no mobility between sectors. Following the new economic geography tradition, spatial equilibrium is simply obtained when perceived real wage of mobile labour is the same in all feasible locations.⁸ Using this conceptual set up we consider what happens when we introduce a tax neutral regionally differentiated payroll tax/subsidy in Norway. We consider two alternatives: an equal tax/subsidy across industries in accordance with the scheme used for the past 25 years and a subsidy on A skilled labour in n only in accordance with the ESA position. The

⁵ This is the Armington (1969) assumption.

⁶ An alternative, considered by Skott and Roos (1997), is a fixed number of intermediate inputs.

⁷ There is empirical evidence that skilled workers are more mobile than unskilled (Shields and Shields, 1989).

⁸ This need not be interpreted in a literal sense, but may be regarded as a reduced form for more sophisticated behaviour. As shown by Baldwin (2001), replacing myopic with forward looking behaviour in the standard core-periphery model (Fujita et al., 1999) does not imply that the qualitative behaviour of the model changes. Of course, in order to actually verify that myopia only is an assumption of convenience also in our 'core-periphery' model, we need to do a similar exercise.

performance of the alternatives is judged by reference to different criteria. Since the main objectives of Norwegian regional policy have been to pursue spatial equality in standards of living and to preserve the spatial pattern of population, we are going to look at real income and population in n and s . Since distortion of competition between firms located in different regions, particular between firms located inside or outside EU, is the foremost concern to the ESA and the EU Commission, we are also going to look at market shares.

Some readers may not be particularly interested in the microeconomic foundations and the algebra involved. It is not necessary to go into these details since the model can be summarised in a few equations. However, studying the foundations may pay off in better understanding of the mechanisms behind the results. A complete presentation of the microeconomic foundations is provided in the Appendix.

4. A general equilibrium model

The model can be summarised in some simple equations. The two equations given by (4.1) imply that supply equals domestic and foreign demand for final goods produced in all the regions. Here r_i represents aggregate income in region i , s_{ij} is the aggregate expenditure share for the good produced in region i and consumed in region j , and t_i is the tax factor in region i (if τ is the payroll tax rate, $1 + \tau$ is defined as the payroll tax factor).

$$r_i(t_i - s_{ii}) = r_j s_{ij} + r_u s_{iu}, \quad i \neq j; i, j = n, s \quad (4.1)$$

The market clearing condition for products made in region u , is not included since adding up implies that only two of the three equations are independent. This is a statement of Walras' law, which basically always is true because of the budget constraints on the market behaviour of each individual. We may also note that imposing market clearing is equivalent to imposing interregional trade equilibrium. There will be balance of payments between the regions, or to paraphrase John Stuart Mill: the produce of a region exchanges for the produce of other regions, at such values as are required in order that the whole of her exports, and net transfers, may exactly pay for the whole of her imports. This is easily seen, by observing that the left side of (4.1) is the factor income net of taxes minus expenditures on home made goods, while the right side is the value of imports.

If tax revenues are to be kept constant, we must have

$$r_n(1-t_n) = r_s(t_s - 1) \quad (4.2)$$

Subsidies mean that the payroll tax factor is below unity in the assisted region and/or sector, and above unity in the non-assisted area and/or sector. Here, region s is paying for some of the imports to region n through the transfer in form of labour subsidies, so $t_s > 1$ and $t_n < 1$.

The present scheme of differentiated payroll tax rates may be imposed by setting

$$t_{nA} = t_{nB} \equiv t_n, \quad t_{sA} = t_{sB} \equiv t_s, \quad t_{uA} = t_{uB} \equiv 1. \quad (4.3)$$

Subscript A and B refer to sector specific factors. The amendments requested by ESA mean

$$t_{nB} \neq t_{nA} \equiv t_n, \quad t_{sA} = t_{sB} = t_{nB} \equiv t_s, \quad t_{uA} = t_{uB} \equiv 1. \quad (4.4)$$

No taxes have been used as point of reference by setting the tax factor equal to unity in region u . In the remaining part of the paper I restrict generality of the payroll tax system to the two schemes (4.3) and (4.4).

Let us now turn to the demand structure of the model. Consider the very general aggregate demand system,

$$s_{ij} \equiv \frac{p_{ij} y_{ij}}{r_j} = \alpha_{ij} + \sum_j \beta_{ij} \ln p_{ij} + \gamma_{ij} f(r_j / cpi_j) + \gamma'_{ij} (m_j + l_j), \quad i, j = n, s, u. \quad (4.5)$$

Greek letters are parameters, p_{ij} is delivered price in region j for the good produced in region i , y_{ij} is quantity of the good, m_j and l_j is A skilled and B skilled labour so $m_j + l_j$ is the population of region j , and cpi_j is the consumer price index for region j . The familiar demand system AIDS, e.g., is a special case of (4.5) with $\gamma'_{ij} = 0$, $f(\cdot) = \ln(\cdot)$ imposed. We are going to consider two alternative specifications here. The most restrictive is a system consistent with Cobb-Douglas preferences, which is obtained by placing a zero restriction on all parameters but α_{ij} . We assume homogeneous consumers in the sense that everybody is using the same share on home made goods and the same share on imports, $\alpha_{ij} = \alpha_{ji} \forall i, j$. The least restrictive is a system consistent with quasi homothetic individual preferences (see the appendix). We assume $\gamma_{ij} = \gamma'_{ij}$, $f(\cdot) = 1/(\cdot)$. For the expenditure shares to add up, we must impose the restrictions $\sum_i \alpha_{ij} = 1$ and $\sum_i \gamma_{ij} = 0$.

When the model is extended beyond homothetic (Cobb-Douglas) preferences, imports are assumed to be luxuries, $\gamma_{ij} < 0$, and home made goods have to be necessities, $\gamma_{ii} > 0$, for adding up to hold.⁹

Since labour is the only input and there is zero profit in equilibrium in the markets for intermediates, it is shown in the appendix that

$$v_i m_i / \beta_q = w_i l_i / \beta_w \quad (4.6)$$

and aggregate nominal income in any region can simply be written,

$$r_i = \frac{w_i l_i}{\beta_w t_i}, \quad i = n, s, u \quad (4.7)$$

The producer wage rate and employment in sector A is v_i and m_i - in the B sector w_i and l_i . The cost share for B skilled labour is β_w , and for intermediates in the production of final goods, β_q . The inverse of the tax factor in any region is the weighted average for the two sectors with β_w and β_q as weights, $1/t_i = \beta_q/t_{iA} + \beta_w/t_{iB}$. Hence, the right side of (4.7) gives us the income distribution between A -skilled and B -skilled labour.

