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Are social welfare states facing a race to the bottom? A theoretical perspective

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Voorwoord

Toen ik in 2003 aan de UGent afzwaaide als ´burgerlijk ingenieur in de natuurkunde’ had ik nooit kunnen bevroeden dat ik nu, 5 jaar later, het waarschijnlijk meest gelezen deel van mijn proefschrift in de economische wetenschappen mocht schrijven. Gods wegen lijken soms ondoorgrondelijk. Gelukkig kan ik – op het risico af de meer godsvrezende medemens te schofferen – enige verlichting brengen in deze transformatie. Het is immers een gradueel en heel logisch proces geweest (ex post dan toch) waarvan de eerste stap gezet werd in 2004 met het voltooien van de aanvullende opleiding in de bedrijfseconomie aan de UGent. Voor de tweede stap moest ik al iets verder gaan, helemaal naar Leuven namelijk, om er in 2005 de titel van Master of Science in Economics te verkrijgen. Hiermee dacht ik helemaal voorbereid te zijn, maar desalniettemin had ik de indruk dat – en ook al hadden meer ervaren mensen me gewaarschuwd voor dit idiosyncratisch risico – die laatste doctorale stap soms meer weg had van een processie van Echternach. Gelukkig kon ik, om de christelijke geïnspireerde literaire overdrijving niet te verlaten, tijdens deze Calvarieweg op heel wat steun rekenen. Deze mensen wil ik dan ook hier bedanken.

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Bert Vanbergen

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Niet-technische Nederlandse samenvatting

Vanaf de eerste stappen in het Europees eenmakingproces leefde de bezorgdheid dat verdere economische integratie gepaard zou gaan met negatieve sociale effecten en een potentiële afkalving van de welvaartsstaat. De recente totstandkoming en uitbreiding van de Europese Unie waarin het handels- en monetaire beleid onder strakke controle staan, maakt deze vrees nog virulenter. Dit proefschrift wil een theoretische bijdrage leveren tot de discussie of globalisering een risico inhoudt voor onze sociale welvaartsstaat.

De dominante stroming binnen de huidige literatuur focust op belastingsconcurrentie voor mobiel kapitaal en argumenteert dat er te weinig publieke goederen voorzien worden van zodra deze productiefactor niet de begunstigde is van de belastingen en wanneer het deze (bron)belastingen kan ontwijken (door migratie). Recente bijdragen in de Nieuw Economische Geografie (NEG) literatuur proberen deze resultaten te plaatsen in een spatiaal kader.

Het model dat in deze dissertatie ontwikkeld wordt, is ingebed in dit NEG-kader. Op die manier kunnen we globalisering niet enkel modelleren via de mobiliteit van een productiefactor (in casu kapitaal) zoals in de standaard modellen van belastingsconcurrentie, maar zijn we ook in staat om te kijken wat de effecten zijn van goederenmobiliteit en handel op belastingsconcurrentie. Gezien de zwaardere belasting op arbeid dan op kapitaal in de Europese context, richten we ons ook op situaties waar er uitsluitend belastingen geheven worden op (immobiele) arbeid. Ten slotte introduceren we een overheid die op basis van een Atkinson verkorte sociale welvaartsfunctie een werkloosheidsuitkering voorziet als verzekering tegen het sociaal risico van werkloosheid. Dit laatste creëren we endogeen via efficiency wages. De introductie van een

herverdelende overheid in plaats van een algemeen publiek goed, maakt dat dit model beter in staat is om sociale zekerheidsconcurrentie te bestuderen.

We starten onze analyse met de meest eenvoudige situatie, nl. autarkie. Deze referentiesituatie laat ons toe om de belangrijkste mechanismen waarlangs de overheid de optimale werkloosheidsuitkering bepaalt, te kenschetsen. Bovendien illustreert dit geval ook de positieve invloed van de ongelijkheidaversie van de overheid op de belastingvoet.

Vervolgens onderzoeken we het geval waarbij er enkel interactie is tussen de regio's via goederenhandel. In dit korte termijnevenwicht gedragen de Nash belastingsvoeten zich als strategische complementen die te allen tijde onder het Pareto niveau liggen. Met andere woorden, er is reeds detrimentele belastingsconcurrentie in een situatie zonder enige mobiliteit van een productiefactor. Daarnaast leidt de studie van de afhankelijkheid van de handelsvrijheid op het Nash evenwicht tot een tweede bijdrage aan de bestaande literatuur, nl. toenemende globalisering leidt tot afnemende belastingsconcurrentie.

Indien we kapitaalmobiliteit toevoegen in de voorgaande context, valt de potentiële positieve invloed van handelsliberalisering op de sociale welvaartsstaat weg. Ook verergert de neerwaartse druk op de welvaartsstaat in een intern locationeel evenwicht als we de vergelijking maken met de situatie zonder kapitaalmobiliteit. Ten slotte kunnen we het Baldwin&Krugman resultaat geldig in een kern-periferie situatie conditioneren op de ongelijkheidaversie van de overheid. Kernregio's kunnen hun agglomeratieopbrengsten blijven belasten zonder vrees voor delokalisatie maar dit subgame-perfect evenwicht wijkt steeds verder af van het door de overheid gewenste niveau van sociale voorzieningen naarmate de overheid meer geeft om ongelijkheid. Het model voorspelt dus dat kernregio's veel meer te vrezen hebben van andere kernregio's dan van perifere regio's. Met andere woorden belastingsconcurrentie speelt zich voornamelijk af tussen gelijken in de blue banana in Europe dan tussen vb. West- en Oost-Europa.

Buiten deze analyse van sociale zekerheidsconcurrentie bevat deze dissertatie ook twee meer theoretische bijdragen over NEG-modellering zelf. Naast een onderzoek van de dynamica van de meeste gebruikte NEG-modellen, combineert het ontwikkelde model ook twee tot nu toe onverzoenbare eigenschappen van dit soort modellen, nl. analytische eenvoud en rijkdom aan eigenschappen.

Chapter 1

Introduction

From its earliest stages in the 1950s, every step in European economic integration appears to have been met with concern about its potential negative social effects, particularly as regards protection against social risks (unemployment, sickness and invalidity, age, etc.) and poverty. This fear lead to many attempts of the European authorities to promote social convergence.

In the beginning of the European integration process, with the signing of the Treaty of Rome in 1957, the dominant opinion of the Member States was written down in article 117 of the Rome Treaty which founded the social policy of the Communities:

> *Member States agree upon the need to promote improved working conditions and an improved standard of living for workers, so as to make possible their harmonisation while the improvement is being maintained. They believe that such a development will ensure not only from the functioning of the common market, which will favour the harmonisation of social systems, but also from the procedures provided for in this Treaty and from the approximation of provisions laid down by law, regulation or administrative action.*

On the one hand this article stipulates that the common market and the provisions of the Treaty concerning the removal of barriers to trade and factor mobility would stimulate growth, spurred by economic integration. Social convergence, the harmonisation of national social security schemes would follow from economic convergence, i.e. convergence in economic productivity and efficiency. This confidence that cross-country differences in labour and wage conditions only stem from productivity differences was high but not complete since, on the other hand, the same article also stated that the Member States recognised the necessity of the improvement of the living standard and labour conditions. Why was such recognition necessary if the Member States were convinced of spontaneous income convergence? Some of the following specific articles on social matters in the Treaty, namely article 119 and 120 regarding the equal treatment of men and women and on paid holidays, affirm the less than complete confidence in the market forces of the Member States. However, article 118 of the EEC Treaty gave the Commission only a modest function on social policy (issuing reports, organising consultations, formulating recommendations, etc.). Undoubtedly the limited function of the Commission with respect to social policy was prompted by the immanent fear of the Member States that they would lose their sovereignty. Hence, much compelling initiative from the Commission was not expected.

In 1974, the European Commission noted that the common market program indeed had spurred economic growth, yet without bringing a solution to the social problems of the Community, which in some cases even had increased. The Commission referred to regions or parts of the population that didn't benefit duly from global economic progress (Commission, [33]). The Commission proposed the Council a more voluntary social policy with three objectives, the Social Action Programme:

- Full employment at regional, national and community level;
- Worker's participation at firm and Community level;
- Improvement of working and living conditions.

The Social Action Programme was motivated by the idea that the European Community had also a political and social dimension and was intended to be "more" than a common market.

> *The insistence that the community was fundamentally a social and political organisation, rather than simply an economic one, which could not tolerate disparities 'unjustifiable in moral terms and which were anti the principle of Community solidarity which is the base of the European Community idea', was the guiding motive behind the attempt to establish a social policy designed not only to remove inequalities*

but to raise the standard of living, unify social systems and pay particular attention to the social conditions of impoverished regions. (Collins [32], p.160).

The Social Action Programme was not a complete success. Some important directives were accepted, mainly regarding equal opportunities, health and safety. But the latter two were never seriously contested and the first concerned individual rights that prevail on national laws and of which application may be enforced by the European Court of Justice. Taking a 'Community-friendly' interpretation of the articles of the Treaty with respect to discrimination contributed considerably to the success of the Social Action Programme. Accomplishments in other fields were far more modest: either the directives were weakened to the point to become irrelevant (like collective lay-offs, see e.g. Vogel-Polsky in [103]) or they were neutralised when implemented in national laws.

Another way to tackle social welfare state competition lies in promoting fiscal co-ordination to harmonise the income side of social security systems instead of the expenditure size. Like in social protection, national vetoes against any change prohibited the realisation of many ambitious goals of the Commission. The only exception to this was the guidelines concerning VAT. There was rather rapidly a consensus that the free mobility of goods (and services) required co-ordination of the VAT-levels which was achieved on a European level in 1977. All direct taxation policies remained the exclusive competence of the Member States.

The fear for a race to the bottom in social security protection became even more apparent with the signing of the first mayor change to the founding treaties, namely the Single European Act at the Luxembourg summit on December 3, 1985. This treaty aimed at further accelerating European integration by introducing qualified majority voting in the field of the internal market. At the same time, a date for the completion of the internal market was set as January 1, 1993. The Commission believed that, in the absence of minimum harmonisation of social policy, Member States or firms might try — in an increasingly unified Europe — to achieve a competitive advantage through 'social downscaling'. This would inevitably lead to social dumping and of the infringement of basic social rights. That's why the commission headed by Jacques Delors took the initiative in 1987 to launch the Social Charter which was passed by the European Council in Strasbourg in 1989 by all members except Great Britain[1]. Contrary to the

[1] It took another decade before Great Britain could accept this soccle of basic social rights. This happened at

Social Action program where one aimed at a social harmonisation at the Community level, the Commission became more political realistically and limited its proposal to a 'soccle' of social rights, enforceable in every Member State. For instance, the Social Charter established the right to belong to a trade union, the right to paid annual leave and a weekly rest period. These and the other rights were acceptable to the overwhelming majority of the Member States. In this way the Commission hoped to ensure that social progress remained in line with economic growth and second, to avert unfair competition (Commission, [34]).

Although the Single European Act stated clearly that measures on fiscal matters required unanimity to be approved, the Commission Delors attempted to extend the application of the qualified majority voting in the field of the internal market to fiscal matters by propagating a market distortion approach of fiscal policies. The commission argued that, if there are as many (capital) taxation regimes as Member States in the European Union, investment decisions can be distorted by rent seeking fiscal optimisation that doesn't improve economic efficiency. This could lead to a shift in the tax burden to the immobile production factors, labour in particular. Based on this argument the Commission obtained the approval by the Council of the merger guideline and the parent-affiliate company guideline. However, the 'market distortions approach' did not enable much progress as regards European co-ordination of others issues of capital and corporate taxation.

The Treaty on the European Union, that was signed in Maastricht on February 7, 1992, meant a new step in the European unification process since it created the European Economic and Monetary Union with the introduction of the euro in 1999 as the most visible result. Just as the Single European Act revived the concerns about the potential negative social effects, the Maastricht Treaty had the same effect: the introduction of the EMU means that the use or menace of 'beggar-thy-neighbour' policies by means of income or social security measures becomes even more tempting because other economic policy instruments such as trade policy or monetary policy are kept under tight control. A further step in fiscal co-ordination had to be taken, this time by commissioner Monti in 1996. He succeeded in reaching two new decisions, based on the same harmful tax competition argument as before, regarding fiscal co-ordination. First, the phasing out of the special tax treatments and, second, the savings guideline were

the Summit of Amsterdam in 1997 where the Social Agreement was incorporated into the text of the EC Treaty.

agreed upon. The latter ensured — although there are still a lot of exceptions — that all rewards to capital were fully declared in the country of origin of the capital owner. For the first, the Commission imposed its view of special tax treatments as public aid and obtained its phasing-out by threatening to charge the Member States before the European Court of Justice for infringement of the Treaty agreements on state subsidies. The agreement on the savings guideline was eventually reached with its unanimously approval by all the Member States and entered into force on July 1, 2005.

In recent times the Member States and the Commission changed tack. Instead of focussing on a harmonisation of the social policies at the community level or even providing a larger soccle of social rights, one now tries to increase the affordability of the social security system by promoting 'activation' and the 'modernisation' of the social welfare state:

> *..the 1997 Treaty of Amsterdam went back on this divergence [the separation between economic and social questions and the sovereignty on social policy of the member States] with its Title on Employment (Title VIII). This was the beginning of the Luxembourg process, which explicitly aims to "modernize" social protection systems in order to eliminate the disincentives to work. It set out employment guidelines which place employability at the heart of the European Employment Strategy (EES). The Social Agenda adopted by the European Council in Nice in 2000 made this one of its priorities, since confirmed for the period 2005-2008.*
>
> *... "Modernization", "activation", "contractualization", "employability" and individual "responsibility" are the key words." (Zimmermann [145], p.36)*

This strategy of activation and modernisation must be distinguished from the Anglo-Saxon workfare approach based on the principle of individual responsibility and which forces the poor into badly paid jobs (Euzéby, [48]). The continental approach also encompasses redistribution and insurance. For instance, the Commission Barroso proposed a European Globalisation Fund with an annual budget of 500 million Euros aimed at facilitating the return to gainful activity of the EU workforce. It provides amongst others time-limited job-search allowances and assistance for workers that suffered from the profound changes of globalisation.

All these renewed attempts to mitigate the tensions between an almost complete economic integration and the social welfare state were found to be inadequate or insufficient for the Dutch and French voters who rejected the EU Constitution. The Eurobarometer ([46], [47]) lists among the top reasons given by the voters for their rejection 'loss of jobs' (31%) and 'not enough social Europe' (16%). This indicates that even today — after half a century of European integration — people remain fearful over a potential race to the bottom in social welfare states. In this work we will try to assess whether this fear is justified, mainly from a theoretical point of view.

In order to define this research question more specific, we start by elucidating the difference between tax competition and social security competition. Tax competition is a form of systems competition where the government's tax setting capabilities are limited because of globalisation. So the two defining characteristics of tax competition are the tax setting of a government and the externalities arisen from globalisation. Globalisation is defined in models as the mobility of goods, firms and/or factors of production. Expenditure competition can be seen as the other side of the same coin. If regions are limited in their tax setting due to globalisation externalities, they are also limited in the scope of social protection schemes under constant preferences. Social security competition has a third defining characteristic, namely a government that provides a social insurance against some risks or — otherwise formulated — a government that redistributes between different groups in society. This redistribution will, contrary to the provision of a general public good or an ad-hoc general redistribution between different groups in society, profoundly affect the globalisation forces in play.

We begin our analysis with a review of the literature. I turns out there have hardly been any attempts to model social security competition. However, there does exist a large literature concerning (capital) tax competition, thus without the inclusion of a social risk, that can serve as a benchmark. Historically most models in this literature focussed on only one dimension of globalisation, namely capital mobility. More recently some models (also) based on labour mobility have been developed. An interesting ramification in this literature concerns models where governments don't provide a general public good with the raised taxes but where they have redistributive aims. These 'welfare state competition' models closely resemble social security competition with the exception of the inclusion of a social risk. The dominant strand in these papers emphasizes a severe race to the bottom. The different strands of the tax competition literature are discussed in chapter 3.

In recent years a new interest in location arose in economic literature with the development of a whole range of 'new economic geography' models. These models are 'lumpy' by their very nature and this casts new light on the conclusions made based on the standard tax competition literature. We discuss the main set-up of these models and their most important characteristics. As an important side-step (but also a way to better understand the new economic geography models) we look at the — hitherto — neglected dynamics of these models. We show that the modelling set-up greatly influences the transitional behaviour of the models. This allows us to make some cautious remarks regarding policy implications. We end this chapter by looking at some recent (capital) tax competition contributions in the new economic geography framework. Contrary to the standard tax competition models, the new economic geography tax competition models have two dimension of globalisation namely goods and factor of production mobility. However, the tax competition in these models remains based on the mobility of capital or labour, not on the goods mobility. In essence, these models indicate that locationally symmetric regions end up with suboptimal low taxes while core regions are able to tax the agglomeration rents without incurring any loss of economic activity. By combining the conclusions based on these richer models and the standard tax competition literature, we are able to indicate four different policy points of view.

In chapter 4 we motivate the main assumptions of the social security competition model developed in this dissertation. In the subsequent chapters we discuss an autarkic situation, a situation where the only dimension of globalisation consists in the trade of goods and a model where there is social security competition in a framework of capital and goods mobility. This allows us not only to see whether tax competition can occur without capital and/or labour mobility but also we are investigating if we can falsify the standard tax competition models. In the final chapter we draw some conclusions and give some suggestions for further research.

Chapter 2

A review of the tax competition literature

2.1 Tiebout: a perfect world

The first strand of the literature starts with Tiebout ([128]). Although his paper was primarily intended to solve the public finance problem of Samuelson and Musgrave[1], it is now considered as the first mayor work on tax competition. In his model consumers are fully mobile and move to the region with a public good level that best satisfies their preferences. The public goods are paid for by a source-based head tax. Due to some fixed resources (e.g. land size) every region has an optimal size where the average cost to provide the public good is lowest. The more regions are allowed in this set-up, the closer the market degree of satisfaction is attained by the public good provision. There is full efficiency in infinitum: people reveal their true preferences by voting with their feet.

To attain this result Tiebout made abstraction of any imperfection. For instance, he excluded any information imperfections by assuming that all consumers had perfect knowledge on regional revenues and expenditures. He also avoided any labour market problems by asserting that everybody lived on dividend incomes.

The original formulation of this model lacked a rationale for the governments. Nowadays

[1] They claimed that there doesn't exist a market type solution to determine the level of expenditures on public goods ([115], [90]). This would mean that a large portion of the GDP would be allocated in a non-optimal way.

it is often assumed that each region's government is controlled by its landowners who want to maximize their after-tax land value. They do this by attracting people with a certain level of public goods. In this way it is clear that the government in fact plays the role of a firm under perfect competition with the after-tax land value as profits and the public goods serving as prices.

This model can easily be extended to include mobile firms and households (Fischel [50], White [133]). Crucial in these extensions is the fact that the mobile factor continues to derive utility from the public goods each region provides. In the case of mobile firms, regions have to provide public input goods such as infrastructure, a law enforcement system, etc.

It is clear that there is no need in the Tiebout-hypothesis for any form of coordination whatsoever. There is no underprovision of the public good nor a tax setting that is too low.

2.2 The basic tax competition model: need for coordination

2.2.1 The origin of the basic tax competition model

The nowadays dominant strand in the tax competition literature really took off with Oates ([92]). As the first to fully grasp the potential pitfalls of tax competition, he described the problem as follows:

> *The result of tax competition may well be a tendency toward less than efficient levels of output of local services. In an attempt to keep taxes low to attract business investment, local officials may hold spending below those levels for which marginal benefits equal marginal costs, particularly for those programs that do not offer direct benefits to local business.*

As Sinn ([118]) noted, the main argument on which Oates based his view stemmed from MacDougall ([86]) and Richman ([108]). These economists claimed that a small open economy can't have an interest in putting a source tax on international mobile capital because mobile factors would flee from this tax. As a result the domestic production and marginal productivity of the complementary immobile factors would fall. This leads to a decline in income of the immobile factors larger than if they had to pay all the taxes by themselves.

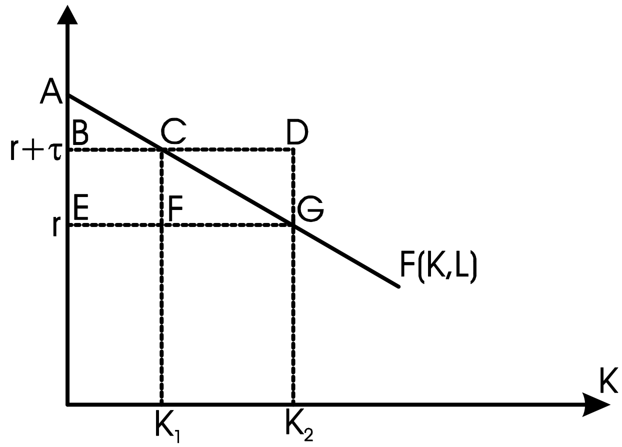

Figure 2-1: Argument of MacDougal and Richman.

Graphically this argument is easily explained. The downward sloping curve on figure 2-1 represents the marginal productivity of capital in an economy that produces under a linearly homogeneous production function and that has a fixed supply of labour. The mobility of capital equalizes the net world market return r. Due to the source-based tax τ on capital, the amount of capital falls from K_2 to K_1 such that the marginal after-tax return to capital is again equal to the world return rate. The tax revenue is equal to BCEF but this amount is smaller than the wage loss the immobile labour incurred (AGE-ABC).

This line of thought lead in the eighties to the first formal models explaining wasteful tax competition. The seminal papers here are Zodrow and Mieszkowski ([144]) and Wilson ([140]). As the model of Wilson is somewhat more complex, we give here the model of Zodrow and Mieszkowski. We refer to this model as the Basic Tax Competition Model (hereafter BTCM).

2.2.2 The model of Zodrow and Mieszkowski

Consider many small regions (N), each with two factors of production: immobile labour[2] L and perfectly mobile capital K. All regions are identical and the residents in each region own an equal share of the labour and capital. As a consequence all national redistributional concerns are omitted in this model. The perfect mobility of capital ensures that all capital earns the

[2] In the original paper of Zodrow and Mieszkowski the immobile factor was land. As the essential part of this factor is his immobility, we replace it by labour as is done in most discussions of this seminal paper.

same return r.

Each Walrasian economy produces the same, homogeneous private good using K and L. This output is traded free of charge, which equalizes the international prices for that good. The utility $u(C,P)$ of each consumer depends on his consumption C of the private good and on the provision of a residential public good P. This public good is provided by the government using a source-based capital tax T and a head tax H on the residents. The benevolent government wants to maximize the consumers' utility taking into account his budget restriction:

$$\begin{aligned} \max_{T,H} \quad u(C,P) = \max_{T,H} \quad & u\left[F(K,L) - (r+T).K + r.\tfrac{K}{N} - H, P\right] \\ s.t. \quad & P = T.K + H \end{aligned} \tag{2.1}$$

Optimisation leads to two first order conditions:

$$FOC(H) \Rightarrow \frac{u_P}{u_C} = 1 \tag{2.2}$$

$$FOC(T) \Rightarrow \frac{u_P}{u_C} = \frac{1}{1 + \frac{T}{K}\frac{dK}{dT}} = \frac{1}{1 + \frac{T}{K}\frac{1}{F_{KK}}} \tag{2.3}$$

The unconstrained equilibrium follows immediately: governments finance the public good solely with the non-distorting head tax H and set the capital tax T equal to zero ($FOC(T)$ is equal to 1). The public good is provided up to the point where the social benefit of higher tax revenues (the marginal rate of substitution between private and public goods $\frac{u_P}{u_C}$) equals one. As a consequence the Samuelson rule for efficient provision of public goods is obeyed.

Things become more interestingly if we exogenously constrain the level of the head tax to be less than the optimal level. The first first order condition drops and the second first order condition will be larger than one because of the negative sign of F_{KK}. In other words, the public good is underprovided ($\frac{u_P}{u_C} > 1$) as soon as governments are limited in their use of head taxes on immobile factor. Total differentiation of equation 2.3 leads to the two remaining main conclusions of the Zodrow and Mieszkowski constrained set-up:

- The less the government can rely on lump-sum labour taxation, the more governments have to rely on capital taxation ($\frac{dT}{dH} < 0$).

- The reduction in the permitted source-based head tax on immobile labour causes a reduction in the provision of the residential public good ($\frac{dP}{dH} > 0$).

As a final remark note that we used the taxes as the optimisation variable in problem 2.1. We could also have taken the public good levels as strategic variables. As could be expected and also proved by Wildasin ([135]) expenditure competition where the tax rates adjust to reflect the chosen budget level leads to the same results as mentioned above.

2.2.3 How can we explain these results?

The best way to understand this model is using some intuitive reasoning (as always). Suppose the government wants a unit increase in the residential public good provision. In the assumption that the government doesn't have the possibility to use head taxes on the immobile labour, she has to increase her capital tax rate by an amount ΔT. This causes a raise[3] in the cost of capital $r + T$. The capital starts to flee the country by an amount ΔK and stops to run away as soon as the marginal productivity of capital has risen enough to compensate for the higher tax rate. At the same time the labour income has to decrease by the same amount as the tax increased because the zero-profit condition of the firms continues to hold in the Walrasian world of the BTCM.

The above reasoning means that the tax rise must be high enough to compensate not only for the cost of the public good itself (marginal cost MC) but also for the loss of tax income ($-T\Delta K$). The optimal level of taxation is where the residents' marginal willingness to pay for another unit of the public good equals their wage reduction ($MC - T\Delta K$). Since the marginal benefit of the public good is higher than its marginal cost in equilibrium, the Samuelson rule is no longer valid and the public good is underprovided.

We are now able to distinguish the two sources of inefficiencies. The first arises because of the increased marginal productivity of capital in the high-tax region. This leads to a world-wide misallocation of capital. The second inefficiency is the suboptimal provision of the public good. These results justify forms of coordination to be implemented. Specific forms of coordination will be discussed in section 3.4.4.

[3] In the BTCM model regions are numerous and small. This means that they can't influence the return rate r.

The cause of these suboptimalities stems from the fact that the government does not account for the positive fiscal externality it entails on the other regions by increasing her tax rate. She does this because she is only concerned with the welfare of her own residents. It is also necessary that the mobile capital has the opportunity to escape a tax it has no benefits from.

2.3 Extensions of the Basic Tax Competition Model: anything becomes possible

In the years following the publication of these seminal papers, a vast literature emerged extending the efficiency results of Zodrow and Mieszkowski in several directions. Some effects discussed in papers not directly linked with the tax competition literature were included in new models.

In our review of the literature we tried to discuss the most important and far reaching extensions of the original Basic Tax Competition Model (hereafter BTCM), besides a short digression on optimal taxation. For other extensions like asymmetric information, commitment problems and double taxations, we refer to the useful surveys of Wilson ([143]), Cremer and Pestieau ([38]) and Fuest, Huber and Mintz ([54]).

2.3.1 The nature of the regions

Large regions.

In the BTCM-model a large number of small regions was introduced. If instead, we assume a more limited number of regions of larger size, the model changes in a fundamental way. Large regions have the market power to influence the after-tax return rate on capital. This means that a tax rise of a region leads to a less than proportional increase of the cost of capital. As a result capital becomes less sensitive to tax changes and the underprovision of public goods is attenuated. This partial capitalisation effect of higher tax rates into the after-tax return on capital is further discussed in Hoyt ([61]).

Asymmetric populated regions.

The original set-up of the BTCM was characterized by perfect symmetry. All regions had the same number of residents and the same capital-to-labour ratio. Both assumptions can be relaxed. The first form of asymmetry is analyzed by Bucovetsky ([26]) and Wilson([141]). These authors show that less populated regions enjoy a higher level of welfare following capital integration and that the small region levies lower taxes. This point of view can be best proved with a reductio ad absurdum.

Suppose that we have two regions with the same tax rate but one region has more residents. Capital mobility ensures the equalization of the after-tax return rate on capital, so the marginal productivity of capital must be the same[4] in both regions. Because the neo-classical production function used in the BTCM only depends on the capital-to-labour ratio, the K/L-ratio also has to be the same in both regions. As a consequence the region with the largest number of inhabitants has to have the largest amount of capital. Due to the partial capitalisation effect mentioned in the paragraph above, the larger region has a cost of capital that is less sensitive to changes in the tax rate. This consideration suggests that the large region will compete less vigorously for capital through tax rate reductions and therefore end up with the higher tax rate. Our initial hypothesis that they have equal tax rates therefore must be incorrect.

Based on this straightforward proof, we define the three aspects of the small region advantage:

- Small countries have lower tax rates than large countries.
- Small countries have a higher capital-to-labour ratio than large countries; there is a negative correlation between tax rates and $\frac{K}{L}$-ratios. Ceteris paribus, small countries have higher per capita incomes.
- Small countries are capital importers; capital should flow from poor to rich countries.

The consequences of the second form of asymmetry are studied by Peralta and van Ypersele ([99]). They show that countries with smaller capital to labour ratios loose from tax competition

[4] $F_K(1-T) = F_{K^*}(1-T^*) \wedge T = T^* \Rightarrow F_K = F_{K^*}$, with T and T^* the tax rates in both countries and with F_K and $F_{K^*}$the marginal productivity of capital in both countries.

following capital mobility. Otherwise said, third world countries have nothing to gain with globalisation.

Both extensions still lead to an underprovision situation where coordination is needed if one would like to attain higher welfare levels.

2.3.2 Multiple tax instruments and optimal taxation literature

In the original set-up of the BTCM the government could choose between a source-based capital tax and a source-based labour head tax. As already explained there is an efficient provision of the public good (but a lot of redistributional concerns) when the public good could be financed using source-based labour tax.

In reality governments often can dispose of more types of taxation. Bucovetsky and Wilson ([28]) investigated this problem. If governments were given the opportunity to levy residence-based taxes, wasteful tax competition would become impossible. The mobile factor can't flee the taxes anymore. Unfortunately administrative and tax compliance problems are often too hard to overcome to implement this form of taxation[5].

Other papers concerning the use of multiple tax instruments often extend the BTCM in several directions. That's why we'll postpone the discussion of these papers (e.g. Cremer and Pestieau ([38]), Richter and Wellisch ([111]), Wilson ([142]), Fuest and Huber ([53])) to the subsequent paragraphs. We hope that this will enhance the understanding of the linkages between the multiple tax instruments and other changes in the set-up of the BTCM made in those models.

The main conclusions one can draw if governments are allowed to use multiple tax instruments are fourfold:

- The use of residence-based taxes would solve the race to the bottom.
- The introduction of multiple tax instruments often leads to an inefficient tax choice by governments.

[5] Some authors (e.g. Lesage ([80])) think that the scope for residence-based taxation is wider than commonly believed.

- The larger the number of tax instruments becomes, the more likely it becomes that the Tiebout result can remain intact.

- It depends on the number and nature of tax instruments if tax coordination is needed from the social planner's point of view.

As soon as one introduces multiple tax instruments that are feasible for a government, the question of defining normative prescriptions for an optimal tax policy becomes relevant. A good survey of this optimal taxation literature can be found in Rosen ([114]), Auerbach and Hines ([5])or Stiglitz ([125]. This literature took off back in the twenties with the Ramsey problem of the optimality of a uniform commodity tax rate ([107]). It turns out that setting the same tax rate for all goods in order not to distort relative goods prices is adequate since one cannot tax leisure. The optimal set of commodity taxes should lead to an equal percentage reduction in the Hicksian demand for all goods[6]. More recent some contributions have been made in this literature concerning an optimal direct taxation scheme. For instance, Stern ([121]) was able to demonstrate that even the most inequality averse governments still shouldn't opt for marginal (linear) income tax rates of 100 percent. Another striking and non-intuitive result has been made by Seade ([116]) who showed that the marginal (non-linear) income tax rate on the highest-income person should be zero.

2.3.3 The nature of the public good

The original model was quite abstract in modelling the task of the government. Zodrow and Mieszkowski introduced a public good beneficial to the immobile residents. In reality the government has more to offer to society. Some aspects of this broader governmental provisional concept have been studied in other papers, although a lot has still to be done.

Public input goods

Some economists claim that public goods can also be beneficial to mobile capital. The consumption public good becomes an input public good, which one can interpret as infrastructure,

[6] When demands for different goods are unrelated, this rule can be simplified to the well-known inverse-elasticity rule stating that tax rates should be inversely proportional to their elasticity of demand.

a judicial system, etc. Social security can also — to a certain extent — be interpreted as a public input good because it helps to preserve social peace in firms which saves costs for capital.

This argument has far-reaching consequences in the BTCM: there is no longer a race to the bottom for the capital taxation. To see this, we look back at figure 2-1. τ now represents the cost of the public input good. If this good is paid for by the immobile residents, the amount of capital remains at K_2 and the labour income drops to AEG-BDEG=ABC-CDG. If on the other hand the mobile factor has to pay for the public good, the capital stock decreases to K_1, capital pays an amount BCEF and the labour income is equal to ABC. This means that the government has no interest in taxing the immobile factor. The mobile factor is willing to pay for the public good because the capital gets something in return. Papers based on this argument are from the hand of Oates and Schwab ([94]), Wellish ([132]) and Oates ([93]). Note that this argument basically is a rephrasing of the Tiebout hypothesis as the beneficiary of the public good is also the payer of the good. Fiscal externalities disappear.

Some researchers investigated this line of thought further by introducing public consumption and public input goods (Keen and Marchand ([65]), Noiset ([91]), Bayindir-Upmann ([12])). They find that the equilibrium pattern of expenditures is inefficiently weighted toward too much public input provision and too little public good provision. This result even holds when the government only cares for the welfare of the immobile residents. We arrive again at a suboptimal provision of the (consumption) public good. This time because these kinds of goods don't attract mobile capital by improving the productivity of capital.

Usage and Congestion costs

Until now we only considered the production cost of the public good. In reality many public (input) goods have usage and congestion costs. Firms pay for the usage costs but don't pay for congestion costs. The government solves this inefficiency by levying a tax equal to the (marginal) congestion externality. The Samuelson rule for public good provision is obeyed.

As regards to the redistributional aspects of the public good provision with usage and congestion costs, one could take two points of view. On the one hand, you could assume that the public good is provided with no scale effects and this assumption will lead to an optimistic assessment of tax competition (see wildasin ([134]), Richter ([109]) and Gerber and

Hewitt ([57])). On the other hand you could follow Bewley ([14]) and Sinn ([118]). They argue that increasing returns to scale in the production of (infrastructure) public goods prevent a competitive equilibrium, since the tax levied by the government and equal to the marginal cost of the public good, is below the average cost. As a result the immobile labourers partially have to pay for the public good provision. Sinn defends his view by stating the Selection Principle: governments have taken over those activities that are not performed well by markets (e.g. non-existence of optimal pricing mechanism as is the case here) and as a consequence introducing competition on those fields won't work.

Public good with spill-over effects

It has longer been known in public finance literature (see e.g. Williams ([139]) and Brainard and Dolbear ([23]) that public goods can have spill-over effects for other regions. Bjorvatn and Schejelderup ([16]) applied this idea in a globalisation context. In this case the Samuleson rule is not followed because the marginal benefits that residents of other regions derive from the provision of the public good aren't included. This leads to a tendency towards underprovision of the public good. Or otherwise said, free-riding behaviour becomes possible. On the other hand these spill-over effects reduce the incentive of the regions to compete for the mobile capital since it becomes irrelevant who has the capital and supplies the public goods. The relative strength of both phenomena determines the equilibrium outcome and is a priori difficult to say.

2.3.4 Introducing mobile labour

Broadly speaking, you could distinguish two ways in which labour could be mobile. In the first case the mobile labour also benefits from the public good in the other region (source-based public goods), in the second case this is no longer the case since the public goods are assumed to be residence-based. In the latter case one can interpret the mobile labour as commuters who don't benefit from the public services provided by the foreign region[7]. Note that in this section all the discussed models remain based on capital mobility and capital taxation.

[7] In the assumption that the public good is not infrastructure, etc. but e.g. social security.

Migrational models.

In the model of Brueckner ([25]) all assumptions except one of the BTCM-model are retained: labourers becomes mobile and chooses the region which offers the highest welfare according to his or her individual preferences. Not surprisingly this set-up continues to lead to an underprovision of the public good because the positive fiscal externalities that a tax rate has on the other regions continue to exist. In fact, the equilibrium condition of the BTCM remains completely valid in this set-up.

A more complicated model with multiple tax instruments and mobile labour is Wilson's model ([142]). In his model each region has a fixed amount of land. Capital and labour are mobile in search of the highest reward[8]. The government maximizes the value of the land using a uniform source-based tax on capital and land and a source-based head tax on labourers[9]. If there are no economies of scale in the provision of the public good, only head taxes are needed to ensure an efficient provision of the public good. This is the same result as obtained in the BTCM-model but again there are a lot of redistributional issues. Notice however that in this case the government uses the head tax to efficiently control migration since the government sets the tax rate equal to the marginal cost of providing the public good to the mobile resident.

If one, on the other hand, would introduce scale economies in the provision of the public good, it becomes impossible for the government to tax the mobile labour appropriate. The marginal cost becomes lower than the average cost. This justifies the use of the uniform tax on capital and labour. Surprisingly the usage of this distortionary capital (and land) tax does not lead to an underprovision of the public good. The Samuelson rule holds. One can understand this as follows: the government uses the non-distortionary head tax to compensate for the distortionary capital tax effects. This is a clear case where multiple tax instruments can lead to an efficient outcome.

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[8] Just as was the case in the model of Brueckner, migrants have individual preferences ensuring that a continuous range of possible levels of public good provision becomes possible.

[9] Note that labour in this model is in fact modelled as capital was in public input goods provision models.

Commuter models

Commuters can't enjoy the benefits of the public good of the regions where they go to work. The set-up in the model of Braid ([22]) is parallel to Wilson's set-up. Competitive firms need immobile land, mobile labour and capital to produce goods. In Braid's model the government can't levy a head tax on the residents but instead she can dispose of a source-based labour tax. The uniform property tax on capital and land remains. Braid finds that an increasing number of regions leads to declining wage taxes, rising property taxes and a stronger underprovision of the public good. This result should come as no surprise since the capital and labour tax are highly distortionary in this model and by using the uniform property tax governments always induce a partial capital flight. Allowing labour to be mobile in a commuter's way creates an additional rationale for the underprovision of the public good.

2.3.5 Redistribution

Some researchers introduced a government that provides no tangible public good but instead cares about inequality. Income is transferred from richer people to poorer people by levying a tax on mobile and/or immobile factors of production. An excellent survey of this literature is given by Cremer, Fourgeaud, Leite-Monteiro, Marchand and Pestieau ([36]). Usually one introduces two factors of production, mobile high-skilled and immobile low-skilled labourers. Taxes are levied on the mobile labourers in an effort to equate the disposable income of both factors of production. As one could expect[10], this tax competition leads to a race to the bottom.

An interesting and recent contribution to this literature is the work of Cremer and Pestieau ([38]). They consider three factors of production: immobile capital, mobile unskilled labour and immobile skilled labour. While the skilled labourers get their wage and a share of the capital income, unskilled labourers only earn a (lower) labour income. The government levies source-based taxes on all three factors of production and uses these revenues to equate the disposable income of both groups of residents. They only succeed in this objective in the autarkic case. The more economies open their border with the region in question, the larger the downward pressure on the redistribution becomes. In a small open economy (with an infinite number of

[10] Just rename the factors of production: the mobile high-skilled labour becomes capital and the immobile low-skilled labour becomes labour in the BTCM.

regions) a complete race to the bottom emerges. A capital tax increase continues to create a positive interregional externality in this model but the reason lies now in the beneficial equity effects. The partial capitalisation of a higher tax rate into the after-tax return on capital (it decreases) creates a more equal income distribution since the high-paid high-skilled labourers also have (more) capital income.

A second example of the recent literature in this strand is the work of Huber ([63]). He also incorporated distributional concerns in his model, but he slightly changed the set-up of Cremer and Pestieau which allowed him to draw another interesting conclusion. Huber's set-up differs in two respects: there is a homogeneous tax on all labour income and he makes capital (again) mobile and labour immobile. This means that in his system the government has to rely on the capital tax to equate disposable incomes between the two groups of labourers. He also emphasizes the importance of the complementarity or substitutability between capital and labour. If for instance a capital stock increase (caused by a tax decrease) shifts the marginal productivity of the high-skilled labourers upwards (complementarity) but decreases the marginal productivity of the unskilled, a tax decrease would be unwanted from a distributional point of view. In either case, Huber's analysis suggest that the capital taxation would remain inefficiently low, although — due to the complementarity or substitutability of the factors of production — the equilibrium capital tax level may be positive or negative. So, whether the equilibrium capital tax on capital is positive or negative does not tell us if it is too low from the perspective of the social planner. Both models indicate that redistributive governments or governments that provide a general public good face the same risk of wasteful tax competition.

2.3.6 The nature of the government

Rawslian versus Benthamite benevolence

The government in the Basic Tax Competition Model only cares for the welfare of the residents. Because there is only one type of residents, the behaviour of a Rawslian benevolent and a Benthamite benevolent government coincides. As soon as more types of residents are introduced in the model as was the case when there is a redistributing government, one has to distinguish between the different types of benevolence. Redistributional issues become important. In autarky a Benthamite government that maximizes the sum of residents' utilities would have no redistribution between the poor and rich residents under the assumption that utility depends linearly on income[11]. A Rawslian government that looks at the primary goods of the least advantaged in society would equate the after-tax disposable income of both groups.

As Cremer and Pestieau ([38])[12] showed in an extension of their model (with mobile skilled labour) discussed in paragraph 2.3.5, globalisation works in a strange way between a Rawslian and utilitarian government. In equilibrium the Rawslian government has to cut back on her redistributional policy while the utilitarian government will tax the rich residents (who are mobile and high-skilled in ([38])) and as such installs a redistributive policy. This is because part of the taxed skilled workers are immigrants who don't count in the objective function of the government. Otherwise said, the Benthamite government can let foreign people pay for the maximisation of the total revenue of natives. This tax exporting behaviour that counteracts the race to the bottom also happens in models with absentee ownership of capital or land. Lee ([76]) and Burbridge and Meyers ([29]) have developed models of this kind.

Leviathan governments

In real life not all governments follow the will of a median voter. Some governments are not benevolent but Leviathan. They try to maximize the government size itself which leads to an overprovision of the public good. It were Brennan and Buchanan ([24]) who first realized that tax competition can be a welfare enhancing tool if one considers this Leviathan effect. It took nearly a decade after the appearing of their article in 1980 before this view was formalized. In the formal modelling of the Leviathan effect, one can on the one hand make abstraction of the electoral systems (Edwards and Keen ([44]), Rauscher ([106]), Gordon and Wilson ([58])), on the other hand one could consider voting models (Persson and Tabellini ([100]), Biglazer and Mezzetti ([15])). We discuss both set-ups.

In the first group of papers re-election concerns are only modelled implicitly by assuming that the objective function of the government is partial Leviathan and partial benevolent. The conclusion these papers embody is rather evident. It depends on the relative weight of both characteristics of the government to assess the efficiency effects of tax competition. If the rents

[11] This will be the case in the social security competition model we will develop later on.

[12] Similar results were obtained for a different set-up through simulations in a paper of Meeusen and Rayp ([89]).

that government officials claim decrease more than tax revenues when tax rates increase, the provision of the public good normally will increase due to tax competition.

A different angle in this research is taken by Gordon and Wilson ([58]). They dichotomize the policies. On the one hand, residents initially set tax rates to maximize welfare (benevolent government), on the other hand, self-interested government officials choose on policies in a Leviathan way. Residents try to provide incentives to officials that curb rent-seeking behaviour while the government tries to attract as many migrants as possible to increase tax revenues. Under the assumption of residential mobility, the governmental competition for mobile households reduces the intrinsic wasteful behaviour of the government. The higher efficiency of the government allows increases in public expenditure and hence also in resident utility. The authors call this governmental behaviour expenditure competition. But the result is not optimal. Gordon and Wilson show that the equilibrium tax rates are above the coordinative tax rates and that public good still may be underprovided.

The second group of papers explicitly model voting. Persson and Tabellini ([100]) introduce median voters in a BTCM set-up and these voters can alter the race to the bottom result. It is shown that tax competition makes the median voter more leftist oriented. This leads to increased government sizes which counteracts the wasteful tax competition.

Biglaser and Mezzetti ([15]) took a different voting approach. They started with a 'bidding for firm'-model[13] to which they added re-election concerns. Officials know that by attracting the new firm they increase their chance of winning the election. As a result they have a tendency to offer tax packages that can exceed the economic value of the investment. Dependent on the strength of this effect, governments may become inefficient.

[13] One extension of the BTCM concerns the discretisation of capital mobility. People like Black and Hoyt ([17]) designed models with this assumption to better reflect the lumpiness in reality of capital investments. When for instance regions want to attract a large car manufacturer they can offer serious subsidies or tax credits specific to that firm without changing their tax system as a whole. They found that bidding for firms can play an efficiency enhancing role since the newly attracted firm also attracts more labourers who can pay for the public good provision. We omitted this strand of literature in our review because the focus of attention in these papers is directed toward optimal locational decisions of firms and not towards the tax competition effects on public good provision.

Vertical tax competition

The Basic Tax Competition Model was a horizontal tax model where all the governments competed at the same level. In reality it can happen that a federal government and a local government impose a tax on the same tax base. This vertical tax competition normally leads to an overprovision of the public good. The rationale behind it is simple. A tax increase of a vertical ranked government will reduce (and not increase) the tax base of the other governments. Each government does not count in this effect and as a result taxes will be inefficiently high. This has been illustrated by Keen and Kotsogiannis ([64]). This kind of systems competition is however more slippery than horizontal tax competition because the political environment becomes important. If for instance, the objective functions of the federal and local government partially overlap, one would see a reduced overprovision of the public good. Another caveat lies in the timing of the political game. As Boadway, Marchand and Vigneault ([18]) showed, a first-mover federal government will create a situation where the federal government cannot do better than if it was directly controlled by states. This is because it foresees the inefficiencies that arise locally and will act accordingly. A more in-depth analysis of these phenomena can be found in Hoyt ([62]).

2.3.7 Introducing labour market imperfections

In all the models we have discussed so far, the labour market was modelled as a perfect full employment market. In the last ten years there have been made some efforts to introduce labour market imperfections in the Basic Tax Competition Model.

The first ones to develop a model of this kind were Lejour and Verbon ([78], [79]). They introduced unemployment in a BTCM set-up using a union-firm wage bargaining process. The benevolent government can only levy source-based labour head taxes to finance an unemployment benefit. Under the specific assumption that the wage elasticity of labour demand is larger than one, it follows that increasing capital mobility leads to lower taxes. Higher capital taxes lead to a capital flight which causes a reduction in labour productivity and hence to more unemployment (if wages cannot adjust to the market clearing level). We again arrive at the race to the bottom. A similar result was obtained by Lozachmeur ([85]) and Leite-Monteiro et. al. ([77]). These results indicate that labour market imperfections may strengthen the underprovision case since there was no underprovision in the BTCM for a case where a labour head tax was available.

Other articles focussed on cases of underemployment. For instance, Fuest and Huber ([53]) made the individual's wage supply elastic in a firm-union wage bargaining model. They also expanded the BTCM with multiple tax instruments: the government can levy a source-based labour and capital tax as well a 100%-profit tax to finance the public good. If the wage elasticity of labour demand is larger than one and government does take into account the effect of their tax setting on the wage bargaining process, wage and tax setting is to low from the point of view of a social planner. If government are myopic and don't consider the effect they can have on wage bargaining, tax setting does not have to be too low

Richter and Schneider ([110]) and Koskela and Schöb ([69]) synthesize both cases in a common framework of analysis. They show that the standard conclusions of BTCM remain intact in most cases but that - dependent on the properties of the production function and on the restrictions of other fiscal instruments - there are cases where tax competition does not necessarily lead to lower taxes. For instance, when labour markets are dominated by monopolies or monopsonies, capital taxes can serve as a (second-best) means to countervail the distortion.

2.3.8 An example of a model with multiple extensions

An interesting example of a model with extensions in several directions is the paper by Richter and Wellisch ([111]). We present their model here as an example of how the several additions to the original BTCM set-up intertwine.

In each region, firms produce (under perfect competition, CRS) a homogeneous good using an immobile factor land, a mobile factor labour and a local public factor (public input good). This public factor has no spill-over effects to the other regions. The only income of the immobile residents is the land rent of all the land in the world but the place of ownership does not have to coincide with the place of residence (absentee ownership extension). The mobile residents earn a wage income and get all the profits of the firms. The government in this model can levy four taxes (multiple tax instruments). It disposes of a head tax on both types of residents, a source-based land tax and a head tax on the profits of the firms. The government that only cares for the immobile residents use these revenues to provide a source-based and local public consumption and input good. These goods are characterized by congestion costs. Ergo, there have been made a lot of extensions toward the public good properties.

In equilibrium the governments will tax the land to the max. They do this because there is tax exporting in the model. The government can bank on absentee owners who can't evade the tax. But by levying high taxes on land, the immobile residents are hurt. That's where the multiple tax instruments come in: the government will use the head tax on immobile residents to compensate for the high land tax (it becomes a subsidy).

The authors also asked themselves what will happen if one restricts the use of the land tax (as done in Zodrow and Mieszkowski ([144]). Using the same reasoning as above, the equilibrium state of the economy would be typified by a government who tries to stop the outflow of rents. She does this by manipulating the land rent. In order to lower the land rent, the government has to tax firms inefficiently high (compared to the social planner) and to underprovide public factors. She also imposes high head taxes on mobile factors. The public consumption good provision remains efficient for two reasons. Firstly, the government cares for the immobile residents who derive utility from it and secondly it is unnecessary to deter the mobile factor by underproviding the public consumption good since the mobile head tax is available and is more directly oriented toward the mobile factor.

The congestion effect manifestates itself when the immobile head taxes and the absentee ownership of land are excluded from the model. In this case the government tries to reduce the congestion costs it can't internalize any longer. To reduce the inflow of the mobile residents, she taxes them too high and underprovides the public goods.

2.4 Conclusion

As far as we know, there have not been developed real social security models in the literature. However, there is a large volume of papers concerning tax competition, thus without the inclusion of a social risk but with the influence of globalisation on the tax setting capabilities of the government. An interesting ramification in this literature concerns the introduction of redistributing governments which in effect creates a social welfare system in a tax competition setting. These different models can serve as a valuable benchmark for our — yet to develop —

social security competition model.

The 'standard' tax competition literature mainly focuses on one aspect of globalisation, namely capital mobility. There are also researchers who enrichened the basic tax competition models, especially in the framework of redistributing governments, by focussing on labour (and capital) mobility. We will encounter even richer set-ups with a third globalisation dimension (goods mobility) when we discuss tax competition models in a new economic geography framework.

The main message from the tax competition literature concerning the potential drawbacks of globalisation is not very optimistic: *Public goods are underprovided as soon as tax payers can escape the taxes necessary to pay for these public goods from which they derive no utility.* The mechanism behind this postulate is quite simple. Tax raises create positive externalities for the other regions since their tax basis increases. However, the home region does not account for this effect and as a consequence the home government will underprovide the public good.

But even when the government manages to tax those who also benefit from the public good (e.g. public input goods) or if it can taxes resources that can't evade the taxes (e.g. absentee ownership, residence-based taxes), a Samuelson provision of public goods is still not guaranteed as some extensions showed. For instance, public goods subject to increasing returns to scale in their production suffer from underprovision since marginal costs (equal to the taxes) are always lower than the average costs.

Fortunately there exist some other extensions that can attenuate or even reverse the race to the bottom result. The introduction of large regions that have the market power to influence the after-tax return rate on capital lead to an attenuation of the underprovision of the public goods. Public goods with positive spill-over effects reduce the incentives of regions to compete for mobile (and taxed) capital. Tax competition can also reduce the overprovision of public goods when governments are purely Leviathan.

Chapter 3

New Economic Geography and tax competition

3.1 Introduction

In recent years a new interest in location arose in economic literature. In neo-classical economics it is assumed that everything takes place in an imaginary world with no dimensions. This is not real life. If one looks at the distribution of economic activity on city, national or even global level, one clearly can come to the conclusion that the distribution is quite uneven. In most countries of the world firms and customers are clustered in large metropolitan areas. This tendency of economic activity to be agglomerated is not new and has already been studied as early as in the beginning of the 19th century by Von Thünen ([127]). In the following century a lot of economists have studied the existence and origin of agglomeration in economies (Hotelling ([60]), Weber ([131]), Cristaller ([30]), Lösch ([84]), ...). Although the immanent importance of location decisions of firms and consumers to decision makers, this strand of literature never succeeded to become mainstream in economic reasoning. As pointed out by Thisse and Ottaviano ([98]) "*the reason for such emargination is likely to be found in the difficulty for the competitive paradigm, which has dominated so much economic research, to explain the formation of economic agglomerations*". The spatial impossibility theorem of Starrett ([120])

showed more formally that there is no competitive equilibrium in a homogeneous space[1] involving transportation as soon as transport is costly and economic activity is not perfectly divisible.

There are two ways to overcome this theoretical deadlock. First nature theorists relax the constraint of a homogeneous space and introduce heterogeneous externalities. For instance Ricardo argued that technological differences are essential in understanding location decisions. In the Heckscher-Ohlin-Samuelson framework factor endowments are crucial. These theories are certainly capable to explain partly the location decision. However a lot of modern clustering is much less dependent on natural advantages and remained unexplained by first nature theories. This is where New Economic Geography modelling (NEG) comes in. It tries to explain economic agglomeration after having controlled for first nature causes (homogeneous space) and avoids at the same time the theoretical deadlock of Starrett's spatial impossibility theorem (perfect competition). The key to develop this general equilibrium framework incorporating increasing returns to scale and transport costs lies — according to the founding fathers of the NEG, Krugman, Venables and Fujita — in a few 'modelling tricks': Dixit-Stiglitz monopolistic competition and Samuelson's iceberg transport costs. Even under these special assumptions NEG modelling remains complex and often analytically intractable.

In the next section of this chapter we start with a short description of the basis features of the new economic geography models, followed by some simulations concerning the dynamics of these models. Despite the large volume of research done in the field of NEG-modelling[2], the dynamics of these models have been scarcely treated. Besides a hopefully increased understanding of the NEG-models, the simulations of the transitional behaviour of NEG-models will also allow us to cast some caveats towards policy-makers. In section 3 of this chapter we give a short review of the still limited literature that combines new economic geography modelling with tax competition. All the models discussed in the previous chapter were smooth models were small changes lead to small effects. NEG-models are lumpy by their very nature and this will shed some new exciting lights on tax competition. We conclude this chapter with an overview of

[1] A space is homogenous if a firm has the same production set in all locations and consumers have the same preferences at all locations.

[2] The amount of research done in this field expanded even to such an extent that a new journal, The Journal of Economic Geography, took off in 2001.

how governments should react given the different models discussed in chapter 3 and 3.4.

3.2 Basic features of New Economic Geography models

3.2.1 General set-up

NEG-models normally have two regions: the north N and the south S. We assume that they are symmetric in terms of tastes, technology and openness to trade so as to rule out first nature explanations. This means at the same time that expressions for both regions are isomorphic. In each region two sectors are active: the manufacturing sector M and the agricultural sector A. The A-sector is made as simple as possible because its prime role is to allow for trade imbalances in the M-sector. Therefore it is modelled as a perfect Walrasian sector (constant returns to scale, perfect competition, ...). The M-sector is characterized by Dixit-Stiglitz monopolistic competition and iceberg transportation costs. As noted by Thisse and Ottaviano ([98]), what the two sectors represent, changes with the stage of development of the economy as well as with the epoch under consideration. For instance in the 19th century the M-sector mainly stood for manufacturing while nowadays tradable services can be included as well in the M-sector.

Although there are good reasons to believe that spatial competition is essentially oligopolistic (Gabsewicz and Thisse ([56])), NEG-models assume for reasons of analytical tractability that the market structure is Dixit-Stiglitz monopolistic competitive. This means that the supply side is modelled as a sector with increasing returns to scale within varieties and no economies of scope across varieties. At the same time one assumes that there are so many firms that they are not in a position to influence on other firm's production levels. The only strategic parameter for the firms is the global production of the market. The demand side can be represented by a consumer whose preferences exhibit 'varietas delectat' not only on the amount consumed of each A- and M-good but also on the number of varieties bought of these goods. Hence, we can represent the consumer's utility as follows[3]:

$$U = C_M^{\mu} C_A^{1-\mu} \qquad \text{with} \qquad C_M = \left(\int_{i=0}^{n+n^*} c_i^{1-\frac{1}{\sigma}} di \right)^{\frac{1}{1-\frac{1}{\sigma}}} \tag{3.1}$$

[3] We follow the notation of Baldwin et. al. ([10]).

The upper tier of the utility function 3.1 represents the constant division between the consumption C_A of the homogeneous A-good (fraction μ) and C_M, the consumption of a composite of all differentiated varieties of industrial goods (fraction $1-\mu$). The lower CES-tie gives the preferences of the consumers over the differentiated manufactured goods with σ the constant elasticity of substitution between the different varieties. For ease of analytical workability we represent the product space as continuous and n and n^* represent the mass of northern and southern[4] manufactured varieties respectively. The consumption of a single variety i is represented by c_i.