What about the labour markets and mobility? I have assumed that everybody supplies one unit of labour, that they are either A skilled or B skilled and that they cannot be retrained.¹⁰ The number of B skilled people in region u is fixed and equal to \bar{l}_u . So is the number of A skilled in region u , equal to \bar{m}_u . Region n and s share a common pool of potential mobile A skilled and B skilled workers, \bar{m} and \bar{l} . We must have:

$$m_u \leq \bar{m}_u, l_u \leq \bar{l}_u, m_n + m_s \leq \bar{m}, l_n + l_s \leq \bar{l} \quad (4.8)$$

We assume that all labour markets clear so that we have full employment, i.e., all the restrictions given by (4.8) are effective.

⁹ Empirical estimates based on time series data for nation states strongly suggests that imports are luxuries, see Bairam (1997).

¹⁰ Retraining could perhaps be introduced in the model by treating the schooling sector analogous to the transport sector. The payoff in efficiency units of one unit of labour employed in the ‘wrong’ sector compared to a unit employed in the ‘right’ sector represents a transport cost in the labour proficiency space. Public policy could then be either directed at lowering transport costs by investing in retraining infrastructure or targeted at lowering private costs through subsidies for retraining to mismatched labour.

When we allow mobility, mobile workers locate wherever perceived real wages are highest. In full spatial equilibrium, perceived real wages in both sectors in region n and s must be equal. Workers observe their nominal wage rates in alternative locations and calculate real wages on basis of information on regional consumer price indices, cpi_j , $j = n, s$. There is mobility equilibrium for A skilled labour if

$$\ln(w_n / t_{nA}) + \ln(l_n / m_n) = \ln(w_s / t_s) + \ln(l_s / m_s) + \ln(cpi_n / cpi_s) \quad (4.9)$$

There is mobility equilibrium for B skilled labour if

$$\ln(w_n / t_{nB}) = \ln(w_s / t_s) + \ln(cpi_n / cpi_s) \quad (4.10)$$

Under the Norwegian regime, (4.10) is the same restriction as (4.9). Hence, one instrument (the tax factor in n) is sufficient to obtain desired levels for the target variables, m_n and l_n .

Under the ESA regime, the tax factor for sector A in n is equal to t_n under the Norwegian regime. Then, m_n and l_n is following from (4.9) and (4.10). Effectively, ESA has placed a cap on the instrument that makes the regional policy objective achieved under the Norwegian regime, infeasible.

Three alternative model specifications concerning labour mobility are considered:

- i Full mobility. Restriction (4.9) and (4.10) are imposed.
- ii Partial mobility (mobility in the A sector only). Restriction (4.9) is still valid, but now (4.8) should be extended, imposing the restrictions $l_n = \bar{l}_n$ and $l_s = \bar{l}_s$.
- iii No mobility. Now neither (4.9) nor (4.10) is valid, and to the list of restrictions under case ii, we must add $m_n = \bar{m}_n$ and $m_s = \bar{m}_s$.

The consumer price index of region j is assumed to take the multiplicative form (the Stone price index),

$$cpi_j = \prod_i p_{ij}^{s_{ij}} \quad (4.11)$$

Delivered prices are in general different from mill prices because of transport costs. I assume only y_{ij} units arrive when $\tau_{ij} y_{ij}$ units are shipped. Hence, τ_{ij} represent transport costs.¹¹ The relationship between delivered prices and mill prices are

¹¹ This is the approach favoured in the new economic geography literature in order to avoid introducing a separate transport sector in the models. Many transport economists would probably not be happy to learn that their subject has been relegated to a kind of iceberg costs. At this point there is a large potential to enrich the model. Transport costs depend on more than distance: transport infrastructure quality, substitution possibilities

$$p_{ij} = \tau_{ij} p_i, \quad i, j = n, s, u \quad (4.12)$$

In order to close the model, we must determine mill prices. The mill prices can be obtained using

$$p_i = w_i \left(l_i m_i^{\sigma/(1-\sigma)} z \right)^{\beta_q}, \quad i = n, s, u \quad (4.13)$$

where the factor z depends on a vector of parameters shared by all regions (on the assumption of identical technology). The vector of parameters consist of the cost share for intermediates (β_q), the elasticity of substitution between any variants of intermediates (σ), and the marginal (ζ_1) and fixed (ζ_0) cost per money wage unit in the production of intermediates. Details are found in the appendix.

5. The Norwegian regime

The distinctive feature of the Norwegian regime is an equal tax rate across industries within one region, as formally stated in (4.3). Starting with case iii, things are simple, since (4.8)-(4.13) are irrelevant in order to solve the model. If we substitute for t_s from (4.2) and the expenditure shares from (4.5), we may use (4.1) to solve for aggregate income in n and s , conditional on aggregate income in u and the tax factor in n . The solution is of course also conditional on A skilled and B skilled population everywhere, assumed exogenously fixed under case iii (given by (4.8) and the two additional restrictions, $m_n = \bar{m}_n$ and $m_s = \bar{m}_s$, defining case iii). Substituting from the solutions for aggregate income back into (4.2), gives us the tax factor in s , respecting the restriction imposed by constant tax revenues.

If we want aggregate income in n and s in terms of the wage rate rather than aggregate income in region u , this is easily accomplished using (4.7). For region u , $r_u = \bar{l}_u / \beta_w$ when the wage rate is numéraire ($w_u \equiv 1$). If we want expenditure shares in order to compute the consumer price indices, we can substitute for aggregate income into (4.5).

between different transport modes, input prices, logistics and thickness of transport markets. Unfortunately, the results of the simpler model may not survive alternative specifications of transport technology. Neary (2001)

If we prefer the solution expressed in producer wage rates rather than aggregate income, this is easily accomplished under the Norwegian regime (4.3). We can substitute from the solutions for aggregate income in n and s and the tax factor in s into (4.7) and obtain B sector producer wage rates for region n and s . A sector producer wage rates can then be obtained using (4.6).

Given information on the appropriate parameters, including the transport costs, delivered prices are obtained using (4.13) and (4.12). Substituting for delivered prices and expenditure shares into (4.11), we obtain consumer price levels everywhere and may compare real income across regions and sectors.