Entry and exit of a firm to a sector is assumed to be costless. This means that competition leads to marginal cost pricing. However in some models[5] entry and exit to a sector are not instantaneous, indicating that pure profits can arise.

The manufactured goods are subject to iceberg transportation costs when exported. This means that in order to have 1 unit exported to the other region, the firm has to send τ units ($\tau > 1$) because a fraction $\tau - 1$ melts away during transport. This ad valorem sales tax models the trade barriers. These can be defined as *all costs incurred in getting a good to a final user other than the marginal cost of producing the good itself: freight costs, time costs, policy barriers, information costs, contract enforcement costs, currency costs, legal and regulatory costs, and local distribution costs* (Anderson and Van Wincoop ([4])). In the NEG-modelling trade this parameter only appears in a transformed way, namely as $\tau^{1-\sigma}$, which is interpreted as the trade freeness ϕ. That is, the freeness of trade rises from $\phi = 0$, with infinite trade costs, to $\phi = 1$, with zero trade costs. In this way an important variable in the NEG-trade models is defined in a compact space which promotes numerical preciseness.

As pointed out by Eckey and Kosfeld ([42]) the formal structure of the New Economic Geography models remains neo-classical as consumers strive for utility maximisation, firms want to maximize their profits and intensive competition drives pure profits to zero.

To complete the set-up, we still have to introduce the cost functions and the cause of agglomeration. These two characterizations differ across the different models as can be seen in table 3.1[6].

[4] All southern varieties are denoted by $*$.
[5] FEVL and FCVL-models, see later.
[6] w is the wage of the skilled workers, w_L is the wage of the unskilled workers, x is production of a firm, F

In 1991 Krugman ([72]) introduced a model based on labour dualism, the Core-Periphery model (CP). There are two factors of production: industrial, skilled labourers H and agricultural labourers L. The immobile agricultural labour is only employed in the A-sector and a_a L-employees are needed to produce one A-good. The H-workers form the fixed and variable cost of the M-sector. The homothetic cost function of firms in the M-sector is given by $(F+a_m x)w$, where F is the fixed input requirement, a_m is the variable input requirement, x is the output of a firm and w depicts the wage of an industrial worker. The migration behaviour of the H-workers is discussed in subsection 3.2.2.

In a European context, full labour mobility is a strong assumption. Martin and Rogers ([88]) introduced in 1995 a model that was not based on labour mobility. This model is called the Footloose Capital model (FC). They make the cost function of the M-sector non-homothetic in a fixed capital requirement and a variable labour requirement as can be seen in table 3.1. There is no longer a difference between skilled and unskilled labour. They assume more realistically that workers are immobile and capital is mobile. This means that capital can be employed in any region but that the capital owner does not move.

Economic theorists noticed that the FC-model is much more tractable because of the non-homothetic cost function. However there is a trade-off with richness of features. As a consequence they tried to compromise the richness of features of the intractable CP-model and the

the number of units of necessary of the fixed input requirement, a_m the number of units of unskilled labour, n the number of firms and P_P the producer price index .

Model	primary f.o.p.	mobility	cost function	dynamics
CP	unskilled labour L	immobile		
	skilled labour H	mobile	$(F+a_m x)w$	$\dot{s}_H=(\omega-\omega^*)s_H(1-s_H)$
FC	labour L	immobile		
	capital K	mobile	$(F\pi+w_L a_m x$	$\dot{s}_H=(\pi-\pi^*)s_n(1-s_n)$
FE	unskilled labour L	immobile		
	skilled labour H	mobile	$Fw+a_m x w_L$	$\dot{s}_H=(\omega-\omega^*)s_H(1-s_H)$
CPVL	labour L	immobile	$(F+a_m)P_P$	$\dot{n}=n\Pi$ and $\dot{n^*}=n^*\Pi^*$
FCVL	labour	immobile		
	capital	mobile	$F\pi+a_m x P_P$	$\dot{s}_n=(\pi-\pi^*)s_n(1-s_n)$
FEVL	labour	immobile	$FP_P+a_m x w$	$\dot{n}=n\Pi$ and $\dot{n^*}=n^*\Pi^*$

Table 3.1: Overview of the discussed models.

relatively easy FC-model without losing too many wanted properties. This was independently done by Ottaviano ([95]) in 1996 and Forslid ([51]) in 1999. They introduce, just like the CP model a labour dualism (unskilled labour L and skilled labour H) and adopt the idea of a non-homothetic cost function in the M-sector ($=Fw + a_m x w_L$)[7] from the FC model. Only the skilled labour is mobile. It is clear from this set-up that F units of skilled labour are needed to produce a manufactured good. As skilled labour is considered to be mobile, firms have to move with these units of skilled labour. Because F is often normalized to 1, many interpret the unit of skilled labour as the entrepreneur. This explains the often-cited name of this model, Footloose Entrepreneur model (FE).

Note that unlike the tax competition models discussed in chapter 2, these NEG-models contain, besides goods mobility, a second source of globalisation, whether it is the mobility of capital, entrepreneurs or skilled labourers. The mobility of these factors of production also constituted the agglomeration source. Because migration of a primary factor cannot always be assumed to be reasonable, models with other agglomeration mechanisms were developed.

For instance, the market size could also be endogenized by introducing vertical input-output linkages between an upstream suppliers sector and a downstream customers sector. This setting introduced by Venables in 1996 in his seminal paper ([129]) is motivated by the growing importance of the services sector with its large business-to-business selling. The primary factor(s) of production in the vertical linkage framework is (are) interregionally immobile but intersectorally mobile. In 1995 Krugman and Venables ([73]) integrated this second cause of agglomeration with the CP-framework in their CPVL-model. In 2002 Robert-Nicoud ([112]) did the same for the FC-model in his FCVL-model. Ottaviano ([96]) modified in the same year the FE-model in a VL-framework. Strictly speaking all these models exhibit horizontal linkages as the upstream and downstream sector were collapsed into one sector to make things simpler. Nevertheless the name 'vertical linkages' remained in the literature. A second simplification lies in the specific modelling of the vertical linkages. For instance, the composite input of the M-sector in the CPVL-model is Cobb-Douglas in labour and the usual CES aggregate of all M-sector varieties. The Cobb-Douglas expenditure share on the CES aggregate is μ. This means that consumers and firms (see expression 3.1) devote the same shares of expenditures on manufacture, that

[7] w_L is the wage of an unskilled labourer and w of a skilled one.

both value variety and that no additional distortions are created. More specifically the price of the composite input good can be described by the producer price index P_P which is a Coub-Douglas aggregate of labour costs and the price index of the manufactured goods. The exact specification of the cost function of these and the previous discussed models can be found in table 3.1.

A third class of agglomeration models based on capital accumulation also excluded mobility of factors of production. The simplest model in this strand of literature is the constructed capital model of Baldwin ([6]). One assumes that capital can be constructed by using a fixed amount of labour but that it also faces a constant probability of 'dying' at every instant (depreciation idea). The equilibrium in each region is defined as the point where the long-run capital cost equals the post-tax reward on capital. In this way agglomerative forces behind the post-tax reward lead to a net creation of capital in the favoured nation and net destruction of capital in the disfavoured nation. Since these models lack a clear dynamical specification, we will omit them in the discussion of the dynamics of NEG-models. However, we will discuss some models of tax competition based on constructed capital set-ups.

3.2.2 Dynamics of NEG-models

The dynamics of the above-mentioned models are kept as simple as possible. In four of the six discussed models (CP, FC, FE, FCVL) the migration behaviour can be expressed by only one differential equation although the evolution in two distinct regions is considered. The reason lies in the fixed cost component of the increasing returns sector: the production of every M-variety requires a fixed amount of a primary factor of production. The endowments of these factors of production are constant and given. In a Dixit-Stiglitz framework every firm produces one variety and a single variety is produced by only one firm (see Baldwin et al. ([10]), p. 42-43). As a consequence the total number of firms n^W is constant. So expressing the number of northern firms n as a share of the total number of firms ($s_n = \frac{n}{n^W}$) does not change the amount of information contained in n. This no longer holds for the CPVL- and FEVL-models where the variation in the total number of firms (via P_P in the fixed cost component) prohibits the reduction of two dynamic equations to one.

Under the right normalization conditions ($F = \frac{1}{\sigma}$) and applying a full employment condition, it can be shown that the number of firms in the CP-framework is equal to the number of skilled labourers. This makes the notation s_H, the share of the northern skilled labourers in the total amount of skilled labourers interchangeable with s_n, the share of northern firms. Similar reasoning applies to the other models so that we can use the variable s_n to describe the transitional behaviour of all the above-mentioned models

The concrete formulations for the laws of motion in table 3.1 can be motivated as follows. The mobile factor in the CP- and FE-model moves as soon as firms in the other region offer a higher real wage. As a consequence the rate of migration s_H is proportional to the real wage gap $\omega - \omega^*$. Additionally it is ad hoc assumed that migration stops as soon as one region has attracted the entire mobile factor of production. The FC and FCVL-model replace the real wage gap in the migration equation by the difference in nominal reward to capital in both regions $\pi - \pi^*$. The capital owners are no longer interested in the real return because all earnings of their capital are repatriated to their country of origin[8]. The dynamics of the CPVL- and FEVL-model are even simpler than the other NEG-models: firms enter a market as soon as there are positive profits and leave the market when the profits are negative (making the non-instantaneous entry and exit of firms in FCVL and FEVL necessary).

It is clear that in the existing dynamical set-up of the discussed NEG-models all agents are myopic. They are only interested in the current wage, profits or reward to capital and don't care about the future. This lack of forward-looking rational behaviour avoids the difficulties encountered in models such as the Ramsey model. Boucekkine, Camacho and Zou ([20]) studied for instance a Ramsey model in infinite and continuous time and space and encountered ill-posed problems.

3.2.3 Main properties of NEG-models

A complete derivation and discussion of all properties of the NEG-models lies outside the scope of this thesis. Instead we focus on the intuition behind some of the most important characteristics of NEG-models.

Before we continue, it is necessary to mention that all characterizations of the NEG-models

[8] Strictly speaking one should continue to consider real returns as the capital owners are still interested in maximizing their real income where this real income is defined as their nominal earning divided by the price index of region where the capital owner lives!

are derived under the assumption that two conditions continuously hold. The first one, the no-black hole condition, puts a limit on the strength of the increasing returns in order to prevent creating models in which agglomeration always occurs independent of the trade freeness. This condition can be shown to be equivalent to stating that $\rho = \frac{\sigma-1}{\sigma}$, the intensity of the preference for variety in manufactured goods must be larger than μ[9]. The second condition is necessary to let the agricultural market clear. Without this non-full-specialization-condition the A-sector would not allow for trade imbalances. The mathematical formulation of this condition depends on the model (see ([10])).

Theorists are interested in finding the short-run and long-run equilibria of NEG-models. These are steady states where all markets cleared and trade is balanced. In the long-run equilibria, additionally, mobile factors have no longer an incentive to move. For instance, the number of active firms in the south and north is exogenously given in the short run for the CPVL-model and endogenized in the long run.

Alternatively one can define these equilibria as the outcome of a dispersion force and two agglomeration forces. The dispersion force can be understood by looking at the local competition. For instance, when a firm migrates from south to north, it intensifies competition in the north and thereby creates an incentive for northern firms to migrate to the south. This force is present in all models discussed in this paper.

The first agglomeration force looks at the effect of a larger home market. Under imperfect competition and trade costs, firms have an incentive to migrate to the larger market and export to the smaller market. If this production shifting in turn leads to further expenditure shifting as is the case in all models except for the FC-model[10], the home-market effect becomes self-reinforcing. This demand-linked circular causality explains how a small temporary shock can lead to a large permanent effect. It can also be shown that an exogenous change in the location of demand leads to a more than proportional relocation of industry to the enlarged region. All models are characterized by this home market magnification effect discussed by Krugman

[9] More formally, one has to impose that the break point (where the symmetricum falls apart) occurs at levels of trade freeness ϕ greater than 0.

[10] Independent where the capital is used (or equivalently stated where firms are located), expenditures do not move as the capital owners repatriate all of their earnings to their region of origin. The FCVL-model with similar assumptions exhibits demand-linked circular causalities because in VL-models firms take part in regional spending.

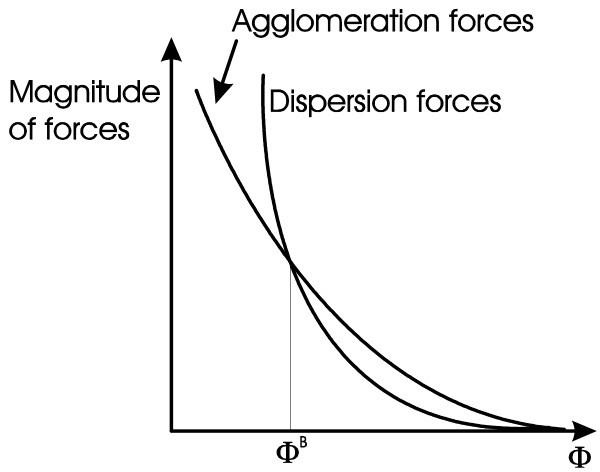

Figure 3-1: Evolution of centripetal and centrifugal forces with trade freeness ϕ.

([72]).

The second agglomeration force is not demand-linked as the previous one but cost-linked. The idea behind this force is neo-classical: firms want to minimize their costs and workers want the highest possible real income. As trade costs serve as a pecuniary externality in NEG-models, location plays an important role in minimizing costs. In the VL-models departing from a symmetricum makes the input less costly for firms in the enlarged region. Mobile consumers earn the highest real wage in regions where the cost-of-living is the lowest. This is in those regions where most firms are located. This cost-of-production or -living effect is self-reinforcing because an increase in consumers (or firms in VL-models) further attracts firms to that region. The only model without cost-linked circular causality is the FC-model because the repatriation of all capital earnings eliminates the importance of price indices.

It can be shown that a reduction in trade costs weakens the dispersion force more rapidly than it weakens the agglomeration force. This is graphically depicted in figure 3-1. As a consequence, at low values of trade freeness only a symmetrical equilibrium occurs. At some point of trade freeness agglomeration becomes overpowering and the model results in total agglomeration. Krugman was able to derive the conditions under which the Core-Periphery structure becomes locally unstable ([72]) and called it the sustain point. The point where the local stability of the symmetricum breaks down is called the break point and was studied by

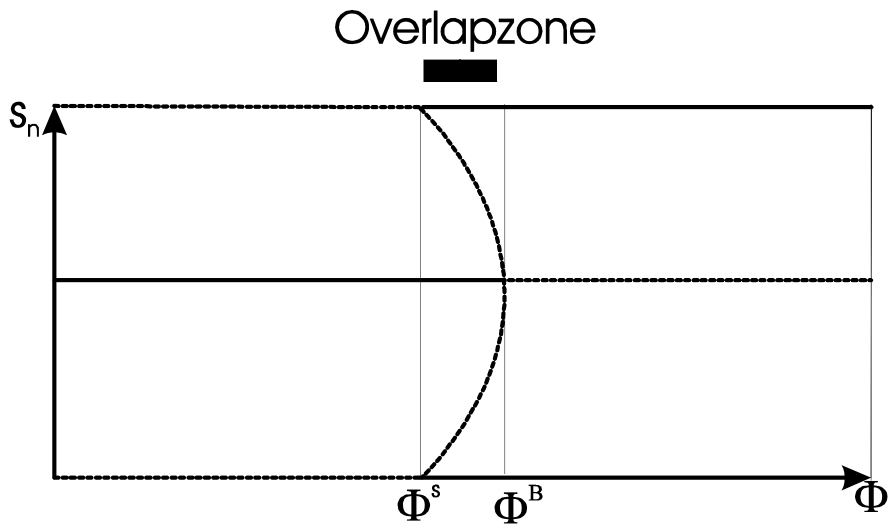

Figure 3-2: Symmetrical tomahawk diagram: stability and bifurcation.

Puga ([104]). This bifurcation behaviour is summarized in the tomahawk-diagram 3-2 in case the initial system is symmetric. Solid lines represent stable equilibria, dotted line unstable equilibria. Note that this diagram holds for all models except the FC-model. In this case the symmetricum is stable for all values of trade freeness, the core- and periphery equilibria are unstable. When there are no trade costs location becomes irrelevant.

The analytical obstinacy of NEG-modelling makes it hard to prove these characteristics formally. It took more than ten years after the 'reinvention' of geography in economic modelling to do this[11]. This was done by Robert-Nicoud ([113]). He proved the isomorphism of all discussed models in a certain economically meaningful natural state space. He called this space natural as it is closely linked to the three driving forces in the models. Based on this space he could prove the following analytically for symmetrical set-ups:

- There are at most five distinct equilibria, two of them being the corner solutions (core and periphery).
- If interior asymmetric steady states occur, they are always unstable.

[11] In the beginning of NEG the local stability of equilibria was studied purely numerically using wiggle diagrams. These diagrams plot the driving force of migration (e.g. real wage gap in CP) against the migration variable (e.g. share of mobile workers in north in CP). These graphs remain however useful to intuitively understand the models.

- Measured by trade freeness, the sustain point comes before the break point. If there is no cost-based agglomeration effect (e.g. FC), break and sustain point coincide.

- There exists a range of parameters where multiple equilibria coexist.

Baldwin ([6]) proved that regardless of initial conditions the system always converges to a steady state. This global stability is valid under the same conditions under which local stability holds.

The stability analysis highlights some other important characteristics of NEG-models besides the before mentioned home-market magnification and circular causality. Contrary to the HOS-framework where factors have an incentive to migrate in a pattern that tends to equalize relative factor supplies, NEG-models are endogenous asymmetric: a progressive lowering of the trade costs between two initially symmetric regions creates at the end regional asymmetries. Moreover, it happens catastrophically. This bang-bang property as Thisse and Ottaviano call it ([98]) is one of the most known properties of NEG-modelling. The fact that multiple stable equilibria exist in a certain range of parameters makes the model path dependent. The reversal of a temporary shock that changed the equilibrium of the model would not necessary imply a returning to the original equilibrium. This 'history matters property' is of great importance in the policy implications of NEG-modelling. For other properties of NEG-models, we refer to the book of Baldwin et. al. ([10]).

All the previous results hold under the assumption that regions are intrinsic symmetric. In reality regions seldom can be assumed to have exactly the same endowments or trade barriers. If we introduce asymmetry, the NEG-framework is enriched. For instance the bifurcation diagram[12] when the southern region has a higher initial factor endowment (or exporting to the south is more expensive than exporting to the northern region) is given in figure 3-3. Mirroring this figure around the $s_n = \frac{1}{2}$ -line gives the case where the north has the largest endowments or highest import tariffs.

This figure shows that the symmetric equilibrium is no longer a straight line but inclines slightly to the southern core-solution. The breaking of the 'handle' of the tomahawk doubles

[12] This figure holds for small asymmetries. It can be numerically shown that for larger asymmetries the break point lies between the two sustain points (see Baldwin et. al. ([10])).

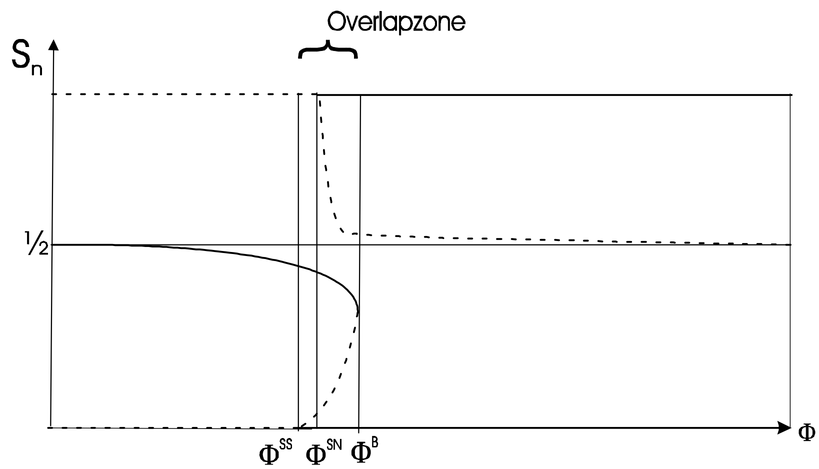

Figure 3-3: Asymmetrical tomahawk diagram: stability and bifurcation in case the southern region has higher initial endowments or higher import tariffs.

the sustain points: the sustain point for the south occurs at lower trade freeness levels than the northern region. These changes enrich the pre-catastrophic behaviour of the model. The full agglomeration in the south becomes more likely compared to the symmetrical bifurcation diagram when trade freeness is increased. This region is now also capable to sustain its core solution at higher levels of trade costs than the north.

The asymmetric bifurcation diagram for the FC-model differs from figure 3-3. Baldwin et. al. ([10]) show that as soon as asymmetry is introduced, the CP-outcome becomes stable in this framework at levels of trade costs different from zero. The larger the asymmetry becomes, the lower the trade freeness may be for the CP-equilibrium to be stable. At values of trade freeness just below the threshold value (where CP-outcome becomes stable), the delocation elasticity is extremely large. This behaviour is called near-catastrophic behaviour. A second difference lies in the fact that the symmetricum is no longer an equilibrium. The larger the northern market size becomes, the larger the equilibrium value for the northern share of firms becomes.

We end this discussion of the main properties of standard NEG-modelling by noting that most theorists have introduced many normalizations in order to make the expressions less cluttered. For instance it is always assumed that F equals 1. Some of these assumptions are model dependent. We refer to Baldwin et. al. ([10]) for a complete survey of these normalizations.

3.3 Simulated dynamics of some New Economic Geography models

3.3.1 Introduction

Dynamics is a subject often forgotten in NEG-papers. As mentioned before, theorists are mainly interested in establishing the local stability of short- and long run equilibria. We look in this section at the dynamics of six NEG-models (FC, CP, FE, CPVL, FCVL and FEVL). From a political point of view, it is not only important to know which equilibrium (core or periphery) can be attained but also how long it takes before the region actually ends up in that equilibrium.

Unfortunately it is not possible to study the dynamics of these models in an analytical way. The main cause for this intractability does not lie in the fact that the dynamical equations are too complex, far from, but in the embedded recursiveness of the equations. From an abstract point of view, the dynamics are all described as (systems of) non-linear first order differential equations $\dot{x} = A(x)x$, but with A implicit in x, making the systems solvable only numerically. For instance, in the CP-model the dynamics are given by $s_H = (\omega - \omega^*)s_H(1 - s_H)$. In this expression the real wage ω can be written as the nominal wage w divided by the price index P. Both numerator and denominator of the price index P depend in a transcendental way on the nominal wage (that depends on the share of northern firms $s_n = s_H$) making it impossible to express the real wage explicitly in function of the share of skilled labourers s_H. The resulting transcendental differential-algebraic system must be simulated numerically. The only systems escaping this intractability are the FC- and the FEVL-model. In these two cases, integrating the dynamical equation(s) lead to complicated and implicit functions. Therefore we rely also in these two cases on numerical simulations.

We try to assess how the different systems evolve toward an equilibrium starting from an inequilibrium. As the initial condition of the systems is independent of the future, we can choose them in such a way that they reflect an extreme disequilibrium. We do this for symmetric and asymmetric set-ups. In all these models[13], we use the values 0.3 for μ and 8 for the elasticity

[13] Of course it could also be argued that, since each model corresponds with a different economic scenario, we

of substitution σ (Brakman and Garretsen [21]), unless otherwise stated. This means that 30% of the produced output of a region is subject to trade costs. In modern countries around 70% of GDP stems from services. As they are harder to trade, the value for μ seems reasonable.

Details about these simulations are given in appendix 8. We did all the the calculations and simulations in *Mathematica 5.0*. The three-dimensional graphs are drawn using the *Graphics3D*-package. In the following subsections we discuss the results of the simulations with respect to some dynamical characteristics.

3.3.2 Discussion of the dynamics

Shape of the transition process

In all the discussed models the transitional shape is similar. If the long-run equilibrium is characterized by a lower share of northern industry compared to the initial condition, the dynamics are concave in the beginning and convex at the end with the point of inflection roughly in the middle. If the northern region attracts more firms in the long run than it had in the beginning, the curve is convex in the beginning and concave in the end. In most cases the inclination is quite weak. This shape is independent of the fact that the system is characterized by one or two dynamical equations. This results in a nearly linear evolution except for the beginning and the end of the transition. In all cases a very long tail could be distinguished. For instance (see A-4) the time necessary to bridge 90% of the gap between the initial state and the final state is three times smaller than the time necessary to cross the remaining 10% gap.

Influence of initial condition and trade freeness on transition time

When trade costs fall, the time necessary to attain the long run equilibrium state increases. This is a manifestation of the decreasing strength of the agglomeration and dispersion forces when trade freeness increases. Besides this general phenomenon, the discussed models exhibit specific dynamics. First of all, the break and sustain point differ. This means that the systems do not evolve toward the same stable long run equilibria at the same levels of trade freeness. As the agglomerative and dispersion forces are roughly equal around the break point, the transition

have to calibrate the parameters in each model differently so as to reflect optimally different base case scenarios.

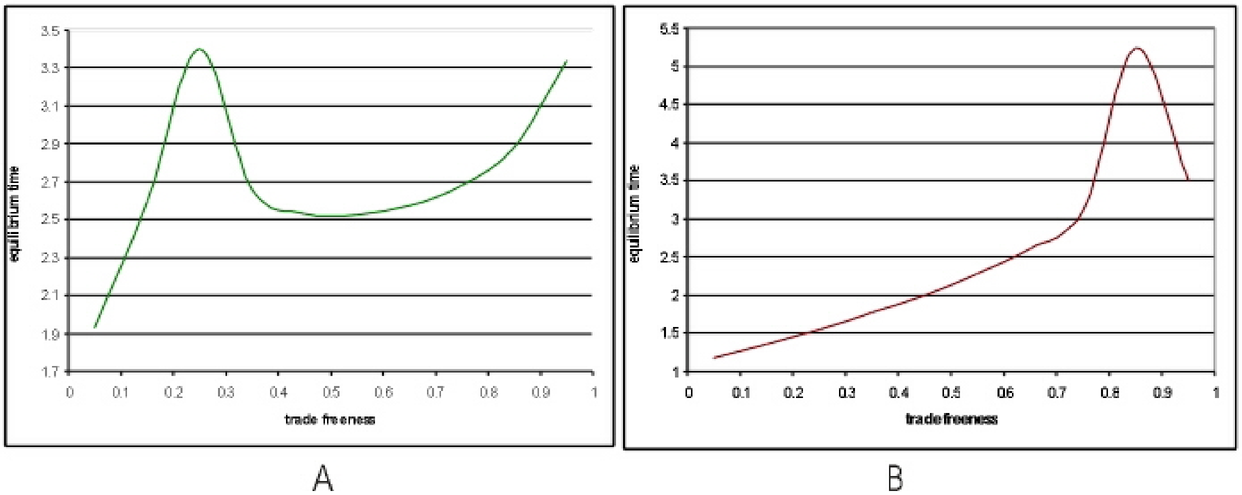

Figure 3-4: Trade freeness dependence of transition times for a) CP- and b) FE-model ($s_n(0) = 0.05$).

becomes asymptotically slow at these ϕ-values. Combining this result with the different break points for the discussed models lets us conclude that the dynamical evolution at the same levels of trade freeness can differ considerably across the models. Figure 3-4 illustrates this conclusion for the CP- and FE-model. The humps in the graphs reflect the occurrence of the break and sustain point.

We also showed that the difference between the initial condition and the stable long run equilibrium serves as a measurement for the number of time steps necessary to attain this equilibrium. The magnitude of this effect compared to the trade freeness dependence, however, is not the same. As can be seen in table 3.2, the impact of a change in trade freeness is many times larger than the effect a different initial condition has on the transition time. In this table the change of the half life for all the discussed models is given in terms of percentage between two extreme trade freeness or initial condition levels[14], where the half life is defined as the the time necessary to bridge 50% of the gap between the initial and final equilibrium state. The negative values in the second row stem from the fact that in the FC-, FE- and FEVL-model the symmetricum is still not breached at ϕ=0.75. The break point in these models occurs at a lower level of trade costs.

[14] As the models are intrinsically symmetric, we only have to consider initial values below 0.50.

Impact of modelling set-up on transition time

From the point of view of a policy maker, it is important to know in which model the transition is fast and in which model it is not. The appendix A-4 lists the transition times for all the discussed models for different values of trade freeness and several initial conditions. The influence of the modelling framework is summarized in figure 3-5. Part A compares the CP-, FC- and FE-set-ups, B depicts the same comparison but now for VL-based models and part C considers the difference in transition time for VL- and migrational models. In all three cases we used a log-linear scale.

We see that the FC-model evolves much slower (10-30 times) toward the final equilibrium than the FE- or CP-setting, except around the break points of the FE- and CP-model. The lack of circular causalities and a cost-based agglomerative force explains this behaviour. The same slowness characterizes the FCVL-model but is explained differently. The dynamics of the FCVL-model are modelled differently than those of the FEVL- and CPVL-model. An increase of the number of varieties produced in the north necessarily means a reduction of the southern varieties in the FCVL-model. The other two VL-models don't have this win-loose dynamics. As a consequence the magnitude of all the forces is larger in the FCVL-model, making the ratio of the dominant force over the smaller force smaller. This smaller ratio explains the slower evolution over the whole trade freeness range.

The FE-setting goes faster (10 times) than the CP-setting toward the equilibrium state for low values of trade freeness but it becomes slower for high values of trade freeness. The reason lies in the different cost structure of both models. In a FE-setting you need the migrational factor of production only for the fixed cost requirement and not for the variable cost requirement as is the case in a CP-setting. This means that, for the same number of people that migrates interregionally, more firms and varieties can be produced in a FE-setting than in a CP-setting. This enhances the dispersion force and the cost-linked agglomerative force relatively more in the

	CP	CPVL	FC	FCVL	FE	FEVL
$\%\Delta T_{1/2}(\phi = 0.05$ to $\phi = 0.95$, $s_n(0) = 0.25)$	1040	690	88108	1531	24600	8340
$\%\Delta T_{1/2}(s_n(0) = 0.05$ to $s_n(0) = 0.45$, $\phi = 0.75)$	384	280	-50	349	-50	-48

Table 3.2: Magnitude of trade freeness and initial condition effect on transition time

FE-setting. There is no divergence in the demand-linked agglomerative force. These elements combined explain the behaviour.

Lastly we conclude that the dynamical evolution of migrational and VL-models is similar, once accounted for different modelling set-ups (CP,FE, FC). Only the FC- and FCVL-model evolve differently but this behaviour is easy explained as the FCVL-model does have a break and sustain point, the FC-model not.

Influence of size asymmetries on transition time

Departing from the symmetrical division of labourers (or capital) has only in CP-setting a reasonable impact. A 0.5% reduction in s_L in these settings suffices to let the system evolve toward the southern core solution even if the northern region is given a small initial advantage. Of course the change of the share of labourers or capital makes the stable symmetrical long run equilibrium no longer stable. This is depicted in the typical asymmetric tomahawk diagrams. In the other set-ups more than 5% of the labourers has to move between the regions before the dynamical evolution starts to change. In these cases, we conclude that, although the stability of equilibria changes, a change in the share of labourers has no influence on the dynamical evolution of the systems.

3.3.3 A tentative attempt to estimate time steps

Until now we only discussed the dynamics of the models in relative terms, not in absolute terms. For a policy maker it is not only important to know that labour mobility leads to faster agglomeration outcomes than capital mobility, unless he or she also knows how many years there are left before the (un)wanted outcome is reached. To fully answer this question one could regress changes in agglomeration data on several factors that can be pointed to one specific modelling set-up. Based on the coefficients, one could get time estimates of transition times.

Because this empirical research lies outside the scope of this thesis, we tried to get a (very) rough time estimate based on data in the literature. We considered a European framework. As labour mobility is low in Europe and trade between firms accounts for a large share in the intra-European trade, we suggest a FCVL-model to reflect the European case. It's a matter of

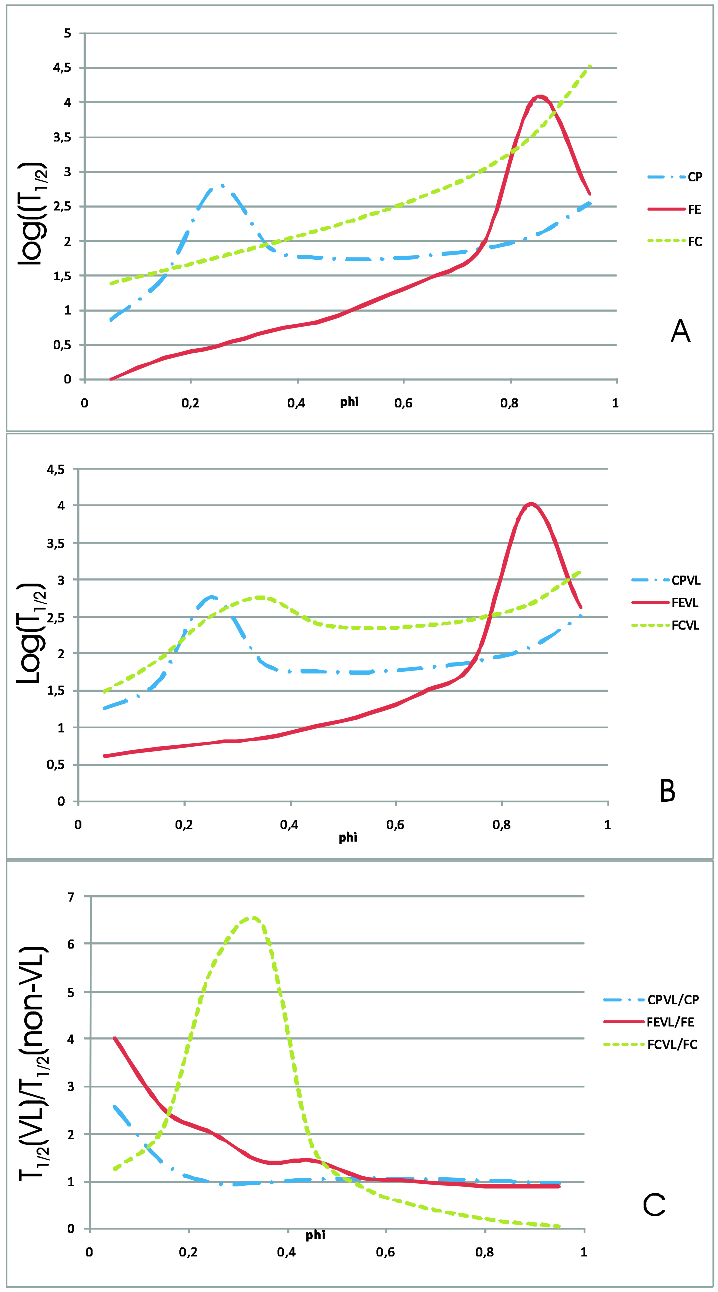

Figure 3-5: Influence of modelling set-up on transition times.

debate to which extent some European regions can be considered as core regions or not. We suppose that 65% of industry is located in the European core.

One can find many different values for trade freeness in the literature. For instance, Anderson and Van Wincoop ([4]) find a trade cost of 170%. Given the fact that the elasticity of substitution between varieties is 8 in our set-up, this figure corresponds to a trade freeness of 0.02. We believe that such prohibitive trade costs don't reflect the European border free case. Instead, we used the minimal estimation of transport costs of Ederington, Levinson and Minier ([81]). They used import data from the 15 largest importers of the U.S. at a 10-digit HS code level to calculate transport costs, controlled for distance and found a trade freeness around 0.85[15].

We looked at the convergence literature to find an estimate of the transition time. Magrini ([87]) used the distributional approach of Quah ([105]) to study whether there is a European income convergence. This means that he divided the European NUTS2-population in different income categories at different time steps (1980-1995) to construct a transition probability matrix. Under the assumption of an invariant transition mechanism, the eigenvalues of the ergodic matrix reflect the time dimension of the con- or divergence. This leads to a half-life of approximately 100 years. As Magrini pointed out, these values are subject to changes if other income discretisations are taken. For instance, Claerhout ([31]) found a half-life of 150 years.

Using all these data, we found that 1 time step coincides with 1,78 months. Based on this result, we conclude, although preliminary, that in most models the transition time is quite long. It varies between 10 to several thousands of years.

3.4 New Economic Geography: a definite farewell to the race to the bottom?

All the tax competition models discussed in chapter 2 were smooth models. Small changes lead to small effects. As made clear in section 3.2, economic geography models are lumpy by their very nature and this will have a huge impact on tax competition results. The amount of

[15] They estimated that the transport cost τ is equal to 1.009082 or otherwise stated that $\phi = 0.93$ ($\sigma = 8$). One standard deviation (σ= 0.034) further away leads to a trade freeness of 0.72. Averaging this out, gives the result of $\phi = 0.85$.

research done in this domain is still quite limited. The first papers concerning tax competition in an economic geography framework appeared around the year 2000. Probably the first one to be published was the paper of Ludema and Wooton ([83]) who showed the potential positive effects of globalisation on tax competition albeit in a non-standard new economy geography framework[16]. Soon several other papers appeared that came to the same conclusions but now in a standard new economic geography framework (Anderson and Forslid ([3]), Baldwin and Forslid ([9]), Baldwin and Krugman ([11]), Kind, Knarvik and Schjelderup ([66])). A good survey of this literature can be found in Baldwin et. al. ([10]). Note that all these models are 'classic' tax competition models, thus without social insurance.

The discussion of NEG-modelling in section 3.2.3 indicated that there are two different locational equilibria. As it turns out, competition for taxed mobile factors hinges strongly on the nature of the locational equilibrium. In order not to obfuscate matters, we look at both cases separately. We start with symmetrical locational equilibria in subsection 3.4.1, followed by tax competition models under CP-equilibrium in subsection 3.4.2.

Since this literature is new, there aren't many extensions to this strand present in the literature. In subsection 3.4.3 we present two of them. The first one, by Borck and Pflüger ([19]) focuses on richer locational equilibria. The second extension, made by Seidel and Egger ([117]) is very interesting since it introduces unemployment and an unemployment benefit in a NEG-framework.

After the review of the standard neo-classical tax competition models in chapter 2 and NEG tax competition models in this section, we are able to give a short resume of the different attitudes that governments can adopt to cope with the possible detrimental effects of tax competition. This is done in subsection 3.4.4.

3.4.1 Tax competition starting from a symmetric equilibrium

In this section we will use three different NEG-models to illustrate that in an economic geography framework it becomes possible to have a race to the bottom with and without capital mobility but that you can also have a race to the top. On the one hand, the mechanisms

[16] They used a framework of homogeneous good oligopoly and moving costs instead of a Dixit-Stiglitz-Spencer framework with iceberg transportation costs.

behind the race to the top or bottom remain the same as in the BTCM set-up. This illustrates the importance of the nature of the public good and the tax instruments. On the other hand, agglomeration causes some effects that are totally unexpected in a BTCM framework.

Footloose Capital model and a public consumption good: Race to the bottom

The model of Martin and Rogers ([88]) is the easiest model to work with[17]. It is also the only NEG-model that is fully tractable. The essence of their model lies – as seen in the previous section – in the cost function of the manufacturing sector. The fixed cost of this sector is made up by mobile capital. Labourers form the variable cost of the M-sector. These labourers are immobile and also work in the agricultural sector. As explained before the capital owners (in casu the labourers) are immobile and all capital earnings are repatriated. This means that the self-reinforcing cost- and demand-linkage are lacking in this set-up. As a result only the symmetricum is a stable equilibrium in the whole range of trade freeness. We don't have to fear a catastrophic agglomeration.

The government uses a head tax on the residential income (labour and capital income) to finance a public good that is produced using goods from the A-sector. The government is benevolent and maximizes the welfare of the residents. Given the basic nature of the footloose capital model, it is not that difficult to show that the Nash equilibrium between the two regions results in a race to the bottom. The taxes drop as trade freeness increases. This result critically depends on the fact that the capital reward is repatriated since it is the cause for the fiscal externality. The tax payer does not benefit from the public good paid by his taxes.

Footloose Entrepreneur Model and a public input good: Race to the top.

In the Footloose Entrepreneur model of Ottaviano and Forslid ([97]) the set-up of Martin and Rogers is retained except for one detail. One interprets the capital now as entrepreneurs who move with their firm. This means that the delocation of the entrepreneur also leads to an expenditure shifting. This puts the demand-linked and cost-linked circular causalities back on track. The tomahawk diagram is that of figure 3-2.

[17] The model described here which can be found in Baldwin et. al. ([10]) actually used a quasi-linear variant of the original model. By doing this one avoids all income effects.

Baldwin and Forslid ([9]) and Anderson and Forslid ([3]) incorporate tax competition in this set-up. They introduce a benevolent government who levies head taxes on residents (labourers and entrepreneurs) to provide a public good for both factors of production (a public consumption and input good). For simplicity, they assume that the public good is produced by the means of the average consumption basket, that is, with the same composite of A- and M-goods as in the consumers' utility function. This means that the taxation does not influence the demand patterns and there is no interaction between the level of spending and the demand of the differentiated good.

For this set-up, one finds that the Nash equilibrium equals the first best equilibrium where there was no entrepreneurial mobility. In conclusion, there is no race to the bottom. Intuitively this result is easy to understand since the entrepreneur has no reason to run away from the tax because he or she benefits from it.

We can also look at the effect of public good provision on the agglomeration. Migration implies that the receiving nation can afford better public goods while the other region can offer only a poorer set of public goods. Hence migrants create a force that tends to promote further migration since they derive utility from the public good provision. This amenities linkage destabilizes the symmetricum. Andersson and Forslid ([3]) called this effect the *bright lights, big city* effect.

Constructed Capital model: race to the bottom without capital mobility

The results of the last two paragraphs could also be attained in a BTCM set-up since they were basically based on public good assumptions. The next model we discuss allows us to derive a result that can't be attained in a basic tax competition model.

The model used for this is the constructed capital model of Baldwin ([6]). As seen before in section 3.2, this model assumes that neither labourers (variable cost of M-sector) nor capital (fixed cost of M-sector) is mobile. The agglomeration is now rooted in the fact that capital can be constructed and destroyed.

The government in this model only cares for the labourers and provides them public goods with the same cost structure of the model of Ottaviano and Forslid ([97]). Tax revenues are collected using a source-based head tax on labour and capital.

In equilibrium tax rates are too low from the perspective of the social planner. This can be explained as a hidden fiscal externality. Capital does not want to pay taxes as it derives no benefit from it. The fact that it can't move physically does not mean that capital stocks can't respond to the fact that capital investments abroad are more attractive. The capital construction sector plays the same role as capital mobility did in the basic tax competition model.

If one allows capital to become mobile in a footloose capital sense in this set-up, one finds a positive correlation between capital mobility and tax rates. Globalisation is good for social welfare! The reason behind it lies in the fact that capital owners don't move with their capital. This acts as a strong dispersion force just as the amenities linkages acted as an agglomerative force in the footloose entrepreneur model. The locational symmetric equilibrium becomes more stable and less changeable by tax rates. Tax competition is attenuated. This shows that agglomerative forces can have an influence on tax competition results. Normally one would expect that in a model where the public good provision is excluded for capital, increased capital mobility would lead to lower taxes. But by making capital mobile one also created an additional dispersion force which made the locational division more fixed.

This result contrasts sharply with the BTCM where capital mobility was the key cause of inefficient tax competition and where removing capital mobility produced first-best taxation. However, the mechanism behind the underprovision result is the same. This model is a good illustration of the fact that — although the agglomeration and tax competition still hinges on the nature of capital — it is not the mobility of goods or factors that is crucial to the race to the bottom but the nature of the public good is. It also shows how agglomerative effects can change tax competition results.

3.4.2 Tax competition and core-periphery equilibria

When trade is sufficiently free, agglomeration forces induce mobile factors to cluster geographically. In this case, mobile factors respond to tax differentials in a manner that is quite different than the one predicted by the BTCM. They become quasi fixed. Baldwin and Krugman ([11]) investigated the consequences of core-periphery patterns for tax competition in a footloose entrepreneur model. They introduce in this set-up a benevolent government that only cares for

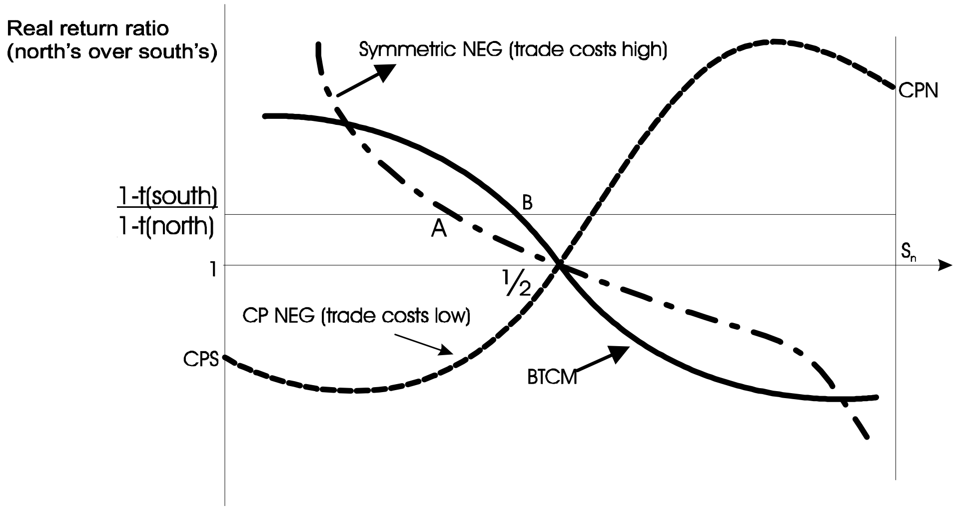

Figure 3-6: Wiggle diagram for a BTCM model and a NEG-model.

the labourers and not for the entrepreneurs. Since the public good is reserved for the immobile labourers but the tax is paid by the mobile and immobile labourers, we would expect a race to the bottom result. It turns out that this is not the case.

Before we turn to their model, we first look at the wiggle diagram 3-6. This diagram plots the driving force of migration, the indirect utility ratio of the entrepreneurs against the migration variable, the share of firms in the north. The diagram is handy for two reasons. First, one can see the stability of the locational patterns: all points where the real return ratio equals one and where the wiggle curve is downward sloping are stable internal equilibria. At these points a further increase of the share of firms in the north would lower the northern return rate compared to the southern return rate. This decrease of the real return ratio would deter entrepreneurs from moving to the north. An analogue reasoning holds when firms move to the south starting from the same stable situation. On the graph we depicted the real return ratio of a neo-classical BTCM-model, of a symmetric and a core-periphery FE-equilibrium. It is easy to see where which equilibrium is stable.

The wiggle diagram also graphically explains the different effect a tax change has in a symmetrical situation compared to a CP-situation. A tax increase in a region lowers the real return for the entrepreneurs in that region[18] and makes the other region more attractive. This means that the equilibrium line shifts from a real return ratio equal to one to the point where the real return ratio Ω equals the tax difference $\frac{1-t_{south}}{1-t_{north}}$[19]. For symmetric situations (and the BTCM case) asymmetric taxations will lead to moderate reallocations of entrepreneurs (point A and B on the wiggle diagrams). The same tax change will not lead to any capital shifting in a core periphery situation. The CP-point for the north (marked as CPN on the diagram) is still above the new equilibrium line. It is only when the ratio of real rewards at CPN becomes smaller than the tax gap, that all entrepreneurs would move. Until that moment, all entrepreneurs behave like fixed factors of production because of the net positive real reward ratio. This ratio is called agglomeration rents and one can prove that they are hump-shaped.

Baldwin and Krugman ([11]) proposed a three-stage limit taxing game. In the first stage the core sets its tax rate, followed by the south in the second stage. In the last stage entrepreneurs migrate and the locational equilibrium is established. This game is solved by backwards induction. After having determined the real wage gap that determines the locational equilibrium pattern in the third stage, one considers the problem facing the south in the second stage and the north in the first stage. Both cases have been depicted on graph 3-7.

The first quadrant depicts the southern problem. The vertical axis plots the value of the government's objective function and the horizontal axis depicts the southern tax rate. The south has two options. If the core stays in the north, the problem of the government is unrestricted and sets is tax rate accordingly ($t_{south,eq}$ on graph). However the south could also try to undercut the northern rate enough in order to become core itself. If the south becomes the core it could tax away the agglomeration rents which results in a higher welfare (see graph). To attain this, the south has to set its tax rate equal to the following tax break rate $t_{south,break} = 1-(1-t_{north})\Omega$. This tax rate depends on the northern tax rate set in the first stage. Two possibilities have been shown on the graph: if the north sets a relatively high tax rate, the south can levy the tax $T1$, if the north has a low tax rate, the south has to set its tax rate below $T2$. Only in the former case, it is profitable for the south to steal the core from the north.

[18] Contrary to the FE-model discussed in subsection 3.4.1 entrepreneurs only derive utility from their remuneration π, not from public good consumption. This means that tax increases unilaterally decrease welfare of entrepreneurs.

[19] This is based on the equalization of the after-tax rewards to capital across regions: $\pi_{north}(1-t) = \pi_{south}(1-t^*)$.

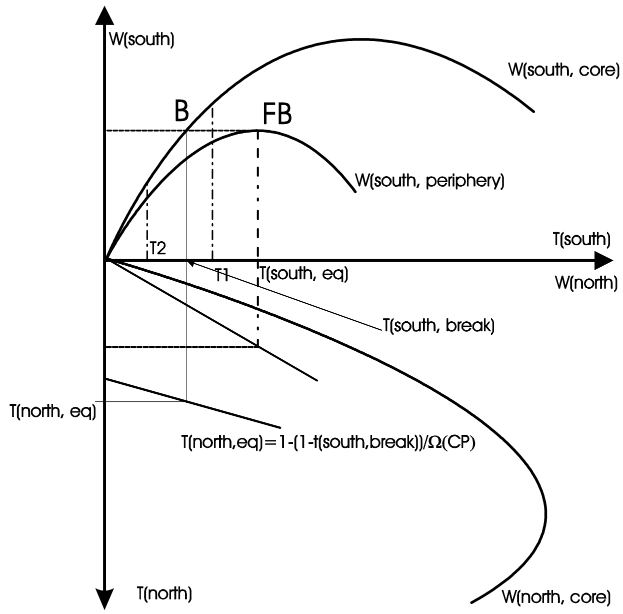

Figure 3-7: Second and first stage of tax limiting game

The northern region in the first stage is aware of the southern problem. Because the welfare of the north is higher when it remains the core (a symmetric set-up), it will set its tax rate at that level that would make the south indifferent between becoming the core or staying periphery. The line $FB - B$ on the graph depicts this situation of equal welfare. The no deviation tax rate of the south that follows from this calculation is used to determine the northern Nash equilibrium rate. This is done by equating the tax gap and the real reward ratio of the entrepreneurs (formula: see graph). This is graphically depicted in the fourth quadrant of the figure.

The lumpy character of the model made it necessary to use the sub-game perfect Nash equilibrium instead of the simultaneous Nash equilibrium as used before. The reason lies in the discontinuity of the government's reaction functions. If the south took the north's rate as given, it would not want to deviate; however, if the north took the south's rate as given, it would wish to raise its tax rate. But if it raised its tax rates, the south would find it optimal to ´steal' the core and then the north's rate would no longer be optimal. As a result the static Nash game has no pure strategy equilibrium.

For reason of simplicity Baldwin and Krugman assume that the public good is luxurious,

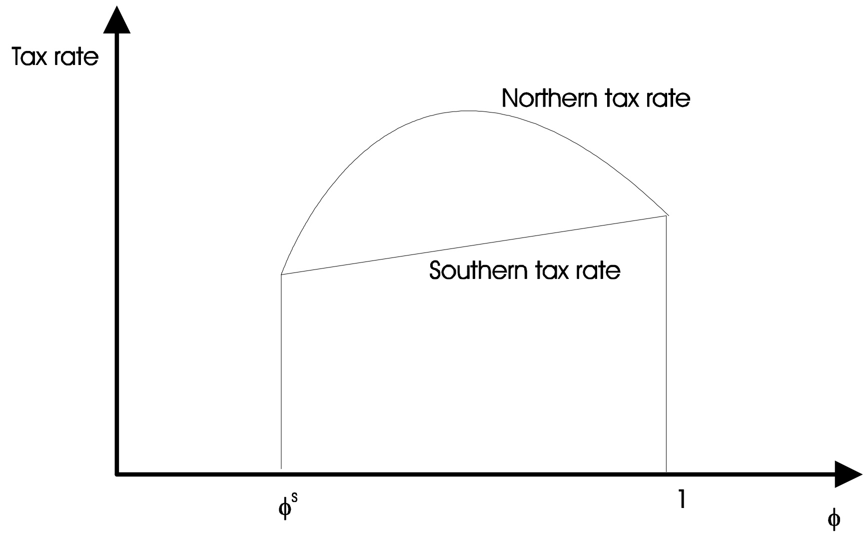

Figure 3-8: Tilted bell tax competition

meaning that richer residents want more of them. Under this assumption it is easy to prove that the northern tax rate is always higher than the southern. This is illustrated on figure 3-7 with the help of the bisector in the fourth quadrant. It also implicates that the southern tax rate increases when trade freeness increases since the real income of people rises.

The hump-shaped agglomeration rents cause a race to the top followed by a race to the bottom for the core if trade costs decline. As could be expected from the game set-up where the south was given the maximal ability to compete fiscally, only the north is restrained by the tax competition and runs the risk of a race to the bottom.

So, if the preferences for public goods rise with per capita income, globalisation may produce a race to the top since the peripheral regions and core regions both raise their taxes with increased trade freeness. The rich nation could increase the tax rate more quickly since it not only becomes richer as the south does (reduced price index) but that it can also tax the agglomeration rents away. For high levels of trade freeness the northern tax rate returns to the southern tax rate. Baldwin et. al. ([10]) called this tilted bell tax competition. We depicted this behaviour graphically in figure 3-8.

We can conclude that the introduction of a core-periphery structure in a tax competition setting has far reaching consequences. It becomes not only possible to have different taxes between symmetric regions (determined by number of immobile residents), but agglomeration rents can also create a race to the top where one would have expected a race to the bottom in a BTCM set-up.

3.4.3 Extensions

The bifurcation behaviour of the standard NEG-literature as discussed in section 3.2.3 is tomahawk-like (see figure 3-2). However, one could also create models where, besides CP- and symmetrical equilibria, stable locational equilibria occur with only partial agglomeration of firms in one of two regions. The clue to create these supercritical pitchfork-bifurcations, as noted by Borck and Pfluger ([19]), lies in the fact that further centrifugal forces are introduced or that centripetal forces are weakened. For instance, Pflüger ([101]) replaced the standard Cobb-Douglas upper-tier utility of expression (3.1) by a logarithmic quasi-linear utility. This in effect removes demand linkages in the manufacturing sector.

Borck and Pflüger ([19]) study tax competition in such a setting. They used a FE-model with a government levying head taxes on the mobile entrepreneurs to finance a public good. This good is absent in the utility function of the consumers (which leads to locational equilibria independent from taxation) and only enters in an ad hoc governmental utility function. Just as was done by Baldwin and Krugman ([11]), they use the sequential Stackelberg game to tackle the tax competition. Based on these ramifications, they are not only able to confirm that the results of Baldwin and Krugman remain valid in a more advanced NEG-setting but they also show that the partial core can maintain a positive tax gap even though in these cases no agglomeration rents accrue to the mobile factor. In other words, agglomeration forces may provide a tax shield in less extreme situations than studied by Baldwin and Krugman ([11]).

Recently an interesting addition to the literature that combines NEG models and tax competition has been made by Egger and Seidel ([117]). They introduce labour market imperfections in a FC-model with tax competition. Unlike similar extensions of the standard tax competition literature (see subsection 2.3.7), they use a fair wage mechanism to introduce endogenous unemployment instead of unionisation. The government raises taxes on the mobile capital to provide a public good which enters in an ad hoc utility function of the government, not in the utility function of consumers. This makes the driving force of agglomeration, the capital reward differential between the two regions, independent from taxes. Based on this set-up, they confirm the race to the bottom result. Capital evades higher taxes which leads to higher unemployment rates in the regions compared to the Pareto situation. They also concluded that the more rigid labour market are, the lower the Nash tax rates become.

3.4.4 Policy implications

Based on the literature review described in chapter 2 and section 3.4 , one can divide the policy implications in two categories.

Unregulated tax competition

If the tax competition leads to an efficient provision of the public good without wasteful tax setting, there is no need to coordinate the tax setting. This is the case in all the models where the beneficiary of the public good is also the payer of the tax necessary to provide the public good (Tiebout, public input goods,..). It also occurs in those models where the tax payer, even if he doesn't derive utility from the public good, can't escape the taxation, e.g. residence-based taxation. The same efficient result can be obtained by using multiple tax instruments, although the inefficient choice between the different tax instruments can lead to redistributional problems.

Secondly there is also no need for any regulation if the tax competition attenuates the inefficient governmental behaviour. Governments can act inefficient if they are Leviathan or when there is vertical tax competition. This last argument is often cited by defenders of the neo-liberal thinking.