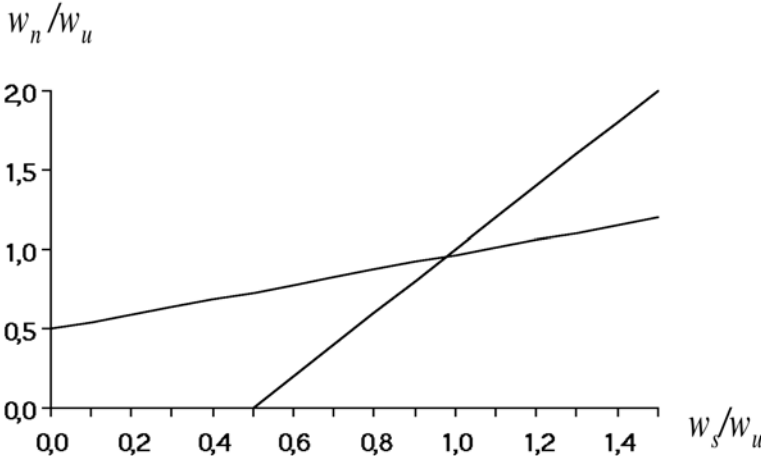


Figure 1. Equilibrium producer wage rates.

Market clearing conditions for goods produced in region n and s under the Norwegian regime with complete labour mobility.

The explicit solution of the model is relegated to the appendix. Here we are content to outline the graphical solution for the B sector producer wage rates (Figure 1). The graphs are drawn for the specific set of parameter values listed in the appendix and the exogenous tax factor, t_n , equal to $9742/10000$. The graphs could of course be drawn for other values of t_n , but we have used this specific value for reasons to be explained below.

refers to older trade theory literature attempting to model an explicit transportation sector: “That approach never led to simple or easily summarizable results, and is now largely forgotten. Perhaps it is due a revival.” (p.550)

When we turn to the more interesting cases allowing for labour mobility, there is a crucial difference as far as methodology is concerned. In the restrictive case with homothetic preferences and homogeneous consumers where everybody use the same share of income at goods from each region, it is (in principle) possible to arrive at closed form solutions for specific cases (see Appendix, Section A.5). However, the algebra involved is messy and we have therefore chosen to rely entirely on numerical methods here in the main text. This brings us back to the specific tax factor value used for the illustration in Figure 1. This is the only value that makes (4.9) and (4.10) fulfilled for the set of parameter values used. Hence, the graphical solution is the solution under full labour mobility when the subsidy is sufficient to compensate for the location disadvantage so that real consumer wages, population, and the distribution of A skilled and B skilled is equal in both n and s . How did we manage to guess exactly what the subsidy had to be? We made a grid search over payroll tax factor values using a computerised version of the model. The search was terminated when there were no difference in real wage between region n and s .¹² Computing imports from different regions of origin in each regional market by volume we also obtain numerical values for market shares.

6. The ESA regime

The distinctive feature of the ESA regime is different tax rates for different industries located in the peripheral region, as formally stated in (4.4). Under the ESA regime, the equation system that was linear under the Norwegian regime, becomes non-linear, even in the simple case without labour mobility. Here we have to rely on numerical methods from the outset.

Only the non-basic A sector in region n is now allowed to continue to benefit from the lower payroll tax rate, hence t_{An} is $9742/10000$ as before. If we ignore adjustment through labour migration and look at case iii, tax neutrality gives the payroll tax factor for the basic B sector in region n and for both sectors in region s , $t_{Bn} = t_s = 10089/10000$ compared to previously

¹² Here and elsewhere, I have used the *Solver Option* available in *Excel 2000*, for the numerical computations. In order to cross validate the results, I have replicated many of the computations using the program package *Mathematica*. However, I have found Excel more convenient to use, offering sufficient precision for the present use.

$t_s = 10273/10000$. Hence, the tax rate in s is down from 2.7 per cent to 0.9 per cent, giving the firms located in s a cost advantage compared to the old system.

If we allow labour mobility in the A sector (case ii), A skilled labour now move from n to s , so that m_n is down by 1.1 per cent (and m_s is up by 1.1 per cent). With full labour mobility between region n and s (case i), there will also be less B skilled labour in n than in s , l_n down by 3.5 per cent. More A skilled will move as well, so that m_n is down by a total of 1.8 per cent. The tax rate in s is down by 1.8 per cent. The total competitive gain enjoyed by firms located in s , through the lower tax rate and higher productivity, is reflected in the reduction in the breakeven price f.o.b., the mill price. Under the Norwegian regime it is equal – under the ESA regime the price in n is 6.1 per cent higher than in s .

The stated policy objectives for Norwegian regional policy have been to pursue spatial equality in standards of living and to preserve the spatial pattern of population. To what extent does the change to the ESA regime affect these objectives?

Table 1. Real individual income. Per cent of real individual income in region u .

Region	Sector	Case i	Case ii	Case iii
n	A	104	104	103
	B	102	99	99
	Average	103	101	101
s	A	104	104	104
	B	102	105	104
	Average	103	104	104
$n+s$	Average	103	103	103

The standard of living is measured by real income per capita. Real income under different assumptions concerning labour mobility is presented in Table 1. Under the Norwegian regime the comparable income was equal to 103 regardless of region and sector. The regional policy objectives can be interpreted in different ways. The objective could be to reduce differences in real regional income per capita. When we compare different regions, the information we have is often some indicator of real income per capita. However, small differences may

conceal large differences in real take home pay for the same job in different locations, because of differences in the industry structure. It is perhaps more reasonable to take the policy objective to be reduced regional differences in real income within the same sector. As can be seen from Table 1, the ESA regime is inferior to the Norwegian regime regardless of interpretation, unless there is perfect interregional mobility of labour in both sectors. Then, equal real wage in each sector regardless of location is following from the labour mobility equilibrium conditions. Aggregate income per capita remains constant although the industry structure at the regional level has changed and wage rates differ between sectors. Table 2 contains information on real aggregate income per capita and real wage per sector in region n compared to s (percentages).

Table 2. Regional policy objectives. Real aggregate income per capita, real wage per sector and population in region n compared to region s (percentages).

	Case i	Case ii	Case iii
Aggregate income per capita	100	97	97
Real wage, sector A	100	100	98
Real wage, sector B	100	94	95
Population	95	99	100

As far as preservation of the pattern of population is concerned, we observe how the ESA regime fares from the last row in Table 2. Higher mobility means fewer people in the periphery. Hence, there appears to be a trade off between income per capita and the number of residents, leaving a room for manoeuvre for the Government if it is able to influence labour mobility.

If case i is interpreted as a long run equilibrium, we would expect that the ESA regime in the long run leads to a smaller population in n with less people working in the subsidised A sector and even less in the non subsidised B sector. However, there will not be larger differences in real per capita income as would be the case if mobility were limited.

If we adopt the small country assumption, common in trade theory in order to abstract from endogenous changes in terms of trade, the content of Table 1 can give us additional information on efficiency. In general, we cannot tell which regime and which case that

performs best in terms of maximising real income. All figures in Table 1 are expressed in terms of the numéraire, which in general will be different in the different situations. However, if the change in regime does not affect wages and prices in region u (the small country assumption), the numéraire remains constant.

On this assumption, we observe that the ESA regime yields the same average income as the Norwegian regime. There are several conflicts of interest, however. A skilled workers, benefiting from continued subsidies, increase their real wage, whereas B skilled workers suffer a loss except in s under restricted mobility (case ii and iii). Residents in n lose on average when there is restricted mobility, whereas residents in s never lose on average. Comparing labour mobility assumptions under the ESA regime, we observe that mobility is best case for residents in n , but worst case for residents in s .

What are the consequences of changing regime for the distribution of market shares? Market shares (volume) under different mobility assumptions are computed and compared to the comparable figures under the Norwegian regime. The qualitative changes are summarised in table 3.

Table 3. Changes in market shares (volume), ESA regime replacing Norwegian regime.

Region of origin	Market n			Market s			Market u		
	case			case			case		
	i	ii	iii	i	ii	iii	i	ii	iii
n	-	-	+	-	-	+	-	-	0
s	+	+	-	+	+	-	+	+	0
u	+	-	-	-	+	+	-	-	0

The table tells us that the changes in market shares are sensitive to mobility assumptions. The market shares for the product from region n fall in all markets except when there is no adjustment through migration. If case iii is interpreted as the very short run, we see that in the short term market shares do not fall anywhere. For products made in region s , the situation is exactly the opposite: region s increases her shares in all markets, except in the short term. The most interesting result is perhaps for products made in region u . In the short term the share at home remains constant, the share in market s goes up whereas the share in market n falls.

When there is partial mobility (case ii), the only difference is that the share at home falls. In the long run with perfect mobility, things turn out to be rather different. Now, the market shares go down in all markets, but market n . Tax neutrality (constant tax revenues) means that in the long run the ESA amendments favour firms located in s making them more competitive. This cost advantage for firms located in region s is sufficient to make up for the loss suffered by less fortunate firms located in region n when selling abroad. Hence, firms located in region u are losing market shares in their home market as well as in their neighbour market abroad.

7. Summary of results and sensitivity analysis

The overall regional policy objectives in Norway have been twofold: to pursue spatial equality in standards of living and to preserve the spatial pattern of population. How these objectives are influenced by the change in payroll tax regime demanded by the EFTA Surveillance Authority depend on the level of economic integration as measured by transport costs and labour mobility. If intranational labour mobility is limited the change in regime almost tautologically does not mean much for the population pattern. On the other hand, standards of living in the periphery compared to the centre will fall. If mobility is high, the opposite conclusion is obtained: the population in the periphery is reduced while standards of living are not affected.

If the wage rate in the economic base sector in EU is not influenced by the actions of consumers and producers located in Norway (the small country assumption), we may conclude that the change in regime does not affect welfare in Norway as measured by real income per capita. However, the income distribution does change conditional on labour mobility assumptions. If labour is perfectly mobile, labour in the economic base sector will lose and labour in the non-basic sector will win. If mobility is restricted, labour in the south will win and labour in the north will lose and the burden will be entirely on labour in the economic base sector since labour in the non-basic sector will benefit from the change. The change in regime affects the preferred domestic distribution of income and population, but does it also affect the distribution of market shares to the advantage of the EU?

A change in regime results in falling market shares everywhere for producers operating from the Norwegian periphery. This should not come as a surprise since the cost advantage through subsidies is reduced. It is more interesting to note that the EU may also lose, both at home and abroad. Hence, the change in regime does hurt the periphery, but may even hurt the EU. In this sense the EU may unintentionally have shot herself in the foot by assisting to the case against the Norwegian Government. The state aid may *de facto* be considered as aid to EU based firms, by offering protection from rivals at the border. The intuition is that for domestic political reasons, these firms have been forced to pay higher taxes to pay for the transfer to the firms in the periphery. When the aid is removed, EU firms face tougher competition at home and in the neighbour market.

To what extent are these conclusions robust to changing parameter values, say other transport costs? If we concentrate on the long run equilibrium, there is no qualitative change. As transport costs rise, the most notable, but unsurprising, effect is a slow move towards autarky. By a seven times increase in transport costs (leading to tripling delivered prices), e.g., home made goods make up roughly 75 per cent of the market. We have performed an extensive sensitivity analysis, maintaining the full mobility hypothesis. Scaling up or down transport costs have no impact on the qualitative results reported in Table 3 as long as the same transport costs are used when comparing the two regimes. However, if we simultaneously change tax regime and transport costs, different results are obtained conditional on the change in transport costs.

If there is a small reduction in short distance costs and a small increase in long distance costs, *the state aid paradox stands up even more clearly*: the only positive sign in Table 3 for goods made in u turns negative while other signs remain constant. This is arguable a possible scenario following a change in policy regime: long distance costs rise because the market in the north is reduced, whereas short distance costs fall because the market in the south grows. The market share for goods made in the union, is now even falling in the north because, in total, higher transport costs dominate relative lower production costs and make goods made in u less competitive.

Other scenarios are of course also possible. The point to be made, however, is that the outcome of the change in policy regime viewed from the union is conditional on the

development of transport costs. There is a risk that the change in regime is harmful to the interest of the union as judged by development of market shares at home and abroad. The available documents from the dispute suggest nowhere that this issue has ever been considered, much less been analysed.

How do other parameters influence the results of the model? If the cost share of intermediates in the production of tradables is increasing, there is again no effect on the qualitative results reported in Table 3. But what happens if there is a simultaneous change in policy regime as well as the cost share? For a sufficiently small drop in the cost share, the only qualitative change from the results in Table 3, is an increase in the share of homemades in region u . If the reduction is somewhat larger, the sign for imports from u in region n also changes (from positive to negative). For even larger reductions, even the signs for goods originating from the other regions are affected: homemades increase their share everywhere and imports reduce their share. We have also looked at the elasticity of substitution. Here, the qualitative results are insensitive to changes, even when the elasticity is changed simultaneously with the change in regime.

8. Concluding discussion

Differential taxes, implying implicit subsidies, must in general be accepted as a legitimate policy option of domestic policy in a decentralised economy. On the other hand, such subsidies may have non-negligible distorting effects on international trade. From a very narrow perspective, subsidies to some producers normally put them on an advantage compared to other producers, including foreign ones competing in the same markets. From this partial approach it looks as if removing subsidies would benefit foreign producers. It is plausible that this perspective is as important as general economic efficiency considerations when governments take action against infringements of international rules of state aid. What seems to be less noticed is the implication of the fact that when someone receives a subsidy there must be someone else paying. Often this is just intended to be a domestic producer-producer transfer. The closest alternative if the subsidy is removed is therefore a flat-rate system keeping tax revenues constant. It is far from clear that foreign producers have anything to gain from such a change. On the contrary, it may just as well mean they will be

losing since many of their contenders now face reduced after tax costs. From one perspective, it is the foreign firms that have been favoured by the domestic subsidy scheme since it offered protection from domestic firms paying for the transfer. We have referred to this situation as the ‘state aid paradox’.