Tax coordination

Tax coordination is wanted from a social planner's point of view if there is a race to the bottom. Generally spoken, this happens as soon as the taxpayer is not the beneficiary of the public good paid for by him or her. This behaviour is not only limited to the BTCM, but can also happen in a New Economic Geography framework (see FC-model). Some of the extensions we discussed can reduce the importance or size of the race to the bottom. For instance, large regions who can affect the after-tax capital return rate face less detrimental effects of tax competition. The same holds for small regions or when public goods have positive spill-over effects to other regions.

A central government acting as a social planner can overcome the inefficient outcome in two ways. She can forbid or impose restrictions on some of the tax policies of the regions. Secondly she can use corrective subsidies to neutralize the inefficiencies of local tax competition. These policies have been suggested and discussed by Wildasin ([136], [137], [138]) and DePater and Meyers ([40]).

Tax harmonisation Contrary to popular belief, tax harmonisation is only applicable in a very limited number of cases: only when the regions are perfectly symmetric and have the same preferences, tax harmonisation achieves the first-best allocation. For instance, an equalisation of tax rates between a large and a small country would lead to an overprovision of the public good in the small country due to the small region advantage. Also when a region has a higher preference for equality between the different factors of production, a tax equalisation does not work as discussed by Cremer and Pestieau ([38]). Depending on the level of the shared tax rate, there is an overprovision of the public good in the low preference region or an underprovision of the public good in the high preference region.

And even in those cases were a tax harmonisation could be beneficial from the point of view of a social planner, there still may be two other problems. The first problem lies in the enforceability of the tax harmonisation scheme. If there are regions that deliberately set their taxes lower than agreed upon, the whole scheme becomes useless. Recent research however partially counters this problem. For instance, Konrad and Schjelderup ([68]) showed that a harmonisation amongst a subset of regions increases the welfare for all regions under the assumption that taxes are strategic complements. Another problem is the possible substitution effect between several policies. It becomes profitable for regions under a tax harmonisation agreement to change some other policies in order to attract the mobile factors. Cremer and Gahvari ([37]) developed a model where governments lower the probability that firms will be checked on their tax payments when the regions have agreed upon a tax harmonisation scheme.

Tax floors Baldwin and Krugman ([11]) show that a special form of tax coordination, namely tax floors may be welfare improving in a core-periphery situation. As explained in section (3.4.2) peripheral regions set their taxes first-best, while the core regions are constrained and set their taxes suboptimally low. This means that the small country only wants to deviate from its chosen tax rate if it is compensated for it substantially. The large region only wants higher tax rates. This problem can be solved by agreeing that the communal tax rate should be set just below the optimal tax for the south. The north can now base its optimal tax on this tax rate that is higher than the no break tax rate. As a result the north can increase its tax rate. This scheme is obviously only a weak Pareto improvement as the southern region does not gain from the tax coordination. And the same caveats mentioned in the paragraph before hold.

Corrective policies The use of corrective subsidies in a BTCM framework haven been investigated by Wildasin ([136], [137] and [138]) and DePater and Meyers ([40]). Typically this corrective subsidy consists of a lump sum transfer combined with a corrective subsidy on the tax revenue of each region. This subsidy is region dependent meaning that two regions levying the same tax can have different subsidies. These corrective policies solve the underprovision problem of the BTCM.

Unfortunately corrective policies face a number of problems. The first problem lies in informational asymmetries. Central governments often have less information than local governments. As Bucovetsky, Marchand and Pestieau ([27]) showed this can lead to an over- or undercorrection of the central authority. The second problem lies in the vertical tax competition that may occur as soon as the central government levies taxes on the same factors as the local government. This problem has already been discussed in section 2.3.6. And of course, in order to impose a central government subsidy, one needs a central government and local governments who are willing to renunciate their sovereignty to a supranational level.

3.5 Conclusion

Recently location and agglomeration received a lot of attention in economic literature. Although this growing literature is still quite new, there have been made some theoretical efforts to study tax competition in a framework of these New Economic Geography settings. While in the classical tax competition literature everything evolves continuously, NEG models are discontinuous by their very nature. This created the scope for some new and exciting contributions to the tax competition literature.

For instance, detrimental tax competition can occur in models without any mobility of factors of production. This indicates that it is not the mobility of goods or factors that is crucial to the race to the bottom but the nature of the public good is. Secondly, some of the newly developed models also showed that increased globalisation (via capital mobility) in a symmetrical locational equilibrium leads to higher tax rates, which is a result never obtained in tax competition models where the beneficiary of the public good is not the mobile payer of the public good. Thirdly and perhaps the most well-known result of this literature, is the possibility that core regions can tax agglomeration rents without risking any delocation.

Although these features are definitely new, most contributions still confirm a race to the bottom result. As it turns out, it is not that easy for governments to overcome this result. Tax coordination schemes such as full tax harmonisation or corrective subsidies face many problems. Often they are not enforceable or they lead to substitution effects between vertical organised governments or between different policy options. Sometimes they are even not applicable. For instance, a tax harmonisation for small and large regions is destined to fail. An interesting way of thinking is the introduction of tax floors by Baldwin and Krugman. This can lead to a weak Pareto improvement in a core-periphery situation.

Besides reviewing these recent contributions to the tax competition literature, we also investigated an often neglected aspect of New Economic Geography models, namely their dynamics. A first investigation of the dynamics of NEG-models seems to affirmatively answer the question whether these dynamics are important. All models exhibit strong trade freeness dependence in their dynamical behaviour. The lower the trade costs are, the longer it takes before the system starts to evolve toward the long run equilibrium state.

The dynamical behaviour of the discussed models also differ greatly. In general the evolution toward the long run stable equilibrium is faster in CP- and FE-based models than in FC-models. For values of trade freeness below the CP-sustain point, the FE-like models evolve faster toward the final equilibrium than CP-models. For high values of trade freeness the reverse is true. The VL-models have the same transitional evolution as the migration-based models. We showed that the influence of regional asymmetries through a deviation in labour or capital share is different in the discussed models. The only models that are strongly influenced by a realistic change in the labour share are the CP-based models.

A policy maker wants to avoid that his region becomes a periphery. The above conclusions give indications for the time he or she has to intervene in order to change the unwanted evolution. They also indicate the importance that the initial condition and the trade freeness have on this transition. For instance, a policy maker of a core-region in a FEVL-setting has very little time to take action for values of trade freeness below the sustain point. The same policy maker but this time in a FC-setting and for high values of trade freeness disposes over a huge amount of time to change the evolution. In some cases a timely increase of trade freeness suffices to maintain the core solution. In other cases (CP-model) measurements to attract southern workers are efficient decisions.

One can draw two general policy warnings based on the results of this section. First, the differences between the models clearly show that one cannot freely interchange the NEG-models although they are mathematically similar as Robert-Nicoud proved ([113]). Secondly we advise some caution if one wants to use the FC(VL)-model as an analytical tractable variant of the FE- or CP-model, especially if one draws conclusions for regions with low interregional trade costs. This is often done in the study of NEG policy implications (and as we will do also). This means not that we cannot use the simpler models, but it stresses the importance of using a factor in the migrational equation of the FC(VL)-model to adjust its dynamical evolution to the other models as the shape of the transitional process is similar for all the discussed models.

We emphasize the fact that policy implications based on the dynamical analysis performed in this chapter remain very tentatively. Firstly the model badly reflects the reality because in real life more than two regions exist, labour markets aren't perfect, regions don't have identical technologies, ... Secondly the calibration of the time steps remains very tentatively. It could well be, for instance, that 1 time step coincides in reality with 5 years or 50 years. Further research could try to calibrate empirically the time scale in the above-mentioned models.

Chapter 4

Motivation of the set-up

We model the tax setting behaviour of a government that might care for the unemployed and that is constrained by the other government's tax setting behaviour in its ability to set unemployment benefits at a level it feels is 'right'. In other words, we determine the condition for social security competition (seen from the expenditure side) in a standard Dixit-Stiglitz framework of international trade in which we included endogenous unemployment and governments that want to redistribute between the employed and the unemployed. In this way we differ in three respects from a first-best case. There are product market imperfections (monopolistic competition), labour market imperfections (unemployment via efficiency wages) and governments taxing labourers to raise revenue for an unemployment benefit.

The tax competition literature discussed in chapters 2 and section 3.4 serves as a benchmark. The dominant strand in the large neo-classical literature concerning tax competition is a race to the bottom result. The same holds, although less unambiguously, for the NEG tax competition literature. The model that resembles most closely our set-up is the recent work of Egger and Seidel ([117]) of 2008. However, their model still lacks the presence of a government that provides insurance against that social risk.

We opt for a social security competition model in the framework of the new economic geography instead of the perhaps more simpler standard neo-classical set-up of Zodrow and Mieszkowski ([144]). The reasons for this are fourfold. Besides the purely academic interest to expand further the modelling framework of the NEG-models, this set-up also allows us to introduce a race to the bottom result in a model without any mobility of factors of production.

In other words, goods mobility suffices to create strong negative pressures on our social welfare states. This intuitive idea already appeared in the work of Ottaviano and Forslid ([97]) but for the first time, it no longer hinges upon factors of production[1]. International goods competition is enough. Thirdly we believe that including agglomeration effects in this set-up better reflects the European economic reality with core and peripheral regions. Lastly, we are able, by introducing unemployment via efficiency wages, to construct a New Economic Geography model that is as tractable as the footloose capital model of Martin and Rogers but that has almost the same characteristics of analytically more difficult models like the CP-model of Krugman or the FE-model of Ottaviano and Forslid.

We now discuss subsequently the specific assumptions of our model that lead to the three deviations from the first-best world, namely the product market imperfections via the Dixit-Stiglitz-Spencer framework, the labour market imperfections via an efficiency wage mechanism and the government facing an Atkinson equity-efficiency trade-off.

4.1 A Footloose Capital Dixit-Stiglitz monopolistic competitive framework

In a Dixit-Stiglitz monopolistic competitive framework ([41]) consumers maximize a constant elasticity of substitution utility function that is symmetric in a bundle of differentiated goods. This reflects the varietas delectat of consumers. In the formulation of Martin and Rogers ([88]) the non-homothetic cost function associated with these differentiated goods has a fixed capital cost component (ensuring increasing returns to scale) and a variable labour cost component (linear technology). The absence of economies of scope and simple parsimony creates the bijective relation between firms and varieties: each variety is produced by only one firm and one firm only produces one variety.

In maximising their profit, firms are considered to act atomistically by neglecting the impact their decision has on the overall market conditions. This Chamberlinian large group assumption is one of the main reasons for the tractability of the Dixit-Stiglitz framework. Trade between the regions is, in a non-autarkic case, inhibited by iceberg trade costs. This means that a certain

[1] Ottaviano and Forslid came to this conclusion based on a constructed capital model of Baldwin.

fraction of the transported good 'melts' away during transport (hence 'iceberg'). Under free entry and exit of firms on the market, these assumptions will lead to a demand system where the equilibrium prices are a constant mark-up over marginal costs. With imperfect competition, the optimal price-marginal cost mark-up depends inversely on the degree of competition. As a consequence these forms of modelling imperfect competition become analytically highly complex. A second reason for the widespread use of Dixit-Stiglitz models — and again an outcome of the invariance of the mark-up — is the mill pricing by firms. Firms fully pass on the transportation costs to the consumers. A firm's producer price is the same for sales to all markets. Thirdly the elasticity of substitution σ is an easy indicator of the degree of competitiveness in the market. The higher σ becomes, the closer the market structure starts to resemble perfect competition.

The above mentioned reasons explain the widespread and dominant use of the Dixit-Stiglitz model in international trade. But the analytical workability of a Dixit-Stiglitz set-up comes at a price. The price elasticities of demand are constant and identical to the elasticities of substitution and equal to each other across all varieties. This entanglement of demand and supply parameters makes it difficult to assess the impact of demand or supply separately on the equilibrium. The constant elasticity of substitution also means that people have the same substitution behaviour independent from the amount consumed of the goods. Besides the lack of identification in comparative static analysis, the modelling set-up also leads to prices that are independent of the spatial distribution of firms and consumers which conflicts results in spatial pricing theory (Anderson, de Palma and Thisse, [2]). Finally, the iceberg assumption implies that trade costs increase as the price of the transported good increases which is highly unlikely. Sometimes one also finds it more convenient to ignore the income effects present in a Dixit-Stiglitz setting.

A possible answer to these critics lies in the use of other utility functions. For instance the Ottaviano-Thisse utility function ([98]) lacks income effects and has a perhaps more realistic definition of the trade costs. Unfortunately as it turns out this set-up does not lead to workable solutions[2]. Simulations of the model, although the analytical results seemed promising,

[2] The full analytical working out of the Thisse model is available upon request. These calculations follow the same path as described in the following chapters 6 to 8.

encountered parameter problems. It was impossible to find parameter values that allowed for a well-behaved economical system.

The footloose capital framework of Martin and Rogers is the analytically most simple model of the New Economic Geography models. The main reason for its analytical workability is threefold. First, the only mobile factor is the fixed factor of production (capital) whereas in other models such as the core periphery model of Krugman ([72])) the variable and fixed factor of production are mobile. Secondly there is a dichotomy between the ownership of the mobile factor and the use of it. The owner does not relocate, the capital itself can relocate. This implies, contrary to the footloose entrepreneur model of Ottaviano and Forslid ([97]), that there are no circular causalities in the FC-model. Besides the analytical tractability of the footloose capital model, it also reflects best, in our opinion, the European context where full labour mobility is a very strong assumption (Krieger and Fernandez, [71]). The third reason for choosing this set-up and perhaps the most important one, lies in the fact that we can simplify our model by abolishing the traditional A-sector of NEG-models without destroying the agglomerative characteristics of our set-up. In most NEG-models a second Walrasian sector is needed to ensure that in core-periphery equilibria, each region preserves the possibility to consume. Since the owners of the mobile factor do not move and receive the rewards to capital irrespective of the location of the employment of the capital each region always has a certain expenditure level. Moreover, it would be difficult to introduce endogenous unemployment in a model with a second perfect Walrasian sector without making additional strong assumptions about the nature of the production factors in that sector. This is for instance the problem that Egger and Seidel ([117]) face. When labourers inelastically supply labour and when there is a Walrasian sector with constant returns to scale that can accommodate all labourers, unemployment becomes unnatural.

As stated above, one of the drawbacks of using a non-homothetic cost function as in the footloose capital model lies in the loss of some of the core-periphery features such as circular causality, locational hysteresis and endogenous asymmetry. However, as it turns out, some of these features are restored in our asymmetric tax competition model by introducing unemployment via efficiency wages. Another possible shortcoming lies in the transitional behaviour of the footloose capital model. Although all New Economic Geography models have an identical mathematical structure as Robert-Nicoud ([113]) proved, that does not mean that all exhibit similar dynamical results. This has been discussed in section 3.3. Finally by reforming the footloose capital model from a two-sector to a one-sector model, we expose the whole economy of a region to international trade. All goods produced are tradables. As non-tradable services form a dominant share of GDP in modern western economies[3] this assumption is quite strong. A possible way to correct for this in our model, is reducing the level of the trade freeness. We act as if the traded and non-traded goods and services are reshaped to traded goods but subject to higher transaction costs.

4.2 Unemployment via efficiency wages

The second deviation from a first-best case in this model is the introduction of unemployment via efficiency wages (Stiglitz, [123]). The main idea behind the efficiency wage hypothesis is that the net productivity of a worker depends positively on the worker's net real income albeit at a decreasing rate. This approach has achieved recently increasing support in the literature (e.g. Kreickemeier and Nelson ([70]) and Grossman and Helpman ([59])) as it is a simple tool to endogenise unemployment.

We use the formulation of Summers ([126]) of efficiency wages where the delivered effort by a worker is positively correlated with the difference between the net wage $w(1-z)$ and a reference wage w_R:

$$a(w) = (w(1-z) - w_R)^{\beta}, \tag{4.1}$$

in which z represents the tax rate set by the government on the gross wage w. The strength of the productivity enhancing effect of higher wages is characterized by β and lies between 0 and 1. The reference wage w_R represents the outside option for the worker. In conclusion, labourers inelastically provide labour and their efficiency depends on the wage offered by the firms.

As pointed out by Stiglitz ([124]) one could motivate the link between wages and workers' productivity for at least five reasons. First, firms don't want to lower wages even if there

[3] 70% or more of GDP stems from services in EU, Japan and U.S. (http://www.ecb.int/mopo/eaec/html/index.en.html).

is an excess supply of labour because high wages reduce labour turnover and hence, training costs. Other theories are based on imperfect and asymmetric information. Firms could have difficulties to assess the characteristics of workers or could face problems in monitoring the labour effort of workers. In the former case, labourers get a higher wage in order to defer lower skilled persons to apply. In the latter case the increased cost of shirking induces the desired behaviour from the workers. The fourth theory stems from the development literature and states that higher wages allow for a level of nutrition above the subsistence level which promotes effort. The last justification for the efficiency wage hypothesis is called the fair wage hypothesis (Akerlof, [1]) or the gift exchange hypothesis (Layard, Nickell and Jackman, [75]). These reciprocity-based voluntary cooperation arguments imply that, if the employee perceives the action of the employer as kind or fair, he will value the employer's payoff positively and as a consequence will deliver a higher effort level. Experiments indicate that employees indeed respond to higher wage offers, combined with higher expected effort, with higher effective effort (Falk and Fehr, [49]).

As could be expected these different explanations give different purports to the reference wage. The traditional approach in choosing the reference wage w_R in efficiency wage models consists in taking the immediate alternative for the worker who may be fired, which may be the unemployment benefit or the weighted average of the wage and unemployment benefit. This approach is thus mainly based on the third motivation of efficiency wages. However, Danthine and Kuman ([39]) argue that this definition of the external wage reference is unable to explain why wage rigidities generate unemployment, since the reference wage is correlated with labour demand. As a consequence, the reference wage can be put by the government at a sufficiently low level such that the labour market clears. Hence, we propose a definition of the reference wage that is independent from the actual market wage or unemployment allowance. A reference wage based on the gift exchange hypothesis is in line with this critique: the reference wage is the wage that would apply if all the workers behaved selfishly, i.e. the market-clearing wage[4]. Or in other words, we define the reference wage in a normative out-of-the-box way as the worst-case scenario for the workers. This definition of the outside option also avoids the

[4] This also implies that the tax rate set by the government equals zero as there are no unemployed people who need an unemployment benefit.

contradiction of a government able to do the first-best chooses for the second-best options. A purely redistributing government is no longer able to remedy any unemployment occurrence by setting the unemployment benefit low enough to ensure that everybody is willing to work. The use of efficiency wages to introduce the social risk of unemployment instead of the mechanism of wage bargaining between employers and trade unions (eg. Lejour and Verbon ([78]) and Leite-Montero et al. ([77])), also resides in the same reason since the government (or median voter) that anticipates the behaviour of the private economic agents (sequential game), could also have restored the first best equilibrium in this case, e.g. by deciding a sufficiently low unemployment benefit in order to restore full employment.

4.3 A government facing an equity-efficiency trade-off

The presence of a redistributing government constitutes the third deviation from the first-best situation. She compensates one market distortion (unemployment) by granting benefits to the unemployed. In order to do so, she has to raise taxes which creates additional distortions in the economy. We assume that the government only raises taxes on labour, not on capital. In most EU countries the tax base consists primarily of immobile production factors, labour in the first place. Mobile factors are largely exempted from taxation, either because of tax competition or because of economic efficiency reasons. E.g. Lindert ([82]) argues that the difference between the welfare state in Europe and the US is not matched by differences in economic efficiency because the structure of taxation in Europe is less distortionary, considering the greater share of labour taxation and consumption taxes in the European government revenue.

The amount of taxes and redistribution is determined by maximising an Atkinson abbreviated social welfare function $\int \frac{x^{1-e}}{1-e} f(x)dx$, when $e \neq 1$ and $\int \log(x) f(x)dx$ when $e = 1$. $f(x)$ represents the probability density function of (real) incomes x in society and $0 \leq e$ is the inequality aversion parameter. This formulation has many desirable characteristics. The utility of each individual $\frac{x^{1-e}}{1-e}$ is symmetric (anonymity) and only depends on the income of that individual, thereby asserting the self-interest of people. This average utility expression for the social welfare also encompasses the principle of transfers (negative second order derivative) and the principle of diminishing transfers (positive third order derivative): a fixed income transfer from a poor person to a rich person decreases the social welfare and this decrease is stronger the lower the income of both persons is. Lastly this representation of social welfare also has the property of equiproportionate income growth neutrality as the coefficient of relative inequality aversion (the elasticity of marginal utility) is constant.

To see that the Atkinson abbreviated social welfare function includes an equity-efficiency trade-off, it suffices to rewrite it in terms of the equally distributed equivalent income ξ, which is defined as the income that, if distributed equally, would generate the same welfare as the existing income distribution ($\frac{\xi^{1-e}}{1-e} = \int \frac{x^{1-e}}{1-e} f(x)dx)$[5]. Since the Atkinson index of relative inequality is defined as the fraction of income that could be sacrificed with no loss of welfare if all income was distributed equally ($I(e) = 1 - \frac{\xi}{\mu}$), the Atkinson abbreviated social welfare function can be rewritten as $\frac{1}{1-e}(\mu(1-I))^{1-e}$ if $e \neq 1$ and $\log(\mu(1-I))$ otherwise. More efficiency (average μ) increases the social welfare as more equity does (inequality index $I(e)$). Based on this new formulation of the Atkinson abbreviated social welfare function, it is straightforward to show that the elasticity of social welfare with respect to equity equals the elasticity of social welfare with respect to efficiency and that both are equal to $1-e$.

Although this concept of social welfare is analytically more complex than an ad hoc social welfare function (e.g. $SW = \lambda U(\text{unemployed}) + (1-\lambda)U(\text{employed})$), we prefer this formulation because it has the main advantage of allowing all possible attitudes towards inequality. If $e = 0$ the government behaves Benthamite and only wants to maximize total sum of (indirect) utilities of its citizens. If, on the other hand, $e = \infty$ the Rawslian government only cares for the well-being of the poorest person of society and devotes no attention at all to efficiency. It also avoids the use of more than one inequality aversion parameter as soon as there are more than two subgroups in society.

In our model there are three individual sources of (real) income: labour income $\frac{w(1-z)}{P}$, unemployment benefits $\frac{b}{P}$ and capital rewards $\frac{CR}{P}$[6]. We assume that the capital rewards are evenly distributed between each individual whether he or she is employed or unemployed. This simplifies the interpretation of the governmental choice since we don't have to introduce a third

[5] If $e = 1$, this becomes $\ln(\xi) = \int \log(x)f(x)dx$.

[6] We divided the nominal incomes (net wage $w(1-z)$, unemployment benefit b and capital reward CR) each time by the price index P to express everything in real terms. Note that labourers don't receive their gross wage but only their wage net of taxes, hence $w(1-z)$.

class of people, namely the capital owners who lead a life of leisure and whose income solely rely on some fixed exogenous parameters on which the government has no influence[7]. As it turns out, the expression for the capital rewards that are evenly distributed among the labour force in a Dixit-Stiglitz setting with efficiency wages is also a constant. This further simplifies the model by reducing the capital rewards to a scaling factor in the indirect utility of the employed and the unemployed. Taking these income assumptions into account, we can restate the Atkinson social welfare as:

$$SW = \begin{cases} \frac{1}{1-e}\left[\sum_{i=1}^{2} f(x_i)x_i^{1-e}\right] = \frac{1}{1-e}\left[(1-u)(\frac{w(1-z)+CR}{P})^{1-e} + u(\frac{b+CR}{P})^{1-e}\right] & \text{for } (e \neq 1) \\ \sum_{i=1}^{2} f(x_i)\log(x_i) = (1-u)\log(\frac{w(1-z)+CR}{P}) + u\log(\frac{b+CR}{P}) & \text{for } (e = 1). \end{cases} \tag{4.2}$$

In this definition u stands for the unemployment rate. If $e = \infty$ the government acts in a Rawslian way and wants to maximize the income of the poorest individual, in casu the income of the unemployed $SW = \frac{(b+CR)}{P}$. A survey of empirical methods to evaluate the inequality aversion parameter empirically (see Stern [122] and Lambert [74]) reveals a wide range of possible values ranging between almost 0 and 10.

In the next chapter we start with the derivation of a model in an autarkic situation based on these assumptions. While this set-up is not very interesting, it enables us to form an analytical workable benchmark for the following chapters. In chapter 6 we introduce social security competition when there is no capital mobility, followed by a model under capital mobility in chapter 7. In this chapter we also derive the locational equilibria in this specific New Economic Geography framework with endogenous unemployment. We look at social security competition in an internal and in a CP-equilibrium.

[7] Except for the evident influence via the price index.

Chapter 5

Autarkic situation

5.1 Consumers' choice

The region is endowed with a fixed number of consumers L and a fixed amount of capital K. Each consumer j consumes an amount c_{ij} (at the price p_i) of a good i. The preferences of these consumers exhibit varietas delectat and are represented by maximising the following CES utility function:

$$U_j = (\int_0^n c_{ij}^{\frac{\sigma-1}{\sigma}} di)^{\frac{\sigma}{\sigma-1}}. \tag{5.1}$$

The integral runs over the exogenously given number of produced goods (n in total) and $\sigma(> 1)$ represents the elasticity of substitution between goods which is equal for all goods. Consumers are constrained by their budget. They cannot spend more on goods as their total income which equals their expenditures e_j as there are no savings in our static model:

$$\int_0^n p_i c_{ij} di = e_j. \tag{5.2}$$

Standard utility maximisation and aggregating the individual demand of all consumers lead to the following result for the market demand of a variety i:

$$c_i = (\frac{p_i}{P})^{-\sigma}(\frac{E}{P}). \tag{5.3}$$

where $E = \sum_{j=0}^{L} e_j$ stands for the total expenditures of the region and $P = (\int_0^n p_i^{1-\sigma} di)^{\frac{1}{1-\sigma}}$ is the price index. Hence $\frac{E}{P}$ is the regional real income. The consumption of a good i decreases as the price of that good increases ($\frac{\partial c_i}{\partial p_i} < 0$) as could be expected. It also increases as the real regional income increases.

Indirect utility V_j of a consumer j is determined by substituting c_{ij} in 5.1 with $(\frac{p_i}{P})^{-\sigma}(\frac{e_j}{P})$:

$$V_j = \frac{e_j}{P}. \tag{5.4}$$

Observe that P is a perfect price index in that real income defined with P is a measure of (indirect) utility.

5.2 Producers' choice

Each manufacturer i produces an amount x_i of only one good using a fixed amount of capital (k units) and a variable amount of labour l_i. The production function of a firm is given by:

$$x_i = a(w_i)l_i. \tag{5.5}$$

Note that the productivity parameter $a(w_i)$ depends on the wage (see section 5.3.1). Given the wage cost w_i and capital cost π_i, the total cost function TC_i is equal to:

$$TC_i = k\pi_i + l_i w_i. \tag{5.6}$$

Under the Chamberlinian large group assumption profit maximisation with respect to the price leads to the typical Dixit-Stiglitz monopolistic competitive price that is a fixed mark-up over marginal labour costs $\frac{w_i}{a(w_i)}$:

$$p_i = \frac{\sigma}{\sigma - 1} \frac{w_i}{a(w_i)}. \tag{5.7}$$

The mark-up over the marginal labour costs of the price, $\frac{\sigma}{\sigma-1}$ decreases when the elasticity of substitution σ increases. When markets are perfectly competitively ($\sigma = \infty$), price equals marginal cost and the producer's surplus is minimal.

We will show in the following section that the labour remuneration is independent from firm-specific parameters. This result allows us to determine in an easy way the price index P, the equilibrium firm scale x_{eq} and the reward to capital π_i. Integrating expression 5.7 over all varieties leads to the following expression for the price index:

$$P = n^{\frac{1}{1-\sigma}} \frac{\sigma}{\sigma - 1} \frac{w}{a(w)}. \tag{5.8}$$

Because there is free entry and exit of firms the zero-profit condition ($p \cdot c_i - w \cdot l_i - k \cdot \pi_i = 0$) has to hold. As a consequence, the sales S of a firm that are equal to pc – can be written – using expression 5.3 and 5.8 – as $\frac{E}{n}$.

Using the market clearing condition (consumption c_i equals production x_i) and expression 5.5 the zero-profit condition can be written as:

$$(p - \frac{w}{a(w)}) \cdot x_i - k \cdot \pi_i \overset{5.7}{=} \frac{p \cdot x}{\sigma} - k \cdot \pi_i = 0. \tag{5.9}$$

Based on this expression, we can easily derive the equilibrium firm scale x_{eq} and the reward to capital π_i. Re-using expression 5.7 in 5.9 gives the following result for the equilibrium firm scale x_{eq}:

$$x_{eq} = (\sigma - 1) \frac{k\pi}{\frac{w}{a(w)}}. \tag{5.10}$$

Firms become bigger as the fixed cost reward increases relative to the variable cost reward and become smaller when the operating profit margin decreases. By realizing that px equals the sales of a firm $S = \frac{E}{n}$ in the expression 5.9, the capital reward π_i is given by:

$$\pi_i = \pi = \frac{E}{n\sigma k}. \tag{5.11}$$

The capital reward depends inversely on the elasticity of substitution σ which should come as no surprise since the producer's surplus diminishes when markets become more competitive. Secondly, since the right-hand side of equation 5.11 is independent of i, the left hand side is also independent of i: all firms pay the same capital reward. The capital reward in our economy is thus determined as the Ricardian surplus of a typical variety.