The dispute over differentiated payroll tax rates between Norway and ESA is a case in point that has been used throughout this paper as an example where the state aid paradox may apply. Moreover, the decision by the EFTA Court in favour of ESA has left the Norwegian Government with no other choice than to find alternative instruments if the regional effects under the ESA regime are considered unacceptable. An interesting policy option that could easily be analysed within the present framework is infrastructure investments reducing transport costs. There are already several studies on this subject, but the specific questions arising in the present context are not answered.¹³ Within the model we have employed, we have seen that the effects on market shares for EU goods are conditional on transport costs. By an appropriate allocation of infrastructure investments, the worst case scenario for the EU with falling market shares *everywhere*, may indeed come true.¹⁴

¹³ Martin and Rogers, 1995a and 1995b, and Kilkenny, 1997.

¹⁴ Could even infrastructure investments qualify as illegal state aid? As long as there is no harmonisation of public infrastructure investment criteria in the European Economic Area, we might think the answer would be ‘no’. But responding to a parliamentary question in 1967, the Commission suggested the answer could be ‘yes’ if the infrastructure were to the benefit of certain undertakings or the production of certain goods (Parliamentary Question 28/67 by M. Dehousse, Journal Officiel des Communautés Européennes 2311, 1967). However, so far it does not appear to be any European infrastructure projects that have been considered illegal state aid.

Appendix. Microeconomic foundations

A.1. Preferences

Consumers have identical preferences regardless of occupation and location of residence. Everybody supplies one unit of labour, receiving v_j/t_{jA} and w_j/t_{jB} depending on skills. Recall that the producer wage rate in sector A is v_j and in the B sector w_j , whereas t_{jA} and t_{jB} are the payroll tax factors. Individual expenditure systems for A skilled and B skilled are

$$\begin{aligned} p_{ij}y_{ij}^{hA} &= \alpha_{ij}v_j / t_{jA} + \gamma_{ij}, \\ p_{ij}y_{ij}^{hB} &= \alpha_{ij}w_j / t_{jB} + \gamma_{ij}, \quad i, j = n, s, u. \end{aligned} \quad (\text{A.1})$$

Hence, preferences are quasi homothetic, i.e., the Engel curves are straight lines (but not through the origin),¹⁵ and consistent with (4.5) in the main text.

A.2. The economic base sector

The economic base sector in a specific region consists of a large number of firms with identical constant returns to scale technology. Aggregate output is determined by assuming that profits are zero due to free entry and exit. Skipping indices for region in the rest of the appendix, the unit cost function for a firm is written

$$\ln(c/y) = \beta_w \ln w + \beta_q \ln q, \quad \beta_w + \beta_q = 1. \quad (\text{A.2})$$

Here, w is the wage rate paid by producers, q is a price index of inputs from the non-basic sector, c/y is unit cost, and the Greek letters again parameters. The primal of (A.2) is Cobb-

Douglas, $\ln y = -(\beta_q \ln \beta_q + \beta_w \ln \beta_w) + \beta_w \ln l + \beta_q \ln z$. The price index, q , is defined by

$$q = \left(\sum_k q_k^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad \sigma > 1, \quad (\text{A.3})$$

where q_k is the price paid for input k , and σ is the elasticity of substitution between any pair of inputs. Using (A.3), I assume a finite number of inputs so large that the integer constraint is not binding. Defining z as a quantity index of intermediates and z_k as the quantity of input k , the primal of (A.3) is the CES function,

$$z = \left(\sum_k z_k^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}.$$

¹⁵ See Deaton and Muellbauer, 1980a, pp. 144-45.

This technology has several well known attractive properties: a) The cost function is separable in w and q , b) costs decrease when the number of inputs from the non-basic sector increases, and c) no input from the non-basic sector is essential. Property a) implies that the cost minimising firm may proceed in two steps: First, it may choose how much labour, l , and aggregate input, z , to use conditional on any output level, y . Second, conditional on the optimal level of z , it may choose how much to use of the different inputs from the non-basic sector, z_k . Property b) means that increased specialisation in the non-basic sector rather than subdivision of labour within a single firm, raises productivity.¹⁶ Property c) implies that the degree of specialisation within any region is endogenous.

Applying Shephard's lemma to the two steps, from (A.2) we obtain the cost shares for l and z ,

$$\begin{aligned} wl / c &= \beta_w \\ qz / c &= \beta_q \end{aligned} \tag{A.4}$$

Hence, the ratio of the wage bill to the cost of intermediates, wl / qz , is constant and equal to β_w / β_q . The larger β_q is, the more important are intermediates for production costs in the basic sector and the stronger is the effect of increased specialisation in the non-basic sector.

From (A.3) we obtain sub cost shares

$$q_k z_k / q = (q_k / q)^{1-\sigma} \quad \forall k. \tag{A.5}$$

We may write (A.5) as $-\ln z_k = \sigma(\ln q_k - \ln q)$ for any k , including $k=s$. Differentiating logarithmically w.r.t. q_s , we obtain the demand elasticity,

$$\varepsilon \equiv \frac{d(-\ln z_s)}{d \ln q_s} = \sigma \left(1 - \frac{q_s z_s}{q} \right). \tag{A.6}$$

¹⁶ This point has been emphasised in the regional context by Nicholas Kaldor (1970, p. 340):

“To explain why certain regions have become highly industrialised, while others have not we must introduce quite different kinds of considerations – what Myrdal (1957) called the principle of ‘circular and cumulative causation’. This is nothing else but the existence of increasing returns to scale – using that term in the broadest sense – in processing activities. These are not just the economies of large-scale production, commonly considered, but the cumulative advantages accruing from the growth of industry itself – the development of skill and know-how; the opportunities for easy communication of ideas and experience; the opportunity of ever-increasing differentiation of processes and of specialisation in human activities. As Allyn Young (1928) pointed out in a famous paper, Adam Smith’s principle of the ‘division of labour’ operates through the constant sub-division of industries, the emergence of new kinds of specialised firms, of steadily increasing differentiation – more than through the expansion in the size of the individual plant or the individual firm.”

When specialisation increases, the sub cost share for input s goes to zero and the demand elasticity is simply equal to the elasticity of substitution.