Since each firm utilizes k units of capital, the total capital reward TCR of all firms is equal to $TCR = nk\pi = \frac{E}{\sigma}$. Dividing the TCR by the total number of inhabitants L in the region, gives us the constant capital income CR of each citizen in terms of σ:

$$CR = \frac{E}{\sigma L}. \tag{5.12}$$

5.3 Labour markets

5.3.1 Determination of the wage

A firm i determines the wage w employees receive by maximising their profit:

$$\max_{w}(p_i \cdot x_i - w_i \cdot l_i - k \cdot \pi_i). \tag{5.13}$$

With the help of the envelop theorem ($\frac{\partial x}{\partial w} = 0$[1]), the first order condition leads to the well known Solow condition:

$$\frac{w_i \dfrac{\partial a(w_i)}{\partial w_i}}{a(w_i)} = 1. \tag{5.14}$$

This condition states that the elasticity of the efficiency function with respect to the wage equals one. The firm keeps hiring additional people as long as the wage per unit of effort is falling.

The final expression for the employee's remuneration is given by combining expression 5.14 and the Summers expression for the efficiency wage $a(w) = (w(1-z) - w_R)^{\beta}$, with $0 < \beta < 1$. We find that the paid wage increases when the reference wage w_R or the effect of higher wages on the productivity increases (β):

$$w_i(z) = w(z) = \frac{w_R}{(1-\beta)(1-z)}. \tag{5.15}$$

Two interesting conclusions can be formed based on this reward to labour expression. First, the labourers' remuneration is independent of firm-specific parameters. As a consequence all northern firms behave identically. They pay the same rewards to the factors of production, produce at the same price and sell the same quantities. Secondly, while the gross wage increases

[1] Since the capital reward is the Ricardian surplus, the envelop theorem also applies to the capital reward.

when the tax on labour increases, the net wage does not. Any tax rise is fully passed through in price increases as the taxation needed for the social security benefits doesn't affect the effort delivered by the labourers.

Substituting the optimal wage 5.15 set by the firms in the Summers' expression of efficiency wages lead to the optimal level of effort procured by the workers:

$$a^{opt} = w_R^{\beta}(\frac{\beta}{1-\beta})^{\beta}. \tag{5.16}$$

5.3.2 Unemployment

We are now able to determine the level of unemployment in the region. Substituting expression 5.7 and 5.5 in the zero profit condition $(p \cdot x_i - w \cdot l_i - k \cdot \pi_i = 0)$ lets us determine the amount of labour each firm employs:

$$l_i = l = \frac{(\sigma-1)k\pi}{w}. \tag{5.17}$$

Each firm recruits less people when the wages rise. Since the capital reward 5.11 is constant in the autarkic case, the total amount of wages paid by all firms to their employees $\sum_{i=1}^{n} lw$ is also invariable. This means that, as could be expected, the tax set by a government does not have any influence on the tax base.

Since in our model all consumers belong to the active population, we can use expression 5.17 to derive an expression for the unemployment level $u(z)$:

$$u(z) = 1 - \frac{nl}{L} \overset{5.17}{=} 1 - \frac{n(\sigma-1)k\pi}{Lw} \overset{5.15,5.11}{=} = 1 - \frac{(\sigma-1)E(1-\beta)(1-z)}{Lw_R\sigma}. \tag{5.18}$$

5.3.3 Reference wage

The reference wage is defined as the wage that would apply if all the workers behaved selfishly, i.e. the market-clearing wage. At this wage level, there is no unemployment $(nl = L)$ and the government does not have to raise any taxes $(z = 0)$. Using expressions 5.17 and 5.11, this definition leads to the following expression:

$$w_R = \frac{(\sigma-1)}{\sigma}\frac{E}{L}. \tag{5.19}$$

The reference wage increases as the GDP per person rises but decreases when people appreciate varieties less. Substituting 5.19 in the expression 5.18, greatly simplifies the unemployment level in our model:

$$u(z) = 1 - (1-\beta)(1-z) = \beta + (1-\beta)\cdot z. \tag{5.20}$$

A simple look at this expression reveals that the unemployment increases when taxes increase and when people are less willing to put more effort into their work given a certain wage level.

5.4 Government

5.4.1 Price index and unemployment benefit in function of taxes

Our model is static and as a consequence, the government has to run a balanced budget. The total amount of taxes raised on the labour income ($nlwz$) must be equal to the total amount of benefits handed out to the unemployed ($(L - nl)b$). We use this balanced budget to write the unemployment benefit in terms of the tax rate set by the government:

$$b(z) = \frac{1-u(z)}{u(z)} w(z)\cdot z \overset{5.20,5.15}{=} \frac{w_R \cdot z}{\beta + (1-\beta)\cdot z}. \tag{5.21}$$

In the simple autarkic model, the unemployment benefit always increases when the tax rate increases. The unemployment benefit is also automatically lower than the reference wage and the net wage in the autarkic case. More formally the income of an inactive person is given by:

$$b + CR \overset{5.21,5.12,5.19}{=} \frac{\sigma - (1-\beta)(1-z)}{\sigma(1-(1-\beta)(1-z))}\frac{E}{L} \tag{5.22}$$

Since the average income of a citizen is given by $\frac{E}{L}$ we conclude that an inactive person has a lower than average income[2]. We also see that, contrary to the labourer whose income was independent from the tax rate, the income of an inactive person rises from CR when $z = 0$ to the average income for $z = 1$. This also validates our previous statement that Rawslian governments only care for the welfare of the unemployed. They always have the lowest income.

The price index 5.8 can be written in function of the tax rate with the help of 5.7 and 5.15:

[2] At the same time a labourer gets a higher than average income: $\frac{w_R}{1-\beta} + CR \overset{5.19,5.12}{=} \frac{\sigma-\beta}{\sigma(1-\beta)}\frac{E}{L}$, since $\sigma > \beta$.

$$P(z) = n^{\frac{1}{1-\sigma}} \frac{\sigma}{\sigma - 1} \frac{w_R}{a^{opt} \cdot (1-z) \cdot (1-\beta)}. \tag{5.23}$$

The derivative of the price index with respect to the tax rate is positive as could be readily verified using 5.23. Higher tax rates mean higher nominal wages which cause a price rice and hence a higher price index. We will use this result later on.

5.4.2 Benthamite case ($e = 0$)

When the government only has efficiency considerations, the social welfare the government wants to maximize is (see 4.2):

$$SW(e=0) = (1 - u(z)) \cdot \frac{w(z) \cdot (1-z) + CR}{P(z)} + u(z) \cdot (\frac{b(z) + CR}{P(z)}). \tag{5.24}$$

Using the balanced budget constraint, the wage definition 5.15 and unemployment definition 5.20, this can be simplified to:

$$SW(e=0) = \frac{CR + w_R}{P(z)}. \tag{5.25}$$

The first order derivative of (5.25) with respect to z equals:

$$\frac{dSW(e=0)}{dz} = \frac{-(CR + w_R)}{(P(z))^2} \frac{n^{\frac{1}{1-\sigma}} \cdot \sigma \cdot w_R}{(\sigma - 1) \cdot (1-\beta) \cdot a^{opt}} \frac{1}{(1-z)^2}, \tag{5.26}$$

which is clearly always negative because $0 < \beta < 1$ and $\sigma > 1$. Since the only way in which the utilitarian government can exert an influence on the social welfare is via the price index and since the effect of a tax raise on the price index is negative, a Benthamite government will always choose for the corner solution of a zero tax rate. As a consequence there will be no unemployment benefit while wages are equal to $\frac{w_R}{1-\beta}$ and unemployment becomes constant at the level β.

5.4.3 Rawslian case ($e = \infty$)

The other extreme is the situation of a Rawslian government. Now the government is only concerned with the welfare of the poorest, in casu the unemployed:

$$SW(e = \infty) = \frac{b(z) + CR}{P(z)}. \tag{5.27}$$

The optimal tax rate for the government in this case will depend on a comparative assessment between the positive effect a tax raise has on the unemployment benefit and the negative effect the same tax increase has on the purchasing power of the unemployed person. Both effects are easily determined via $\frac{dSW}{dz} = \frac{dSW}{dz}\Big|_{P=cst} + \frac{dSW}{dz}\Big|_{b=cst}$, where the first term on the right-hand side of the equation represents the benefit effect and the second term the price effect. Simple calculus leads to the following expressions for these effects:

$$\frac{dSW}{dz}\bigg|_{P=cst} = \text{benefit effect} = \frac{\beta w_R}{(\beta + (1-\beta)z)^2 \cdot P(z)} \tag{5.28a}$$

$$\frac{dSW}{dz}\bigg|_{b=cst} = \text{price effect} = \frac{-(b(z) + CR)}{(1-z) \cdot P(z)}. \tag{5.29}$$

The first order derivative $\frac{dSW}{dz} = \frac{dSW}{dz}\Big|_{P=cst} + \frac{dSW}{dz}\Big|_{b=cst}$ is equal to zero in the optimum. This leads to a quadratic equation in z of which the (largest) root is given by[3]:

$$z^{opt} = \frac{-\beta \cdot (w_R + (1-\beta) \cdot CR) + \sqrt{\beta \cdot w_R \cdot (w_R + (1-\beta) \cdot CR)}}{(1-\beta) \cdot (w_R + (1-\beta) \cdot CR)}. \tag{5.30}$$

Simplifying this expression by substituting the reference wage w_R by its definition 5.19 and the constant capital income of each individual CR by 5.12, shows that the corner solution of a zero tax rate only becomes possible if $\beta > \sigma - 1$. Or in other words, it becomes more likely for a Rawslian government to opt for a zero tax rate the higher the productivity enhancing effect of higher wages becomes or the stronger people prefer variety. The reason for this lies in a dominant price effect. For these extreme values of β and σ the price index approaches zero which makes everybody almost equally rich. As a result the government no longer sees the need

[3] The smallest root is always negative.

to redistribute. One can understand this more intuitively by realizing that these extreme values for β and σ coincide with a very high value for the capital reward per capita ($CR > \frac{W_R}{\beta}$). This high value in effect means that all people become (in the limit) equally rich. In this case, governments should focus on the real income of people and the best way to maximize the real income of their citizens is by setting taxes equal to zero.

5.4.4 General case

We already know that on the one hand, a utilitarian government will choose for a zero tax rate since any tax increase will reduce the efficiency of the economy. On the other hand a Rawslian government normally chooses for a positive tax rate as she is only concerned in the welfare of the unemployed person. In this subsection we generalize these conclusions by considering the general social welfare function. An inspection of 4.2 reveals that besides the effect a tax increase has on the purchasing power (the price effect) and the benefits (benefit effect), there is now also a third effect, namely the unemployment effect. Any tax increase will increase the unemployment and hence reduce the efficiency of the economy. Taking the total first order derivative of the general social welfare function with respect to the tax rate z and keeping the relevant variables constant ($\frac{dSW}{dz} = \frac{dSW}{dz}\big|_{P,u=cst} + \frac{dSW}{dz}\big|_{b,u=cst} + \frac{dSW}{dz}\big|_{b,P=cst}$) gives the expressions for the three effects:

$$\frac{dSW}{dz}\bigg|_{b,u=cst} = \text{price effect} = \begin{cases} \dfrac{-1}{1-z} & (e=1) \\ \dfrac{-(P(z))^{e-1}}{1-z}\Big[(1-\beta)\cdot(1-z)\cdot(\cdot\dfrac{w_R}{1-\beta}+CR)^{1-e}+ & \\ (\beta+z\cdot(1-\beta))\cdot(b(z)+CR)^{1-e}\Big] & (e\neq 1) \end{cases} \tag{5.31}$$

$$\left.\frac{dSW}{dz}\right|_{P,u=cst} = \text{benefit effect} = \begin{cases} \dfrac{\beta \cdot w_R}{(b(z)+CR)\cdot u(z)} & (e=1) \\[2ex] \dfrac{w_R \cdot \beta}{u(z)\cdot P(z)} \cdot (\dfrac{b(z)+CR}{P(z)})^{-e} & (e \neq 1) \end{cases} \tag{5.32}$$

$$\left.\frac{dSW}{dz}\right|_{b,P=cst} = \text{unemployment effect} = \begin{cases} (1-\beta)\cdot \log(\dfrac{b(z)+CR}{\dfrac{w_R}{1-\beta}+CR} & (e=1) \\[2ex] \dfrac{1-\beta}{1-e}\cdot \dfrac{1}{(P(z))^{1-e}} \cdot & \\[2ex] \left[(b(z)+CR)^{1-e} - (\dfrac{w_R}{1-\beta}+CR)^{1-e}\right] & (e\neq 1). \end{cases} \tag{5.33}$$

The sign of these effects in the general case are unambiguously determined. The price effect and the unemployment effect[4] are always negative, while the benefit effect is always positive. If we equate the sum of these three effects to zero, we would be able to derive an expression for the optimal tax rate. Unfortunately this is not analytically possible in the general case and therefore, we rely on simulations.

The parameters in this simulation are calibrated in such a way that comparability between the simple autarkic model and the subsequent more complicated models is facilitated. It also serves intuition. We set the non-crucial parameters $L = n = k$ equal to 1 and take the value 0.6 for β. Calibration in the two-country case made us choose this relatively high value for the leap-frogging effect compared to the value Summers suggest ([126]) since lower values of β (e.g. 0.1) lead in the two-country simulations to values of the unemployment benefit which were significantly higher than the net wage. We wanted to exclude these cases from our model. The elasticity of substitution is taken to be equal to 2.5. An alteration of these parameters will shift the curves but will not change the nature of the solutions.

As a first step we determine the optimal tax rate in function of the inequality aversion e.

[4] This can be seen by realizing that the net wage $w(1-z) = \frac{w_R}{1-\beta}$ always exceeds the unemployment benefit $b(z)$.

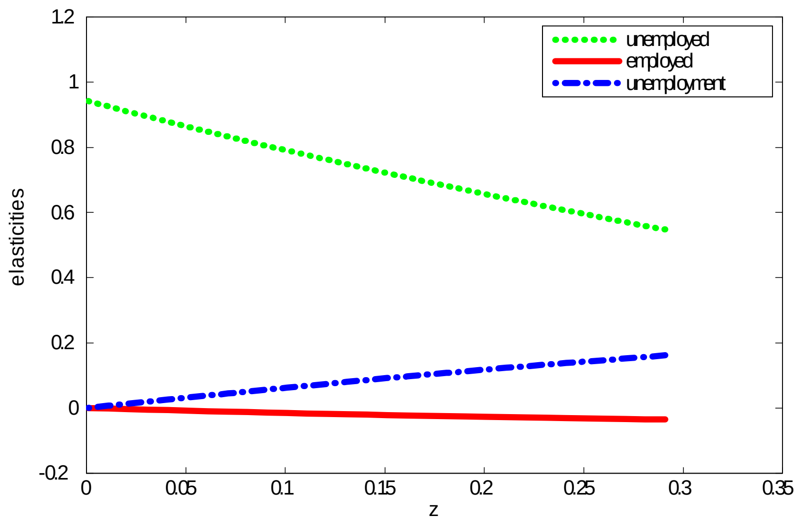

Figure 5-1: Elasticities of the real income of the employed, unemployed and unemployment rate with respect to the tax rate.

This is represented in graph **??**. We clearly see that as governments take greater care for the worse off persons in society, the tax rate increases. Only for low values of the inequality aversion parameter, the strongly utilitarian inclined government chooses not to levy any taxes. Table 5-2 gives some tax rates in function of the inequality aversion parameter e.

This result is general and can be understood be looking at a positive analysis of the effects of a tax change on the constituents of the social welfare function. In figure 5-1 we plot the elasticities of the real income of the unemployed (green dotted line), of the employed (full red line) and of the unemployment rate (blue dotted line) with respect to the tax rate. It is clear from this graph that a tax increase results in a positive effect on the real income of the unemployed while the effect on the real income of the employed is negative. The unemployment rate elasticity with respect to the tax rate is positive but small in absolute terms. When the inequality aversion increases, governments care more for the unemployed in the society. Since the weighting factor of their real income in the social welfare function (the unemployment rate) increases when the tax rate increases and since the elasticity of their real income with respect to the tax rate is positive, governments will choose for higher tax rates.

In our set-up the government with an inequality aversion parameter larger than 10 mimics

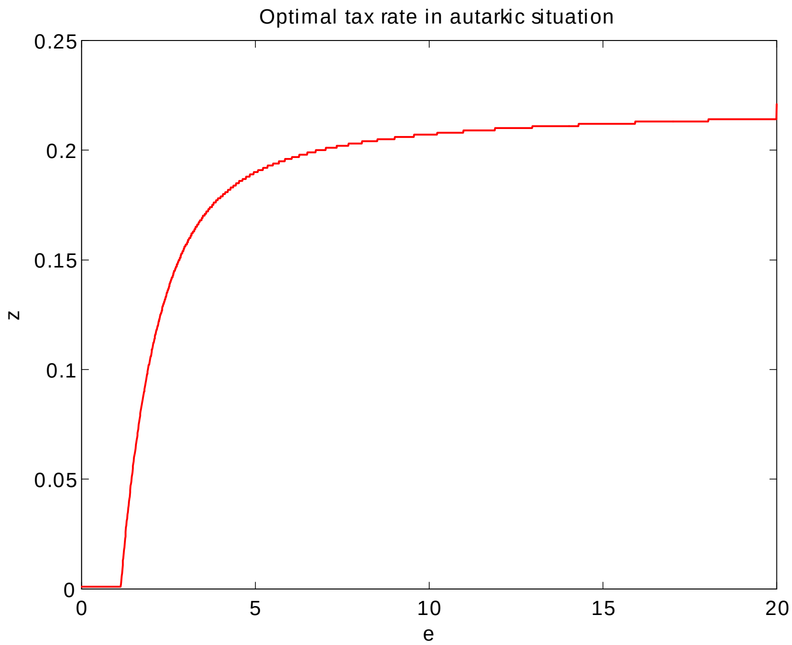

Figure 5-2: Optimal tax rate in function of inequality aversion e.

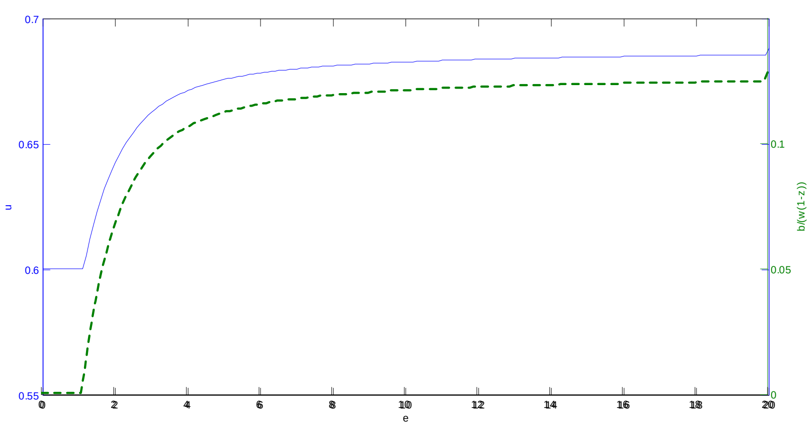

Figure 5-3: Unemployment rate u (full line) and the replacement ratio $\frac{b}{w(1-z)}$ (dotted line) in the optimum.

e	0	1	2	3	5	10	15	25	∞
$\mathbf{z}_{opt}$	0	0	0.107	0.17	0.19	0.207	0.212	0.215	0.221

Table 5.1: Optimal tax rates in function of inequality aversion

the Rawslian behaviour, formally defined at $e = \infty$. We also plot two important economic variables, the unemployment rate u and the replacement ratio $\frac{b}{w(1-z)}$ in the optimum for different values of the inequality aversion e. This is done in figure 5-3 where the left Y-axis gives the values for the unemployment rate and the right Y-axis measures the replacement ratio. We see that the unemployment rate is always high but increases steadily the more the government behaves in a Rawslian way. At the same time, the replacement ratio increases. Note however that this ratio remains quite small even for very high values of the inequality aversion. This can be explained by the minimal tax base remaining for Rawslian-like governments. Too much people need benefit funded by taxes from too few labourers remaining. It also stresses the importance of the price effect in the government's choice of the optimal tax rate. High values for the unemployment benefit lead to high values of the price index which causes in time a drop in the real income (= indirect utility) for the unemployed.

When σ is increased in the simulation, the optimal autarkic tax rates will also increase (e.g. $z_{opt}(e = \infty) = 0.346$ at $\sigma = 5$ and $z_{opt}(e = \infty) = 0.384$ at $\sigma = 8$). An increase in σ will increase the competition on the goods markets and hence, make the economy more efficient (a higher tax base). The income of the unemployed and the employed increases by the same amount (via the reference wage w_R). So the inequality index does not change. But given her fixed equity-efficiency trade-off, the government decides to raise her taxes. A rising elasticity of substitution σ also means that the capital reward CR given by 5.12 decreases. The share of capital income in the total income of an average resident $\frac{E}{L}$ becomes less important which makes deviations in the labour income (or unemployment benefit) more important.

The total expenditures level E and the number of inhabitants L in a region don't have any influence on the optimal tax rate. Both parameters only appear combined (as E/L) in the expression for the reference wage 5.19 and the capital reward 5.12 and hence don't influence the unemployment benefit or the net wage differently[5]. They only affect the price index and the

[5] Recall that a change in the reference wage has the same impact on the unemployment benefit b and the wage w.

average capital reward and a change in these can only lead to equiproportional changes in the social welfare function which don't affect the optimal choice of the tax rate (the SW-function only shifts up- or downwards) . On the other hand, a raise in the number of firms n and the units of capital required as a fixed cost k has a positive impact on the chosen tax rate. The reason for this lies in the combination of the decrease in the average capital reward and the increase (for n) or the status quo (for k) of the price index. The other constituents of the social welfare function, namely the unemployment benefit and the unemployment rate are invariant to a change of these two parameters as can be easily seen from 5.20 and 5.21. This causes a non-homothetic shift of the social welfare function. Otherwise said, the real increase of the indirect utility due to an increase of n or k is less strong for the unemployed than the employed and as a result of this, the government raises her taxes. Since this divergent evolution of the relative utility between the unemployed and the employed can only occur through the average capital reward and we don't focus on this constant term, we will assume in the subsequent chapters that the values of the parameters remain constant at $L = n = k = E = 1$.

5.5 Conclusion

The autarkic model in this chapter highlighted the underlying mechanisms present in our set-up. Governments equilibrate three mechanisms in choosing their optimal tax rate. Tax rate increases positively affect the unemployment benefit (benefit effect) but they have also two negative effects on the welfare of their residents. It not only increases the unemployment rate (unemployment effect) which reduces the tax base but it also increases the price index (price index effect). This last effect will reduce the indirect utility for labourers and non-labourers by reducing their purchasing power.

Secondly, we also illustrated the effect of the inequality aversion on the chosen tax rate. The more government value equity, the more they shift from Benthamite to Rawslian behaviour, the higher the optimal tax rate becomes. Since government in our general framework care for the indirect utility and hence also have to consider the price index effect, they will not opt for maximal tax rates even if they are Rawslian. Replacement ratio's remain limited to maximal 15%. Under some extreme conditions it is even possible that government with $e = \infty$ still opt for a Benthamite zero tax rate.

Thirdly we also investigated the role of some parameters on the optimal tax rate. For instance, higher values for the elasticity of substitution σ lead to higher chosen tax rates. Markets become more efficient but the equity of society does not change. Hence, government facing a given equity-efficiency trade-off will opt for higher tax rates in this situation.

Chapter 6

Two-country case without capital mobility

6.1 Consumers' choice

There are two regions, called the north and the south. We assume that both regions are symmetric in terms of consumers' tastes, technology, openness to trade and factor supplies. The northern region is endowed with a fixed number of consumers L^N, the south has L^S inhabitants. We also assume that the inhabitants of the northern region have an endowment of K^N units of capital while the south has K^S units of capital at its disposal. The worldwide capital endowment is denoted as $K^W = K^N + K^S$. We will often work with the capital shares instead of simple endowments: $s_K = \frac{K^N}{K^W}$ and $1 - s_K = \frac{K^S}{K^W}$. For reasons of expositional simplicity, we will limit the exposition to the northern region.

The constrained optimisation problem for the northern consumer j with an expenditure level e_j who consumes an amount c_{ij} (at the price p_i) of a good i is now equal to:

$$U_j = (\int_0^{n+n^*} c_{ij}^{\frac{\sigma-1}{\sigma}} di)^{\frac{\sigma}{\sigma-1}} \tag{6.1}$$

$$\text{s.t.} \int_0^{n+n^*} p_i c_{ij} di = e_j. \tag{6.2}$$

The integral runs over the exogenously given number of produced goods (n northern goods and

n^* southern varieties summing up to n^W).

Standard utility maximisation and aggregating the individual demand of all consumers lead to the following result for the northern market demand of a variety i:

$$c_i = (\frac{p_i}{P})^{-\sigma}(\frac{E^N}{P}). \tag{6.3}$$

where $E^N = \sum_{j=1}^{L^N} e_j$ [1]stands for the total northern expenditures and $P = (\int_0^{n+n^*} p_i^{1-\sigma} di)^{\frac{1}{1-\sigma}}$ is the northern price index[2]. The consumption of a good i decreases as the price of that good increases ($\frac{\partial c_i}{\partial p_i} < 0$) as could be expected[3]. It also increases when the income of the region increases.

Indirect utility V_j of a consumer j is determined by substituting c_{ij} in (5.1) with $(\frac{p_i}{P})^{-\sigma}(\frac{e_j}{P})$:

$$V_j = \frac{e_j}{P}. \tag{6.4}$$

Observe that P is a perfect price index in that real income defined with P is a measure of (indirect) utility.

6.2 Producers' choice

6.2.1 Prices

The production function x_i and the total cost function TC_i of a northern manufacturer i are, just as was the case in autarky given, by:

$$x_i = a(w_i)l_i \tag{6.5}$$

$$TC_i = k\pi_i + l_i w_i. \tag{6.6}$$

[1]For the south we have a similar expression $E^S = \sum_{j=1}^{L^S} e_j$. The sum of the northern and southern expenditures, the world expenditures is denoted as E^W.

[2]The southern price index is equal to: $P^* = (\int_0^{n+n^*} p_i^{1-\sigma} di)^{\frac{1}{1-\sigma}}$.

[3] $\frac{dc_{ij}}{dp_i} = e_j * p_i^{-\sigma-1} * P^{\sigma-1} * (-\sigma + (\sigma-1) * (\frac{p_i}{P})^{1-\sigma})$

This is negative iff $(\frac{p_i}{P})^{1-\sigma} < \frac{\sigma}{\sigma-1}$, which is always the case.

Contrary to the autarkic case, a firm now sells in two regions. The export to the southern region is inhibited by iceberg trade costs τ (> 1). The total production of a firm x_i is in equilibrium, when the markets clear, equal to the sum of the consumption of the good i in the north c_{iN} and the consumption of the good in the south c_{iS} multiplied by the trade costs:

$$x_i = c_{iN} + \tau * c_{iS}. \tag{6.7}$$

Under the Chamberlinian large group assumption profit maximisation with respect to the price that the northern firm applies in the north p_{iN} and in the south p_{iS}, leads to the typical Dixit-Stiglitz monopolistic competitive price that is a fixed mark-up over marginal labour costs:

$$p_{iN} = \frac{\sigma}{\sigma - 1}\frac{w_i}{a(w_i)}, \tag{6.8}$$

$$p_{iS} = \frac{\sigma}{\sigma - 1}\frac{w_i}{a(w_i)}\tau = \tau p_{iN}. \tag{6.9}$$

Comparing 6.8 and 6.9, it is clear that firms find it optimal to engage in mill pricing. The full shipping costs to the southern region are passed on to the southern consumers.