A.3. The non-basic sector

The non-basic sector, the A sector, is also assumed to consist of firms with identical technology, but this time increasing returns to scale internal to the firms because of set up costs. The cost function for firm k is written,

$$b_k = (z_k \zeta_1 + \zeta_0) \nu \quad (\text{A.7})$$

Here, b_k is total costs and ν is the producer wage rate prevailing in the non-basic sector. The primal to (A.7) is

$z_k = (m_k - \zeta_0) / \zeta_1$, where m_k is labour input. Marginal cost is $\zeta_1 \nu$ and the set up cost is $\zeta_0 \nu$. With internal economies of scale, there must be some kind of imperfect competition to obtain market equilibrium. Following most of the literature in the new economic geography tradition, let us assume that market structure is monopolistic competition. The first order condition for profit maximising is

$$q_k (1 - 1/\varepsilon_k) = \zeta_1 \nu. \quad (\text{A.8})$$

Assuming specialisation is sufficient to substitute σ for ε_k (cf. eq. (A.6)), the profit maximising price for each differentiated product is equal to a constant mark up over marginal cost,

$$q_k = \frac{\sigma}{\sigma - 1} \zeta_1 \nu. \quad (\text{A.9})$$

Monopolistic competition implies that profits vanish in equilibrium,

$$q_k z_k - b_k = 0. \quad (\text{A.10})$$

Since there are no profits, only labour input and intermediates are non-tradable, we note that the cost of intermediates for the basic sector is equal to the wage bill for the non-basic sector, $qz = \nu m$. By (A.4),

$$\nu m / \beta_q = \nu l / \beta_w \quad (\text{A.11})$$

as claimed in the main text.

Substituting for q_k from (A.9) and b_k from (A.7), we obtain the equilibrium output,

$$z_k = \zeta_0 (\sigma - 1) / \zeta_1, \quad (\text{A.12})$$

and labour input,

$$m_k = \zeta_0 \sigma. \quad (\text{A.13})$$

Full employment means that

$$m = \zeta_0 \sigma n \quad (\text{A.14})$$

where n is the number of firms. Since B sector productivity rises when the number of intermediate inputs rise and there is internal economies of scale, the number of firms is also equal to the number of products since it is not profitable for two firms to produce the same product. Using (A.9) and (A.14), we may rewrite (A.3) logarithmically as

$$\ln q = \frac{1}{1-\sigma} \ln \left(\frac{m}{\zeta_0 \sigma} \right) + \ln \left(\frac{\sigma \zeta_1 v}{\sigma - 1} \right) \quad (\text{A.15})$$

In order to simplify, different normalisations are suggested in the literature. We could, e.g., set ζ_0 and ζ_1 in such a way that $\zeta_1 \equiv 1/\zeta_0 - 1 \equiv \sigma - 1$, and write

$$q_k = \sigma v, \quad z_k = 1/\sigma, \quad m_k = 1 \quad (\text{A.16})$$

This means that we can use m for the number of intermediate inputs. Although this kind of normalisations may prove useful for specific purposes, we should be aware that a change in σ implies an automatic change in the cost parameters and is probably best to avoid when comparative statics and numerical simulation is carried out.¹⁷

A.4. Mill prices

With free entry, mill prices are just sufficient to cover unit production costs in equilibrium,

$$\ln p = \beta_w \ln w + \beta_q \ln q \quad (\text{A.17})$$

Substituting for $\ln q$ from (A.15), using (A.11), we may express the mill price as a function of the B sector producer wage rate and labour inputs,

$$\ln p = \ln w + \beta_q \ln l + \beta_q \frac{\sigma}{1-\sigma} \ln m + \beta_q \ln z \quad (\text{A.18})$$

where,

$$\ln z = \frac{\sigma}{\sigma-1} \ln \sigma - \ln(\sigma-1) - \frac{1}{1-\sigma} \ln \zeta_0 + \ln \zeta_1 + \ln \left(\frac{\beta_q}{1-\beta_q} \right) \quad (\text{A.19})$$

as claimed in the main text.

¹⁷ See Neary (2001), p.549, for other critical remarks on the use of normalisations in the new economic geography literature

A.5. Equilibrium with Cobb-Douglas preferences

Let us first consider market clearing based on aggregate demand systems consistent with individual Cobb-Douglas preferences and homogeneous consumers in the sense that everybody is using the same expenditure share on imports from either source, say α_F , and the same share on home made, α_H . For adding up to hold, this means that $\alpha_H = 1 - 2\alpha_F$. It is reasonable to assume that expenditures on home made at least match expenditures on imports from either other source, so we restrict the discussion to $\alpha_H \geq \alpha_F$. When adding up holds, this means that $\alpha_F \leq 1/3$.

In order to simplify, we will throughout assume symmetrical transport costs, $\tau_{ij} = \tau_{ji}$, that transport costs between region s and the two other regions are equal and smaller than between n and u , $\tau_L \equiv \tau_{nu} > \tau_{su} = \tau_{ns} \equiv \tau_S$, and ignore domestic distribution costs, $\tau_{ii} = 1$. It is convenient to denote τ_S / τ_L by τ .

Consider the following equation system,

$$\frac{w_n l_n}{\beta_w} \left[1 - \alpha_H \left(\frac{\beta_q}{t_{nA}} + \frac{\beta_w}{t_{nB}} \right) \right] = \frac{w_s l_s \alpha_F}{\beta_w t_s} + r_u \alpha_F, \quad (\text{A.20})$$

$$\frac{w_s l_s}{\beta_w t_s} (t_s - \alpha_H) = \frac{w_n l_n \alpha_F}{\beta_w} \left(\frac{\beta_q}{t_{nA}} + \frac{\beta_w}{t_{nB}} \right) + r_u \alpha_F, \quad (\text{A.21})$$

$$\frac{w_n l_n}{\beta_w} \left[\left(\frac{\beta_q}{t_{nA}} + \frac{\beta_w}{t_{nB}} \right) - 1 \right] = \frac{w_s l_s \alpha_F}{\beta_w t_s} (t_s - 1), \quad (\text{A.22})$$

$$\frac{w_n l_n}{m_n t_{nA}} = \frac{w_s l_s}{m_s t_s} \frac{cpi_n}{cpi_s}, \quad (\text{A.23})$$

$$\frac{w_n}{t_{nB}} = \frac{w_s}{t_s} \frac{cpi_n}{cpi_s}, \quad (\text{A.24})$$

$$\frac{cpi_n}{cpi_s} = \left(\frac{1}{\tau} \right)^{\alpha_F} \left(\frac{w_n}{w_s} \left(\frac{l_n}{l_s} \right)^{\beta_q} \left(\frac{m_n}{m_s} \right)^{\sigma \beta_q (1-\sigma)} \right)^{\alpha_H - \alpha_F}. \quad (\text{A.25})$$

Equation (A.20) and (A.21) are the market clearing conditions for products made in region n and s , corresponding to (4.1) in the main text. (A.22) corresponds to (4.2), the restriction that tax revenues should be

kept constant. (A.23) and (A.24) are the mobility equilibrium conditions, corresponding to (4.9) and (4.10) (to go from (4.9) to (A.23), use (A.11)). Equation (A.25) is obtained by plain substitution.