We will see in paragraph 6.3.1 that, similar to the case in autarky, the labourers' remuneration is independent of firm-specific parameters[4]. This means that prices (a fixed mark-up over marginal labour costs) and the consumption of a certain variety c_i are non-specific to firm characteristics (albeit region-specific). All northern varieties are hence produced in the same amounts and also sold in the same amounts on each market. This allows us in the subsequent elaboration of the model to introduce four 'kinds' of goods: a 'northern' variety sold in the north, a northern variety sold in the south, a southern variety sold in the south and a southern variety sold in the north. The prices and amounts consumed of these types of goods are respectively given by:

$$p_{NN} = \frac{\sigma}{\sigma - 1}\frac{w}{a(w)}, \qquad c_{NN} = (\frac{p_{NN}}{P})^{-\sigma}\frac{E^N}{P}, \tag{6.10}$$

$$p_{NS} = \frac{\sigma}{\sigma - 1}\frac{w}{a(w)}\tau, \qquad c_{NS} = (\frac{p_{NS}}{P^*})^{-\sigma}\frac{E^S}{P^*}, \tag{6.11}$$

[4] The optimised labour productivity a^{opt} will also become independent from the wage w.

$$p_{SS} = \frac{\sigma}{\sigma - 1}\frac{w^*}{a^*(w^*)}, \qquad c_{SS} = (\frac{p_{SS}}{P^*})^{-\sigma}\frac{E^S}{P^*}, \tag{6.12}$$

$$p_{SN} = \frac{\sigma}{\sigma - 1}\frac{w^*}{a^*(w^*)}\tau, \qquad c_{SN} = (\frac{p_{SN}}{P})^{-\sigma}\frac{E^N}{P}. \tag{6.13}$$

6.2.2 Price indices

Based on the previous four expressions for the prices, we can work out the northern and southern price index as follows:

$$P = \alpha\frac{w^*}{a^*}(\epsilon s_n + (1 - s_n)\phi)^{\frac{1}{1-\sigma}} = \alpha\frac{w^*}{a^*}\Delta^{\frac{1}{1-\sigma}} \tag{6.14}$$

$$P^* = \alpha\frac{w^*}{a^*}((1 - s_n) + s_n\epsilon\phi)^{\frac{1}{1-\sigma}} = \alpha\frac{w^*}{a^*}(\Delta^*)^{\frac{1}{1-\sigma}}. \tag{6.15}$$

We grouped the constant parameters in $\alpha = \frac{\sigma}{\sigma-1} \cdot (n^W)^{\frac{1}{1-\sigma}}$. We also redefined the number of firms in each region (n and n^*) in terms of shares: $s_n = \frac{n}{n^W}$ is the share of northern firms, $1-s_n$ the share of the southern firms. Note that in a two-country model without capital mobility the share of capital employed in the northern region s_n, is per definition equal to the initial endowment of capital s_K. $\phi = \tau^{1-\sigma}$ represents the well-known freeness of trade which can also be described as the economic distance between the two regions. That is, the freeness of trade rises from $\phi = 0$, with infinite trade costs, to $\phi = 1$, with zero trade costs. In this way we defined two important variables in our model in a compact space. This is handy for inspection of the expressions and also makes the numerical simulations later on more reliable. The last, yet to explain variable is ϵ, which is equal to the northern relative production costs raised to the power $(1 - \sigma)$: $(\frac{w/a(w)}{w^*/a^*(w^*)})^{1-\sigma}$. When the north has lower (higher) production costs than the south, ϵ is larger (smaller) than 1. So ϵ can serve as a measure of the relative competitiveness of the northern region versus the southern region and varies in principle between 0 and ∞.

By writing the price indices in function of Δ and Δ^*, we can see that each price index is composed of a part stemming from the sales of the domestic firms and a part stemming from imports, weighted by the economic distance between the two regions ϕ, the relative competitiveness ϵ or both.

6.2.3 Sales and the equilibrium firm scale

In a next step we determine the sales of a firm in function of the share of expenditures s_E. We will use this later on when we focus on the capital reward. The total sales of a northern firm S equal the sum of his sales in the north ($p_{NN} \cdot c_{NN}$) and the sales in the south ($p_{NS} \cdot c_{NS}$). This can under the market clearing condition be written as:

$$S = p_{NN} \cdot c_{NN} + p_{NS} \cdot c_{NS} = p_{NN} \cdot (c_{NN} + \tau c_{NS}) = p_{NN} \cdot x. \tag{6.16}$$

Using the definition of the consumption and prices of northern goods sold in the north 6.10 and the south 6.11, we can rewrite the northern sales as:

$$S = \frac{\sigma}{\sigma - 1} \frac{w}{a} E^W \left(\frac{(\frac{\sigma}{\sigma-1} \frac{w}{a})^{-\sigma} s_E}{P^{1-\sigma}} + \tau(1 - s_E) \frac{(\tau \frac{\sigma}{\sigma-1} \frac{w}{a})^{-\sigma}}{(P^*)^{1-\sigma}} \right).$$

In this expression we used the new notation s_E that stands for the share of expenditures which is also equal to $\frac{E}{E^W}$.Substituting the northern and southern price indices with the appropriate expressions 6.14 and 6.15 allows for the following simplification of the sales in terms of the share of expenditures:

$$S = \frac{E^W}{n^W} \epsilon \left[\frac{s_E}{\Delta} + \frac{\phi(1 - s_E)}{\Delta^*} \right] = \frac{E^W}{n^W} B. \tag{6.17}$$

The southern sales S^* are similarly derived:

$$S^* = \frac{E^W}{n^W} \left[\frac{\phi s_E}{\Delta} + \frac{(1 - s_E)}{\Delta^*} \right] = \frac{E^W}{n^W} B^*. \tag{6.18}$$

By realizing that $s_n \cdot B + (1 - s_n) \cdot B^* = 1$, it is easy to interpret the B's in 6.17 and 6.18 as the biases in sales, as the extent to which the sales of a variety exceeds the world average per variety sales. This is a familiar way of writing sales in a NEG-framework. A closer look at 6.17 and 6.18 shows that a price increase always reduces the sales of a firm ($\frac{\partial S}{\partial p_{NN}} < 0$) which should come as no surprise since the elasticity of substitution $\sigma (> 1)$ equals the elasticity of demand in a Dixit-Stiglitz framework. Secondly, it is easy to derive that an increase of the share of expenditures in the home country of the firm always increases the sales of the firm

($\frac{\partial S}{\partial s_E} > 0 \Leftrightarrow 1 > \phi^2$, which always holds[5]).

To determine the equilibrium firm scale, we apply the zero-profit condition which equates the operating profit to the total capital reward. The operating profit of a northern firm equals $S - w \cdot l$, which can be written as $p_{NN} \cdot x - \frac{w}{a} \cdot x = p_{NN} \cdot \frac{x}{\sigma}$ using 6.5 and 6.10. As a consequence the equilibrium firm scale of a (northern) firm is equal to:

$$x^{eq} = \frac{(\sigma - 1)\, k\pi}{\frac{w}{a}}. \tag{6.19}$$

Firms become bigger as the fixed cost reward increases relative to the variable cost reward and becomes smaller when the operating profit margin decreases. This mimics the autarkic case result.

6.2.4 Capital reward

Since physical capital is only used in the fixed cost component of industrial production, the reward to capital is the Ricardian surplus of a typical variety, that is, the operating profit of a typical variety divided by the units of capital k used to produce one differentiated good[6]. We get the following expressions for the capital reward of the north π and the south π^*:

$$\pi = \gamma\epsilon \left[\frac{s_E}{\Delta} + \frac{\phi(1 - s_E)}{\Delta^*}\right] = \gamma B, \tag{6.20}$$

$$\pi^* = \gamma \left[\frac{\phi s_E}{\Delta} + \frac{(1 - s_E)}{\Delta^*}\right] = \gamma B^*. \tag{6.21}$$

Due to the symmetry of our model ($k = k^*$), the regrouping of a string of constant parameters, $\gamma = \frac{E^W}{k \cdot \sigma \cdot n^W}$, is the same for both regions. Since $0 < s_n < 1$ and $\epsilon > 0$, Δ and Δ^* will always be positive. This lets us conclude that, if s_E lies between 0 and 1 (as it will), both the profit in the north and in the south are positive. The positivity of both expressions is important for the numerical simulations later on.

[5] $\frac{\partial S}{\partial s_E} = \frac{E^W}{n^W}\left[\frac{1}{\Delta} - \frac{\phi}{\Delta^*}\right]$ is positive if and only if $\frac{1}{\Delta} > \frac{\phi}{\Delta^*}$, which can be rewritten using the definition of Δ and Δ^* as $1 - s_n > (1 - s_n)\phi^2$.

[6] The reward to capital would be bid up to the point where it equalled the operating profit as noticed by Baldwin et. al.([10]).

6.3 Labour markets

6.3.1 Determination of the wage

A firm i determines the wage w_i employees receive by maximising their profit:

$$\max_{w_i}(p_{iN} \cdot c_{iN} + p_{iS} \cdot c_{iS} - w_i \cdot l_i - k \cdot \pi_i). \tag{6.22}$$

With the help of the envelop theorem ($\frac{\partial x}{\partial w} = 0$), the first order condition leads to the well known Solow condition that is exactly equal to the autarkic case:

$$\frac{w_i \frac{\partial a(w_i)}{\partial w_i}}{a(w_i)} = 1. \tag{6.23}$$

This condition states that the elasticity of the efficiency function with respect to the wage equals one. The firm keeps hiring additional people as long as the wage per unit of effort is falling. Just as in the autarkic case, we find the final expression for the employee's remuneration by substituting the expression of Summers for the efficiency wage $a(w) = (w(1-z) - w_R)^\beta$ in expression 6.23:

$$w_i(z) = w(z) = \frac{w_R}{(1-\beta)(1-z)}. \tag{6.24}$$

This proves our previous statement that the wages are set firm-independently. As a consequence all northern firms behave identically and sell the same amount of goods to each market. An inspection of 6.24 also reveals that, once again, the gross wage increases when the tax on labour increases but the net wage does not. It also shows that the wage setting is independent from the foreign tax setting[7]. The expression for the optimal level of effort procured by the workers is the same as in the autarkic case:

$$a^{opt} = w_R^\beta (\frac{\beta}{1-\beta})^\beta. \tag{6.25}$$

[7] Under the condition that the northern tax rate does not depend directly on the southern tax rate and vice versa. We are only considering first-order effects in the model.

The symmetry between the two regions entails the identity between the northern efficiency parameter β and the southern one β^*. Owing to this, the southern equivalents for 6.24 and 6.25 are easily derived to be equal to:

$$w^*(z^*) = \frac{w_R^*}{(1-\beta)(1-z^*)}, \qquad a^{*,opt} = (w_R^*)^\beta (\frac{\beta}{1-\beta})^\beta. \tag{6.26}$$

6.3.2 Unemployment

We are now able to determine the level of unemployment in the region. Substituting expression 6.10 and 6.5 in the zero profit condition ($p_{NN} \cdot x - w \cdot l - k \cdot \pi = 0$), lets us determine the amount of labour each firm employs:

$$l = \frac{(\sigma-1)k\pi}{w}. \tag{6.27}$$

Each firm recruits less people when the wages rise. Although this expression is identical to the autarkic one, there is a big difference between the two frameworks. While in the autarkic case the total amount of wages paid by all firms to their employees $\sum_{i=1}^{n} lw$ is constant, this is no longer the case in the two-country case. Tax changes will change the capital reward and as a consequence influence the tax base.

From expression (6.27) it is only a small step to the unemployment level $u(z)$:

$$u(z,z^*) = 1 - \frac{nl}{L^N} \overset{6.27}{=} 1 - \frac{n(\sigma-1)k\pi(z,z^*)}{L^N * w} \overset{6.24,6.20}{=} 1 - \delta \cdot s_n \cdot (1-z) \cdot \pi(z,z^*). \tag{6.28}$$

We grouped all the constant parameters in a new parameter δ which is equal to $\frac{(\sigma-1)\cdot(1-\beta)\cdot n^W \cdot k}{L^N \cdot w_R}$. Note that this expression for the unemployment 6.28 does not guarantee that the unemployment rate is always equal to or larger than zero. We will have to impose an additional restriction on the social welfare optimisation later on in order to ensure meaningful results.

6.3.3 Share of expenditures

The capital reward of a region depends on the expenditure shares of the regions (see 6.20 and 6.21) and the expenditure shares of a region hinge on the capital and labour rewards earned in the same region. This means that we have to solve this circularity before we can introduce a government choosing a tax rate. We do this by finding a closed expression for the share of expenditures in terms of the tax rates. We start by looking at the total reward TLR stemming from labour income (employed and unemployed):

$$TLR = n \cdot l \cdot w \cdot (1 - z) + (L_N - n \cdot l) \cdot b. \tag{6.29}$$

Using the same budget balance of the government as in the autarkic case $(n \cdot l \cdot w \cdot z = (L^N - n \cdot l) \cdot b)$ and expression 6.27, expression 6.29 can be written in terms of the capital reward:

$$TLR = n \cdot l \cdot w = (\sigma - 1) \cdot k \cdot n^W \cdot s_n \cdot \pi. \tag{6.30}$$

People not only earn income from working (or receiving an unemployment benefit) but also from having a certain amount of capital. Just as before we assume that each individual has an equal share of the total capital income of a region, TCR. However, determining the total capital reward of a region is a lot trickier in comparison to the autarkic case, since we normally would have to know where the capital owned by the northern residents is working. The introduction of supplementary variable[8] can be overcome by assuming that a fixed amount of (northern) capital is working in either region. The most logical assumption in the model without capital mobility would be the case where all northern capital is working in the north (and southern capital in the south)[9]. However, we don't opt for this assumption and instead assume, as Martin and Rogers did in their footloose capital model ([88]), that half of the capital used in each region belongs to the northern capital owners regardless of s_n. This implies at the same time that each region owns half of the worldwide capital ($s_K = \frac{1}{2}$). In this way, the comparability between the model without capital mobility and with capital mobility is enhanced, while keeping a link with the existing literature. Under the Martin and Rogers assumption, each unit of capital, independent of the ownership of it, earns the world average reward to capital ACR . This is

[8] Namely, the amount of the northern-owned capital that is working in the north. The amount of the northern-owned capital working in the south would be equal to 1 minus the previous amount.

[9] Under this assumption the TCR would be equal to $s_n \frac{E^W}{\sigma} B$ and the share of expenditures would simplify to $s_E = s_n B$.

given by:

$$ACR = \frac{TCR + TCR^*}{K^W} = \frac{nk\pi + n^*k\pi^*}{K^W} \overset{6.20,6.21}{=} \frac{kn^W\gamma(s_nB + (1-s_n)B^*)}{K^W} \overset{s_n*B+(1-s_n)*B^*=1}{=} \frac{E^W}{K^W\sigma}. \tag{6.31}$$

Multiplying the average capital reward ACR with the total number of units of capital owned by the north K gives us the total northern capital reward $TCR = s_K\frac{E^W}{\sigma}$. Given both components of income (or expenditures) in a region, the share of expenditure is easily derived as:

$$s_E(z, z^*) = \frac{TCR + TLR}{E^W} = \frac{1}{2\sigma} + \frac{\sigma - 1}{\sigma}s_nB. \tag{6.32}$$

Substituting B by (6.17) and solving for s_E gives a closed-form expression for the northern share of expenditures:

$$s_E(z, z^*) = \frac{(\sigma - 1)s_n\epsilon\phi\Delta + \frac{1}{2}\Delta\Delta^*}{\sigma\Delta\Delta^* - (\sigma - 1)s_n\epsilon(\Delta^* - \phi\Delta)}. \tag{6.33}$$

Note that although we started from a classical footloose capital set-up, we didn't obtain a share of expenditures that is independent from s_n. This result even holds when capital is immobile. Due to the introduction of endogenous unemployment via efficiency wages we have that — in the case that capital is mobile — production shifting (Δs_n) leads to expenditure shifting (Δs_E). This linkage will put the demand-linked circular causality back on-line as we will discuss in chapter 7. As a final remark, it is important to realize that the share of expenditures in a region depends on the tax of the home country but also on the tax rate of the foreign country. Since the capital reward depends on s_E, all the variables depending on the capital reward such as the unemployment and the unemployment benefit also depend on the tax rates of both countries.

Before we go on and determine the reference wage, we assess the conditions under which the share of expenditures given by formula 6.33 always lies between 0 and 1. This in order to make sure that the numerical simulations we will rely on later on don't give unrealistic results. As it turns out the share of expenditures automatically fulfils this restriction. The restriction $s_E > 0$ can be rewritten using the definition of Δ (6.14) and Δ^*(6.9) as follows:

$$\sigma\epsilon^2\phi s_n^2 + \sigma(1-s_n)^2\phi + \quad \sigma\epsilon\phi^2(1-s_n) + (1-s_n)s_n\epsilon(1-\phi^2) + \ \sigma\epsilon\phi^2 s_n(1-s_n) > 0, \quad (6.34)$$

which always holds because the exogenous parameters s_n and σ in here have the right sign restrictions: $0 < s_n < 1$ and $\sigma > 1$. The other side of the inequality, $s_E < 1$ can be rewritten as $s_n\epsilon(\frac{1}{2} - 1) < \phi(1-s_n)(\sigma - \frac{1}{2})$, which under the same parameter restrictions on the exogenous parameters and given the fact that the denominator of 6.33 is positive ($s_E > 0$) , evidently holds.

6.3.4 Reference wage

The reference wage is defined as the wage that would apply if all the workers behaved selfishly, i.e. the market-clearing wage. At this wage level, there is no unemployment ($nl = L^N$, $n^*l^* = L^S$) and the government does not have to raise any taxes ($z = 0$, $z^* = 0$). Given the symmetric nature of our regions, this means that the share of firms in each region also equals 1/2. Using expressions 6.27, the northern definition of the reference wage becomes:

$$w_R = \frac{n^R(\sigma-1)k\pi^R}{L^N}, \quad (6.35)$$

with n^R equal to $\frac{1}{n^W \cdot 2}$. The capital reward in this benchmark case is given by (6.20). Given the fact that $s_n = s_K = \frac{1}{2}$, the share of expenditures s_E in the region is equal to $\frac{1}{2}$ which allows us to rewrite the profit π^R as γ. As a result, we can write the reference wage as:

$$w_R = \frac{1}{2}\frac{n^W}{L^N}(\sigma-1)k\gamma = \frac{\sigma-1}{2\sigma}\frac{E^W}{L^N}. \quad (6.36)$$

Under the additional assumption that $L^N = L^S$, the reference wages of both regions are equal. Just as in the autarkic case, the reference wage increases when the GDP per person rises.

6.4 Government

6.4.1 Unemployment benefit, unemployment rate and price index in function of taxes

The balanced budget constraint of the government allows us to determine the unemployment benefit in function of the tax rate:

$$b(z,z^*) = \frac{1-u(z,z^*)}{u(z,z^*)} \cdot w(z) \cdot z \overset{6.28,6.24}{=} \frac{\delta \cdot s_n \cdot w_R \cdot \pi(z,z^*) \cdot z}{(1-\beta) \cdot (1-\delta \cdot s_n \cdot \pi(z,z^*) \cdot (1-z))}. \tag{6.37}$$

Replacing the capital reward in the denominator by $\gamma \cdot B(z,z^*)$ (see 6.20) and using the definitions of the parameters δ and γ, we can simplify this expression further as follows:

$$b(z,z^*) = \frac{(\sigma-1) \cdot E^W \cdot w_R \cdot s_n \cdot B(z,z^*) \cdot z}{L^N \cdot w_R \cdot \sigma - s_n \cdot B(z,z^*) \cdot (1-z) \cdot (\sigma-1) \cdot (1-\beta) \cdot E^W}. \tag{6.38}$$

In the simple autarkic model, the unemployment benefit always increases when the tax rate increases. The (positive) unemployment benefit was also automatically higher than the reference wage. Contrary to the autarkic case, the complexity of formula 6.38 makes it impossible to analytically guarantee that the unemployment benefit is always lower than the net wage people receive. This means that we have to impose a second extra restriction on the social welfare optimisation by the government.

The term $B(z,z^*)$ in expression 6.38 is equal to its definition given by 6.20 with the share of expenditures s_E substituted by 6.33 and with Δ and Δ^* in this substituted expression replaced by their definitions 6.14 and 6.15 respectively. This leads to:

$$B(z,z^*) = \frac{\epsilon(z,z^*) \cdot (1 - s_n + 2s_n\epsilon(z,z^*)\sigma + (1-s_n)(2\sigma-1)\phi^2)}{2\sigma\phi + 2s_n((s_n-2)\sigma\phi + s_n(\epsilon(z,z^*))^2\sigma\phi + (1-s_n)\epsilon(z,z^*)(1+(2\sigma-1)\phi^2))}. \tag{6.39}$$

After these substitutions in $B(z,z^*)$ one still has to substitute the competitiveness $\epsilon(z,z^*)$ with $(\frac{w/a(w)}{w^*/a^*(w^*)})^{1-\sigma}$, which can be simplified using the wage definitions 6.24 and 6.26 and the assumption that each region has the same number of inhabitants to $(\frac{1-z^*}{1-z})^{1-\sigma}$.

We can use the above expression 6.39 together with $\pi(z,z^*) = \gamma \cdot B(z,z^*)$ in 6.28 to derive the unemployment rate in function of the optimising variable for the government z:

$$u(z,z^*) = \frac{2\sigma\phi + s_n(2+(s_n-2)\sigma\phi + 2s_n(1+(z-1)\gamma\delta)(\epsilon(z,z^*))^2\sigma\phi}{2(\sigma\phi + s_n((s_n-2)\sigma\phi + s_n\cdot(\epsilon(z,z^*))^2\sigma\phi + (1-s_n)\cdot\epsilon(z,z^*)\cdot(1+(2\sigma-1)\phi^2)))} +$$

$$\frac{(1-s_n)(2-(1-z)\gamma\delta)\cdot\epsilon(z,z^*)\cdot(1+(2\sigma-1)\phi^2))}{2(\sigma\phi + s_n((s_n-2)\sigma\phi + s_n\cdot(\epsilon(z,z^*))^2\sigma\phi + (1-s_n)\cdot\epsilon(z,z^*)\cdot(1+(2\sigma-1)\phi^2)))} \tag{6.40}$$

Again we still have to substitute $\epsilon(z,z^*)$ with $(\frac{1-z^*}{1-z})^{1-\sigma}$ which we omitted in order not make the expression too cumbersome.

The last important determinant of the social welfare yet to express in function of the tax rates is the price index 6.14, which is done using the definition of the wage 6.26 and of the competition ϵ that is, again under the same assumptions as above, equal to $(\frac{1-z^*}{1-z})^{1-\sigma}$:

$$P(z,z^*) = \frac{w_R\alpha}{(1-\beta)a^{*,opt}} \frac{((\frac{1-z^*}{1-z})^{1-\sigma}s_n + (1-s_n)\phi)^{\frac{1}{1-\sigma}}}{(1-z^*)(1-\beta)}. \tag{6.41}$$

6.4.2 Benthamite case (e=0)

The government chooses a tax rate by maximising the social welfare function given by 4.2. The only analytical solvable case is the Benthamite case. For all other attitudes towards inequality, we have to rely on numerical simulations. Just as in the autarkic model, the social welfare function for a government with only efficiency considerations is given by:

$$SW(e=0) = (1-u(z,z^*))\frac{w(z)\cdot(1-z)+CR}{P(z,z^*)} + u(z,z^*)(\frac{b(z,z^*)+CR}{P(z,z^*)}). \tag{6.42}$$

Using the balanced budget constraint and the definition of the gross wage 6.24, expression 6.42 can be simplified to:

$$SW(e=0) = \frac{(1-u(z,z^*))w(z)+CR}{P(z,z^*)}. \tag{6.43}$$

Substituting the unemployment rate and the gross wage by their definitions 6.28 and 6.24 and taking the first order derivative leads to:

$$\frac{\partial SW(e=0)}{\partial z} = \frac{\delta s_n w_R}{(1-\beta)P(z,z^*)}\frac{\partial \pi(z,z^*)}{\partial \epsilon}\frac{\partial \epsilon(z,z^*)}{\partial z} - \frac{\delta s_n w_R \pi(z,z^*) + CR\cdot(1-\beta)}{(1-\beta)(P(z,z^*))^2}\frac{\partial P(z,z^*)}{\partial z}. \tag{6.44}$$

The derivative of the capital reward $\pi = \gamma B(z,z^*)$ (given by 6.39) with respect to the indicator of the competitive effect ϵ, the derivative of $\epsilon = (\frac{w/a(w)}{w^*/a^*(w^*)})^{1-\sigma}$ to the tax rate z and the derivative of the price index $P(z,z^*)$ also with respect to z (see 6.41) are respectively given by:

$$\frac{\partial \pi(z,z^*)}{\partial \epsilon} = \gamma\frac{(\sigma - s_K)s_n^2(1+\epsilon^2) + 2s_n(1-s_n)\epsilon\sigma\phi + \phi^2\sigma(1-s_n)^2 + s_K(1-\phi^2) + s_K(1+\epsilon^2)\phi^2 s_n^2}{(\sigma\phi + s_n((s_n-2)\sigma\phi + s_n\epsilon^2\sigma\phi + (1-s_n)\epsilon(1+(2\sigma-1)\phi^2)))^2}, \tag{6.45}$$

$$\frac{\partial \epsilon(z,z^*)}{\partial z} = \frac{1-\sigma}{1-z}\epsilon, \tag{6.46}$$

$$\frac{\partial P(z,z^*)}{\partial z} = \frac{s_n \epsilon P(z,z^*)}{(1-z)\Delta}. \tag{6.47}$$

Expressions 6.45 and 6.47 are always positive, while the second expression 6.46 is unambiguously negative. As a consequence, the first order derivative of the Benthamite social welfare function 6.44 is always negative. The only possible solution in this case is the corner solution of a zero tax rate as could be expected given the result in the autarkic model.

Note that the fact that 6.45 is positive, also means that in the two-country model without capital mobility, higher tax rates always lead to lower capital rewards and since the taxable base nlw can be written as $\pi kn(\sigma-1)$ (see 6.27), it also follows that any tax reduction automatically leads to higher tax revenues under the assumption that only positive values for z are allowed.

6.4.3 General case

Only for the specific case of a utilitarian government we were able to explicitly derive the optimal tax rate chosen by the government. For all the other cases we rely on simulations. We will discuss the results of the two-country model without capital mobility in three steps.

Firstly we will look at the effects which determine the optimal tax rate set by a government given the foreign tax rate. Secondly we will identify the channels through which a southern tax rate affects the northern social welfare and vice versa. This gives intuition to the observed Nash equilibrium between the two countries. Finally we will shortly discuss the influence of the choice of the parameter σ, s_n and ϕ on the Nash equilibrium.

Benefit, unemployment and price effect

A government wants to maximize social welfare by choosing an appropriate tax rate given its inequality aversion. In the first order condition of this optimisation problem, the tax rate, just as we observed in the autarkic model, works through three channels. Firstly, higher taxes induce higher unemployment benefits. This positive effect is offset by two negative effects in equilibrium. Higher taxes lead to a reduced purchasing power of the economic agents and they also induce higher unemployment rates, thereby gnawing the tax base. The absence of the benefit effect evidently explains the corner solution of the zero tax rate in the Benthamite case.