Under the Norwegian regime we have that $t_{nA} = t_{nB} = t_n$ and the policy instrument, t_n , is used to obtain a desired level for employment in the basic sector in the periphery, say the symmetric distribution $l_n = l_s = \bar{l} / 2$. Then, for (A.23) and (A.24) to hold, employment in the nonbasic sector must be given by $m_n = m_s = \bar{m} / 2$, and total population equally distributed, so we do indeed have a symmetrical outcome. With symmetry imposed, (A.23) is identical to (A.24), so we may ignore (A.23). Substituting from (A.25) in (A.24), the system is reduced to 4 equations. Furthermore, we may use (A.20) and (A.21) to obtain,

$$\frac{w_n}{w_s} [1 - (1 - 3\alpha_F) / t_n] = 1 - (1 - 3\alpha_F) / t_s. \quad (\text{A.26})$$

Equation (A.22) can be rewritten as

$$\frac{w_n}{w_s} (1 / t_n - 1) = 1 - 1 / t_s, \quad (\text{A.27})$$

and (A.24),

$$\left(\frac{w_n}{w_s} \right)^{3\alpha_F} = \frac{t_n}{t_s} \left(\frac{1}{\tau} \right)^{\alpha_F}. \quad (\text{A.28})$$

The reduced system (A.26) – (A.28) can in principle be used to solve for w_n / w_s , t_n and t_s . First we may notice that if there is no locational disadvantage for the periphery ($\tau = 1$), wage rates are equal and laissez-faire prevails regardless of expenditure shares ($w_n / w_s = t_n = t_s = 1$) which of course is what we would expect from an intuitive point of view. When there is a disadvantage ($\tau < 1$), we notice that if we move towards autarky ($\alpha_F \rightarrow 0$), the right side of (A.26) becomes equal to the right side of (A.27) whereas the left sides take on different signs. Hence, the only possibility is that both sides equal zero, which is true when there is no taxation ($t_n = t_s = 1$). Then, the regional wage rates are independent (w_n / w_s can take any value). If we move towards more openness, eventually with equal shares on home made and imports ($\alpha_F = 1/3$), equation (A.26) implies that $w_n / w_s = 1$. Substituting into (A.27) and (A.28) and solving, we get

$$t_n = \frac{1 + \tau^{1/3}}{2},$$

$$t_s = \frac{1 + \tau^{-1/3}}{2}.$$

This is a very special case, however, since it implies that the relative price level given by (A.25) is equal to $(1/\tau)^{\alpha_F}$ whatever the distribution of employment is and whatever the relative wage rate is. Since changes in industry structure would have to work on the core-periphery structure through the relative price level, and the relative price level here is independent of industry structure, there is no endogenous core-periphery mechanism and we could have done without the vertical industry structure since it does not add anything interesting to the model. However, this is very different when we consider intermediate cases between autarky and maximum openness.

Use (A.26) and (A.27) to cancel out w_n/w_s and solve for t_s conditional on t_n . Substitute for t_s in (A.27) and solve for w_n/w_s conditional on t_n . Substitute for w_n/w_s in (A.28) and define $m/n \equiv 3\alpha_F$, where m and n are integers with m less than n when α_F is less than $1/3$. We may then write,

$$t_n^{n-m} [m + 2n(t_n - 1)]^n - m^m [m + (2n - m)(t_n - 1)]^{n-m} \tau^{m/3} = 0. \quad (\text{A.29})$$

This is an equation of degree $2n-m$. When m is less than n , the equation must be of degree 3 or more. With $m=1$ and $n=2$, corresponding to $\alpha_F = 1/6$, we have a cubic equation. With $m=2$ and $n=3$, corresponding to $\alpha_F = 2/9$, we have a quartic equation. As shown by Abel in 1823, there is no algorithm for solving general algebraic equations of degrees higher than four, using radicals and arithmetic operations. Hence, it is possible to find the solution to the system for $\alpha_F = 1/6$ and $\alpha_F = 2/9$, but not the general solution for any permitted value of α_F .¹⁸ We are therefore content to look at the two cases and study the qualitative behaviour of the system.

For $\alpha_F = 1/6$, equation (A.29) can be written

$$t_n^3 - \frac{3}{2}t_n^2 + \frac{3}{16}(3 - \tau^{1/3})t_n + \frac{1}{8}\tau^{1/3} = 0.$$

Defining $x = t_n - 3/4$ the equation can be transformed into the simpler equation

$$x^3 - \frac{3}{16}\tau^{1/3}x + \frac{1}{32}(1 + \tau^{1/3}) = 0.$$

¹⁸ This is strictly speaking incorrect, since Abel's non-existence result only pertains to algorithms based on radicals and elementary arithmetic operations. For solutions of algebraic equations of higher degrees using modular functions, the reader is referred to King (1996).

The discriminant of the equation is positive, so we know there is one real root (and two complex roots).¹⁹

Substituting $t_n - 3/4$ for x in the solution, we obtain

$$t_n = \frac{1}{2} + \frac{1}{4} \left(-1 + \sqrt{-\tau^{1/3} - 2\tau^{2/3} - \tau - \tau^{1/3}} \right)^{1/3} + \frac{1 + \tau^{1/3}}{4 \left(-1 + \sqrt{-\tau^{1/3} - 2\tau^{2/3} - \tau - \tau^{1/3}} \right)^{1/3}}$$

For $\alpha_F = 2/9$, equation (A.29) can be written

$$t_n^4 - 2t_n^3 + \frac{4}{3}t_n^2 - \frac{2}{27}(4 + \tau^{2/3})t_n + \frac{1}{27}\tau^{2/3} = 0.$$

Transforming the quartic equation into a cubic, the Cardano formula can again be used to obtain

$$t_n = \frac{1}{2} + \frac{1}{2} \sqrt{\frac{2}{9} + \frac{3 \left(-\frac{8}{3} - \frac{8}{27} (-8 - 2\tau^{2/3}) \right)}{4 \sqrt{1 + 2^{2/3} (-1 + \tau^{2/3})^{1/3} \tau^{2/9}}} - \frac{1}{9} 2^{2/3} (-1 + \tau^{2/3})^{1/3} \tau^{2/9}} + \frac{1}{6} \sqrt{1 + 2^{2/3} (-1 + \tau^{2/3})^{1/3} \tau^{2/9}}$$

It may be instructive to compare graphically the solutions for t_n with ($\alpha_F = 1/6$ and $\alpha_F = 2/9$) and without ($\alpha_F = 1/3$) the endogeneous core-periphery mechanism. The solutions are plotted in Figure A.1.

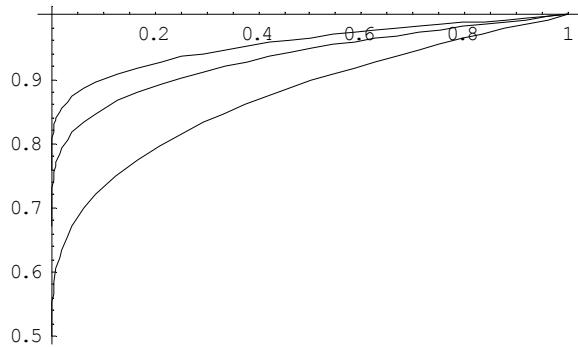


Figure A.1. Regional subsidies compensating for locational disadvantage.

Note: The payroll tax rate in the north along the vertical axis and the locational disadvantage parameter, τ , along the horizontal axis.

The more open the economy is (α_F large), the larger the necessary subsidy (small t_n) has to be in order to maintain the symmetric population equilibrium. The figure also suggests that the curvature, reflecting the elasticity of substitution between subsidies and disadvantage, is more pronounced the more closed the economy

¹⁹ See Sydsæther (1981), p.54.

is. Hence, it appears to be relatively more demanding in terms of transfers to compensate a deterioration in relative transport costs, the more closed the economy is.

In principle, we could now proceed by solving for the other endogenous variables. However, it is clear that the algebra at best would be messy, possibly without providing interpretable results. This lead based on closed form solutions is therefore left for future research. Here, we continue based on numerical methods that also allows for more general preferences.

A.5. Equilibrium

Without mobility, it is straightforward to solve the model as suggested in the main text. The aggregate income equations for region n and s , are

$$r_n = \frac{\alpha_{nn}}{t_n - \alpha_{nn}} r_s + \frac{\alpha_{nu}}{t_n - \alpha_{nn}} \frac{\bar{l}_u}{\beta_w} + \frac{1}{t_n - \alpha_{nn}} \sum_j \gamma_{nj} (m_j + l_j) \quad (\text{A.20})$$

$$r_s = \frac{t_n - 1 + \alpha_{sn}}{1 - \alpha_{ss}} r_n + \frac{\alpha_{su}}{1 - \alpha_{ss}} \frac{\bar{l}_u}{\beta_w} + \frac{1}{1 - \alpha_{ss}} \sum_j \gamma_{sj} (m_j + l_j) \quad (\text{A.21})$$

Solving for aggregate income in n , we get

$$r_n = \frac{1 - \alpha_{ss}}{(1 - \alpha_s)(t_n - \alpha_{nn}) - \alpha_{ns}(t_n + \alpha_{sn} - 1)} \left[\left(\frac{\alpha_{ns}\alpha_{su}}{1 - \alpha_{ss}} + \alpha_{nu} \right) \frac{\bar{l}_u}{\beta_w} + \frac{\alpha_{ns}}{1 - \alpha_{ss}} \sum_j \gamma_{sj} (m_j + l_j) + \sum_j \gamma_{nj} (m_j + l_j) \right] \quad (\text{A.22})$$

The solution for aggregate income in s is even longer on terms and therefore left out.

The illustration and the numerical computations used in the main text are based on the following set of numerical values: set $\gamma \equiv 1/10$ and let $\gamma_{ii} \equiv \gamma$ and $\gamma_{ij} \equiv -\gamma/2$ for all i,j . Set $\beta_w = \beta_q$ and all α_{ij} equal, i.e. all Engel curves are assumed to have the same slope. Set $\bar{m}_u \equiv \bar{l}_u \equiv 1$, $\bar{m} \equiv 2\bar{m}_u$ and $\bar{l} \equiv 2\bar{l}_u$, and let $m_i = l_i$ for all i .

Then, (A.20) and (A.21) are simply

$$r_n = \frac{1}{3t_n - 1} r_s + \frac{2}{3t_n - 1} \quad (\text{A.23})$$

$$r_s = \frac{3 - 2t_n}{2t_n} r_n + 1 \quad (\text{A.24})$$

and the solutions conditional on t_n

$$r_n = \frac{2t_n}{t_n(3t_n-1)-1} \quad (\text{A.25})$$

$$r_s = \frac{2(t_n(t_n-1)+1)}{2t_n^2-1} \quad (\text{A.26})$$

For the computation of real income, set $\sigma = 2$ and use the normalisations (A.16). Also, assume symmetrical transport costs, $\tau_{ij} = \tau_{ji}$, assume that $\tau_L \equiv \tau_{nu} > \tau_{su} = \tau_{ns} \equiv \tau_s$, and ignore domestic distribution costs, $\tau_{ii} = 1$. Set $\tau_L \equiv 3/2$ and $\tau_s \equiv 5/4$ which means that transport costs between u and n equal half the price f.o.b. while the transport costs to and from region s equal a quarter.

We may express (A.20) and (A.21) using the producer wage rates, rather than aggregate income. Since

$$r_n = \frac{w_n l_n}{\beta_w t_n}, \quad r_s = \frac{w_s l_s}{\beta_w t_s} \text{ and } r_n(1-t_n) = r_s(t_s-1), \text{ we have } r_n = \frac{l_n}{\beta_w t_n} w_n \text{ and } r_s = \frac{l_s}{\beta_w} w_s - \frac{(1-t_n)l_n}{\beta_w} w_n. \text{ Substituting}$$

in (A.20) and (A.21), we obtain the wage equations, illustrated in Figure 1 in the main text,

$$w_n = \frac{t_n}{l_n(t_n - \alpha_{nn} + t_n \alpha_{nn} - t_n^2 \alpha_{nn})} \left[\alpha_{nn} l_s w_s + \alpha_{nu} \bar{l}_u + \beta_w (t_n - \alpha_{nn}) \sum_j \gamma_{nj} (m_j + l_j) \right] \quad (\text{A.27})$$

$$w_s = \frac{1}{l_s(1-\alpha_{ss})} \left[((1-t_n)(1-\alpha_{ss})t_n + t_n - 1 + \alpha_{sn}) l_n w_n + \alpha_{su} \bar{l}_u + \beta_w \sum_j \gamma_{sj} (m_j + l_j) \right] \quad (\text{A.28})$$

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