The strength of these effects are found by taking the first order derivative of the social welfare function with respect to the tax rate z and keeping the relevant variables constant ($\frac{dSW}{dz} = \frac{dSW}{dz}\big|_{P,u=cst} + \frac{dSW}{dz}\big|_{b,u=cst} + \frac{dSW}{dz}\big|_{b,P=cst}$). After simple but cumbersome calculations these three effects are equal to:

$$\frac{dSW}{dz}\bigg|_{b,u=cst} = \begin{cases} \dfrac{-s_n \cdot \epsilon(z,z^*)}{(1-z)\cdot\Delta(z,z^*)} & (e=1) \\[2ex] \dfrac{-s_n \cdot \epsilon(z,z^*)}{(1-z)\cdot\Delta(z,z^*)} \cdot (1-e)\cdot SW(z,z^*) & (e\neq 1) \\[2ex] \dfrac{-s_n \cdot \epsilon(z,z^*)\cdot(b(z,z^*)+CR)}{(1-z)\cdot\Delta(z,z^*)\cdot P(z,z^*)} & (e=\infty) \end{cases} \tag{6.48}$$

$$
\left.\frac{dSW}{dz}\right|_{P,u=cst} = \begin{cases}
\frac{\delta \cdot s_n \cdot w_R}{(b(z,z^*)+CR)\cdot u(z,z^*)\cdot(1-\beta)} \cdot \\
\left[\pi(z,z^*)\cdot(1-\delta\cdot s_n\cdot\pi(z,z^*)) + z\frac{\partial\pi(z,z^*)}{\partial\epsilon}\frac{\partial\epsilon(z,z^*)}{\partial z}\right] & (e=1) \\
\frac{\delta\cdot w_R\cdot s_n}{(1-\beta)\cdot u(z,z^*)}(\pi(z,z^*)(1-\delta\cdot s_n\cdot\pi(z,z^*)+z\frac{\partial\pi(z,z^*)}{\partial\epsilon}\frac{\partial\epsilon(z,z^*)}{\partial z})\cdot \\
(b(z,z^*)+CR)^{-e}\cdot(P(z,z^*))^{e-1} & (e\neq 1) \\
\frac{\delta\cdot w_R\cdot s_n}{(1-\beta)\cdot(u(z,z^*))^2\cdot P(z,z^*)}\cdot(\pi(z,z^*)\cdot(1-\delta\cdot s_n\cdot\pi(z,z^*))+ \\
z\cdot\frac{\partial\pi(z,z^*)}{\partial\epsilon}\cdot\frac{\partial\epsilon(z,z^*)}{\partial z}) & (e=\infty)
\end{cases} \tag{6.49}
$$

$$
\left.\frac{dSW}{dz}\right|_{b,P=cst} = \begin{cases}
\delta\cdot s_n\cdot\log(\frac{b(z,z^*)+CR}{\frac{w_R}{1-\beta}+CR})\cdot(\pi(z,z^*)- \\
(1-z)\cdot\frac{\partial\pi(z,z^*)}{\partial\epsilon}\cdot\frac{\partial\epsilon(z,z^*)}{\partial z}) & (e=1) \\
\frac{\delta\cdot s_n}{1-e}\cdot\frac{1}{(P(z,z^*))^{1-e}}\cdot(\pi(z,z^*)-(1-z)\cdot\frac{\partial\pi(z,z^*)}{\partial\epsilon}\cdot\frac{\partial\epsilon(z,z^*)}{\partial z})\cdot \\
\left[(b(z,z^*)+CR)^{1-e}-(\frac{w_R}{1-\beta}+CR)^{1-e}\right] & (e\neq 1) \\
0 & (e=\infty).
\end{cases}
$$

The derivatives $\frac{\partial\pi(z,z^*)}{\partial\epsilon}$ and $\frac{\partial\epsilon(z,z^*)}{\partial z}$ in these three definitions are given by the expressions 6.45 and 6.46 respectively.

Competition and real income effect

In the previous paragraph we analyzed the effect the home tax rate has on the home social welfare. In this paragraph we look at the externalities that the foreign tax rate (in casu the southern) has on the own (northern) social welfare. We do this by considering the first order derivative of the (northern) social welfare with respect to the southern tax rate. We can distinguish two channels. The first one is analogous to the previous paragraph, namely the price index. A tax drop in the south will decrease the southern gross wage w^* which shifts the marginal costs downwards. Due to mill pricing, the prices for the southern goods will also decrease while the northern goods won't change in price. The result is a lower price index in both regions. Since the Atkinson index of relative inequality is independent of equiproportional income changes, the northern inequality does not change. However, the real average income (the measurement of efficiency) increases. Given the constant inequality-efficiency trade-off of the government, this means that she has to raise taxes to increase the equality between the working and unemployed people in its society. The real income effect leads to tax rates that are substitutes between each other.

The second mechanism through which the southern tax rates affect the northern region is called the competition effect. The price drop of southern goods from the decrease of the southern tax rate will increase the southern sales and decrease the northern sales since the northern firms ask the same prices as before and because the elasticity of demand, equal to the elasticity of substitution between goods, is larger than 1. This also implies that the northern reward to capital decreases while the southern one increases. The reason for this lies in the zero-profit condition[10]. But a lower (northern) reward to capital has as a consequence that the tax base in the north decreases because the tax base is equal to a fraction of the capital reward (again zero profit condition!). So we can conclude that a southern tax decrease creates a negative externality on the northern region: the northern tax base shrinks because of the increased competitiveness of the southern region. The northern government is thus faced with higher unemployment rates and a smaller tax base to collect taxes to pay for the unemployment benefits. This not only lowers the efficiency of their economy (lower average income) but also negatively affects the equity (more unemployed). The government with a given equity-efficiency trade-off tries to counter this by also decreasing its tax rate. As a result, the competition effect leads to tax rates that are complements between each other.

[10]More formally this mechanism can be understood as follows. A drop in the southern tax rate z^* lowers w^* and hence the north looses competitiveness (lower value for ϵ). By 6.33 this means that s_E drops which, by 6.20 also implies lower levels of π and also of l (by 6.27). This in turn leads to a lower tax base but also to higher levels of unemployment (by 6.28).

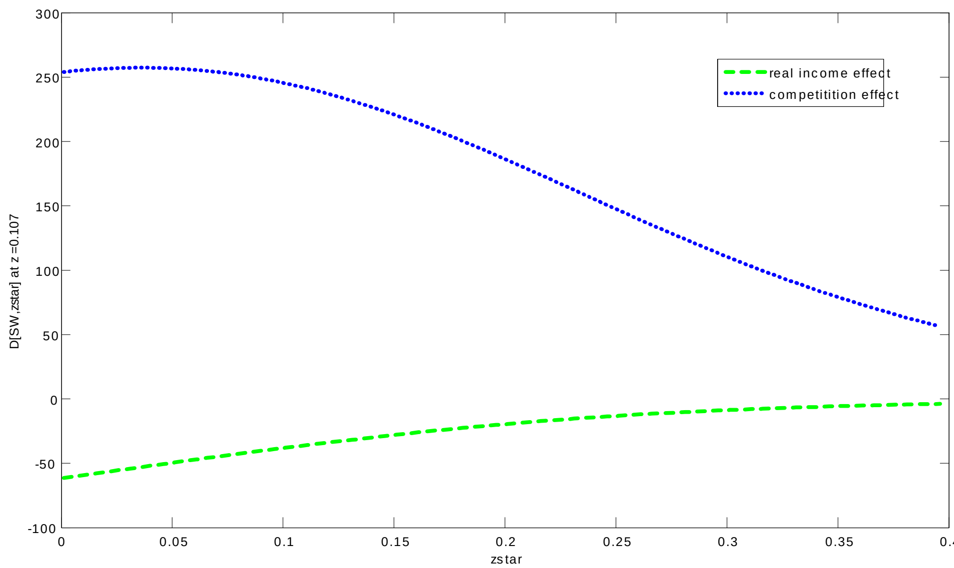

Figure 6-1: Effects of foreign tax on SW at $\beta = 0.6$, $e = e^* = 3$, $\sigma = 5$, $s_n = 0.5$, $z = 0.106$ and $\phi = 0.5$.

We plotted both effects in a characteristic case. We calculated the first order derivative of the northern social welfare with respect to the southern tax rate and plotted this value against the southern tax rate. The inequality aversion of both regions is assumed to be equal to 3. Each region has also the same number of firms and the trade freeness is set to be equal to 0.5. For the northern tax rate value we took the Nash equilibrium value corresponding to these values of the parameters. The other parametric values are $E^W = 1$, $L^N = 1 = L^S$, $s_K = \frac{1}{2}$ and $k = 1$.

Figure 6-1 clearly shows that the competition effect from an increase in the foreign tax increases the social welfare of the north, while the real income effect decreases the social welfare of the north. We also see that the competition effect outweighs the real income effect although both forces become less strong for increasing values of the foreign tax rate. This can also be seen by representing the reaction curves of both regions. We represented the reaction curves for a given value of trade freeness ($\phi = 0.5$) and with the same parametric values as before ($\sigma = 3$, $\beta = 0.6$, $E^W = 1$, $L^N = 1 = L^S$, $s_n = s_K = 1/2$, $k = 1$).

The vertical (red) lines in figure 6-2 represent the northern optimal tax rate given a southern

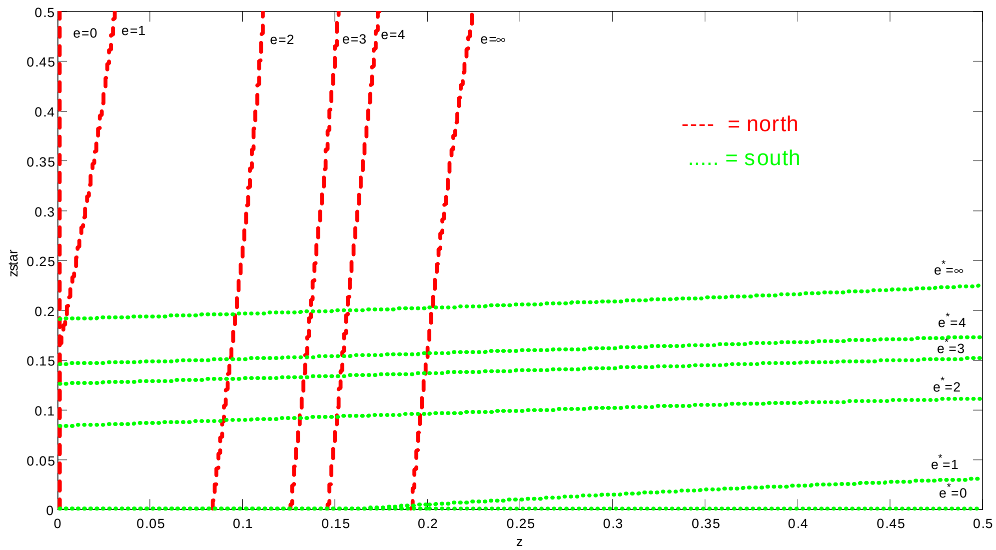

Figure 6-2: Reaction curves in function of inequality aversion at $\phi = 0.5$ and $\beta = 0.6$.

tax rate (on Y-axis). The horizontal (green) lines are the reaction curves of the south given a northern tax rate (on the X-axis). The intersection of both curves is the Nash equilibrium. As illustrated on the graph this Nash equilibrium shifts towards higher tax rates when the inequality aversion of the regions increases. This is intuitively quite clear since a higher inequality aversion means that governments care more about the unemployment, hence want higher unemployment benefits and, as a result, set higher tax rates.

Based on this graph we can conclude that the tax rates set by each government act as strategic complements: any tax reduction of the foreign region will lead to a tax reduction in the home region. The negative externality imposed by a foreign tax reduction on the home tax base outweighs the positive real income effect and as a result of this, the home region also lowers its tax rate. There is, in other words, social security competition between the two regions.

The severity of the social security competition can also be seen by looking at the optimal tax rate a social planner would choose compared to the separate regions. We define the social planner as the government that sets a single tax rate in both regions to maximize the sum of the indirect utilities over the inhabitants of both regions[11]. In table 6.1 the second row represents the optimal tax rate set by two regions with the same inequality aversion (allows us to compare it with the social planner), the third row represents the optimal tax rate set by the social planner. We used the same parameter values as in the previous simulations (σ= 2.5). It is clear that the social planner opts for higher tax rates because he or she will internalize the effects we discussed before. This is an illustration of the regulatory chill effect. Although a government would like to increase social security protection, it is afraid to do so due to the fear of losing competitiveness.

	$e = e^* = 0$	$e = e^* = 1$	$e = e^* = 2$	$e = e^* = 3$	$e = e^* = 4$	$e = e^* = \infty$
$z = z^*$	0	0	0.075	0.126	0.151	0.208
z_{SP}	0	0	0.107	0.157	0.179	0.221

Table 6.1: Optimal tax rates of social planner and two equally inequality averse regions for several values of the inequality aversion

.Note also that the choice of the social planner nearly mimics the choice of the autarkic region. This should come as no surprise as both optimisations are identical except for some minor parametric values (e.g. $L = 1$ versus $L^N = L^S = 1$). This again illustrates the social security competition in our model.

Influence of σ, ϕ and s_n

As a final step we discuss the impact of some parameters on the Nash equilibrium. We start with the elasticity of substitution σ. The effect is mixed. The elasticity of substitution characterizes the fierceness of the competition on the goods market and as a consequence will lead to a stronger negative externality, a stronger competition effect. That's why higher values of σ are coupled with lower tax rates set by individual governments. The loss of taxable base associated with a tax rise increases when the elasticity of substitution increases. At the same time a social planner that internalizes the externalities associated with trade will opt for higher taxes since the average income of the people increased (see autarkic case). The Nash rates chosen by the social planner are depicted in table 6.2 for three different values of the elasticity of substitution

[11] This means that we exclude a priori a social planner that chooses a different tax rate in each region. This is a not illogical assumption in our symmetric model.

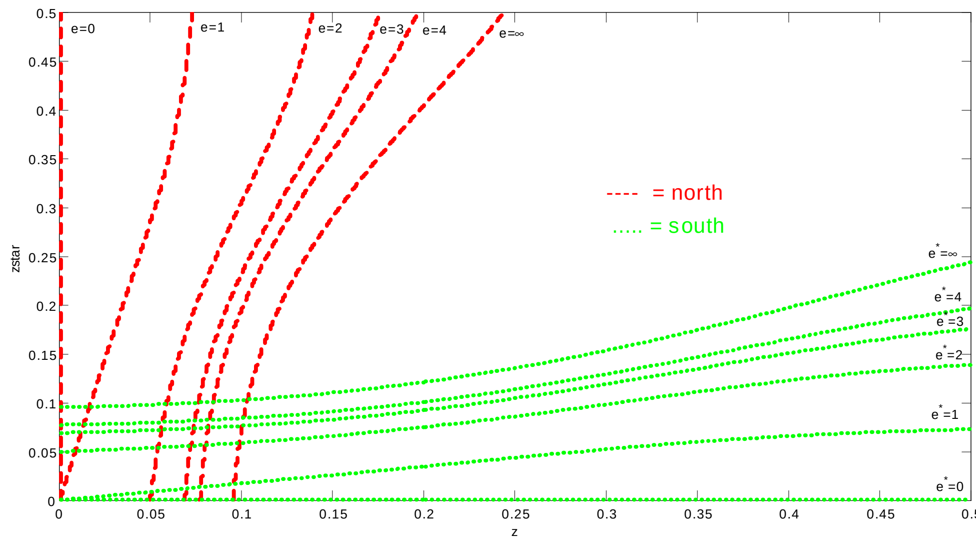

Figure 6-3: Reaction curves in function of the inequality aversion for a high value of the elasticity of substitution ($\sigma = 8$).

and in function of the inequality aversion.

	$e = e^* = 0$	$e = e^* = 1$	$e = e^* = 2$	$e = e^* = 3$	$e = e^* = 4$	$e = e^* = \infty$
$\boldsymbol{\sigma = 2.5}$	0	0	0.107	0.157	0.179	0.221
$\boldsymbol{\sigma = 5}$	0	0.151	0.261	0.301	0.321	0.351
$\boldsymbol{\sigma = 8}$	0	0.206	0.311	0.344	0.357	0.383

Table 6.2: Influence of sigma

To show the influence of σ for the regions, we plot the reaction curves of both regions for a high value of $\sigma(= 8)$. Other parameters have the same values as before ($\phi = 0.5$, $\beta = 0.6$, $E^W = 1$, $L^N = 1 = L^S$, $s_n = s_K = \frac{1}{2}$, $k = 1$). The reaction curves intersect at lower values of tax rates. Note that the shape of the reaction curves in this case can be explained by referring to figure 6-1. The overall positive effect of the foreign tax rates on the northern social welfare function changed most heavily for intermediate values of the foreign tax rate. This is exactly the zone where the second order derivative of the reaction curves is highest.

Secondly, we look at the influence of the share of firms in a region s_n. When the share of firms in a region increases, the price index in that region drops. Normally, the number of employed people will also increase. This means that given a fixed tax rate, the inequality will rise, besides a further increase of the average income. The only way a government can overcome this unwanted straddle is by raising the tax rate to increase the equality between the people. This effect can be seen by looking at the northern Nash rates in table 6.3. Due to the symmetric set-up, the southern Nash tax rate when $s_n = 0.1$ is equal to the northern Nash tax rate for $s_n = 0.9$. To illustrate this effect we plot the reaction curves for s_n=0.9 in figure 6-4. A higher share of firms for a region shifts the reaction curves of that region to the right[12]. Note also that for the region with the high share of firms the tax rate is almost independently set from the foreign tax rate.

	$e = e^* = 0$	$e = e^* = 1$	$e = e^* = 2$	$e = e^* = 3$	$e = e^* = 4$	$e = e^* = \infty$
$\mathbf{s}_n$= **0.1**	0	0	0	0.021	0.056	0.126
$\mathbf{s}_n$= **0.5**	0	0	0.075	0.126	0.151	0.208
$\mathbf{s}_n$= **0.9**	0	0.021	0.101	0.146	0.171	0.241

Table 6.3: Northern Nash rates for different shares of firms

Lastly, we look at the effect of lower trade costs. We plotted the reaction curves in function of the trade freeness in graph 6-5[13]. We can see that the Nash rates decrease until the trade freeness lies around 0.25. After that, the optimal tax rates start to increase again and even surpass the optimal taxation level associated with high trade costs. To illustrate this phenomenon better, we depicted the optimal Nash rates together with the optimal tax rate chosen by the social planner in function of the trade freeness for the same parametric values as before. This is done in figure 6-6. For high values of trade costs, the Nash tax rate is always lower than the Pareto tax rate of the social planner, while, at the high end of trade freeness, the regions will want to have higher tax rates than the social planner who always chooses the same tax rate in function of ϕ. Based on this figure, one could come to the conclusion that sustained lowering of trade barriers would lead to a world with less social security competition and higher tax rates. However, as explained in the motivation of the set-up (see chapter 4) one could reasonable

[12] The parameters in this simulation are the same as in the previous graphs: $\phi = 0.5$, $\beta = 0.6$, $E^W = 1$, $L^N = 1 = L^S$, $s_K = \frac{1}{2}$, $k = 1$, $\sigma = 2.5$.

[13] We took the following parametric values $e = e^* = 3$, $\sigma = 2.5$, $\beta = 0.6$, $E^W = 1$, $L^N = 1 = L^S$, $s_n = s_K = \frac{1}{2}$, $k = 1$.

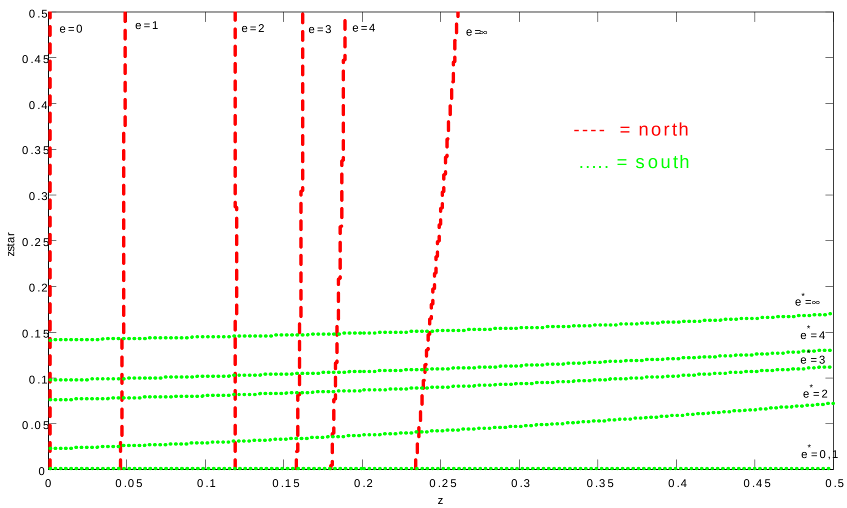

Figure 6-4: Reaction curves for s_n=0.9.

assume that the realistic range of the trade freeness lies in the lower half of possible values for ϕ since the whole economy (including services) are subject to trade in our model.

To explain the evolution of the regional Nash rates in function of the trade freeness ϕ, we look at the change in the 'cost' that a tax shift of the own tax rate has on the social welfare. As seen before, the home tax rate works through three channels on the social welfare function. On the one hand there is the price index effect, on the other hand one can also distinguish the unemployment and benefit effect. Since the latter two basically cause a change in the tax base, we will group these two effects into a single effect, namely the tax base effect and we will focus, without any loss of generality, on the effect that a change in the trade freeness has on the sensitivity of the tax base to the tax rate. The price index effect will have a restraining effect on the optimal tax rate since a tax raise increases the price index and hence reduces the real income of the economic agents. The decrease in the tax base caused by an increase in the tax rate will increase the social welfare since it provides the basis for an unemployment benefit. So the smaller the loss of the tax base associated with a tax increase becomes, the higher the chosen tax rate will be.

We start by looking at the evolution of the price index effect in function of the trade freeness.

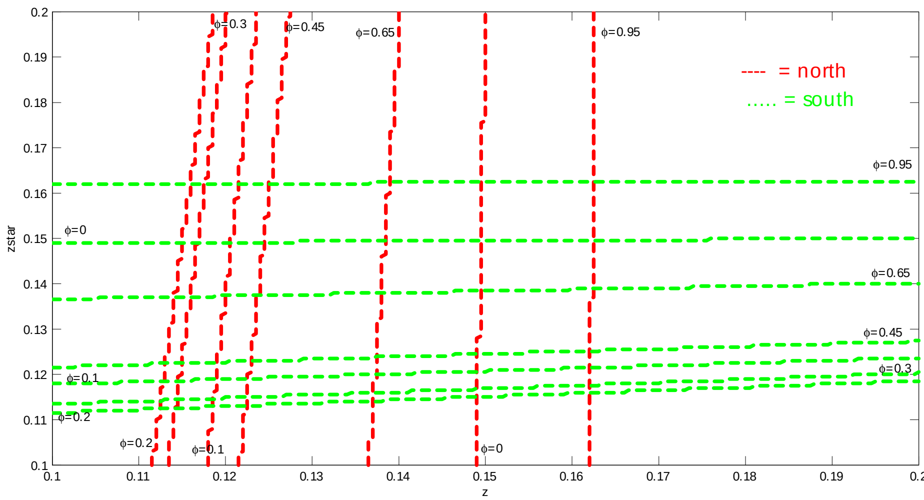

Figure 6-5: Reaction curves for different trade freeness values at $e = e^* = 3$.

When trade costs decrease, all imported goods become cheaper and this will have a positive impact on the real income of active and inactive persons. As a consequence a social welfare maximising government with a fixed equity-efficiency trade-off will choose for a higher tax rate to let the equity keep pace with the increased efficiency. Or stated otherwise, the negative effect associated with a home tax raise (namely the drop in real income) will become less powerful for higher values of the trade freeness. We captured this phenomenon by looking at the elasticity of the price index with respect to the tax rate in function of the trade freeness. This is illustrated in graph 6-7 where we see that the elasticity of the price index with respect to the tax rate is positive but that it decreases when the trade costs decrease.

The evolution of the second effect is less straightforward due to the non-linearities present in the model. We now look at the elasticity of the tax base with respect to the tax rate in function of the trade freeness[14]. This elasticity is again represented in graph 6-7. We see that this elasticity sharply diminishes until the trade freeness lies around 0.25 after which there is no significant change any more in the elasticity. So, the same tax rate change will induce a much larger decrease in the tax base for values of the trade costs at the high end. As a consequence,

[14] Remember that the tax base $n \cdot l \cdot w$ equals $n \cdot (\sigma - 1) \cdot k \cdot \pi$ (see 6.27).

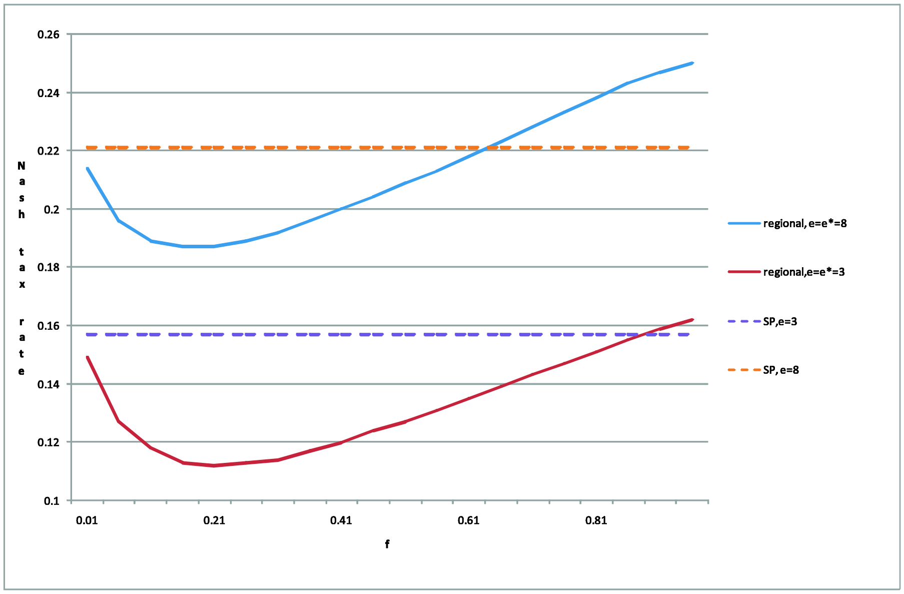

Figure 6-6: Nash tax rates for the region and the social planner in function of trade freeness for two values of the inequality aversion.

the government will decrease its chosen tax rate (if it only looks at this effect) when ϕ evolves from 0 to 0.25. For lower values of the trade costs, the government will, based on this tax base effect, see no reason to change the tax rate any longer.

To understand this phenomenon better, we split $\frac{d\log(\pi)}{d\log(z)}$ into three parts using expression 6.20 for the northern profit:

$$\frac{d(\log(\pi)}{d\log(z)} = \frac{z}{\epsilon}\frac{\partial \epsilon}{\partial z} + \nu \cdot (\frac{z}{s_E}\frac{\partial s_E}{\partial z} - \frac{z}{\Delta}\frac{\partial \Delta}{\partial z}) + (1-\nu) \cdot (\frac{-s_E}{1-s_E}\frac{z}{s_E}\frac{\partial s_E}{\partial z} - \frac{z}{\Delta^*}\frac{\partial \Delta^*}{\partial z}). \qquad (6.50)$$

The weighting factor for the second and third term of this expression is equal to the share of the total sales done in the north:

$$\nu = \frac{\frac{s_E}{\Delta}}{\frac{s_E}{\Delta} + \phi\frac{1-s_E}{\Delta}}.$$

The tax base (or sales) in a country decreases when that region increases its taxes because the prices of home-made goods increase relative to the foreign goods (first term of 6.50, $\sigma > 1$) and because the northern consumers have less money to spend. The latter effect, the home market effect, is described by the second term on the right-hand side of expression 6.50. Since capital

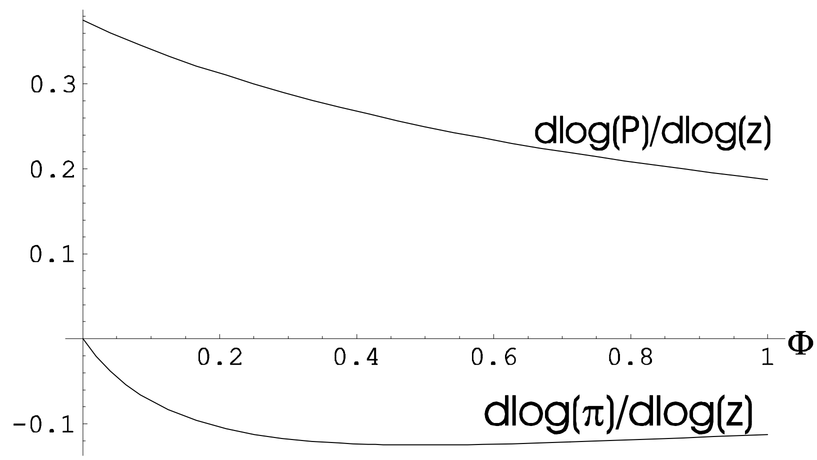

Figure 6-7: The unequal influence of the trade freeness on the tax base and the price index (at $z = z^* = z^{OPT}(e = e^* = 3)$).

and firms are immobile between regions ($s_n = \frac{1}{2}$), the increased share of expenditures in the south will inevitably lead to an increased demand of northern goods by southern consumers. The increased export demand for northern goods is described by the last term of 6.50. The change in the expenditures in both regions can only affect the northern sales to the extent that the regional demands weigh in the total northern sales which is depicted by the weighting factor ν. The loss in the sales or profit of a northern firm due to the decrease in the northern share of expenditures, $\frac{z}{s_E}\frac{\partial s_E}{\partial z}$, by the fact that all northern firms loose competitiveness $(-\frac{z}{\Delta}\frac{\partial \Delta}{\partial z})$ which is an attenuating factor to the negative demand effect. The same holds but in reverse for the last term of 6.50. We plotted all three effects in figure 6-8 in function of the trade freeness. Only the home demand and the export demand effect are influenced by a change in the trade freeness. The export demand effect increases less than the home demand effect decreases since each region has a home bias ($B > 0$). The combined effect leads to the evolution of the tax base elasticity with respect to the tax rate in function of the trade freeness as depicted in figure 6-7.

By combining both effects, we are able to explain the evolution of the Nash tax rates. For low values of the trade freeness, the tax base effect dominates the price index effect and this will lead to a decrease of the Nash rate. After $\phi = 0.25$ the tax base effect ceases to have a

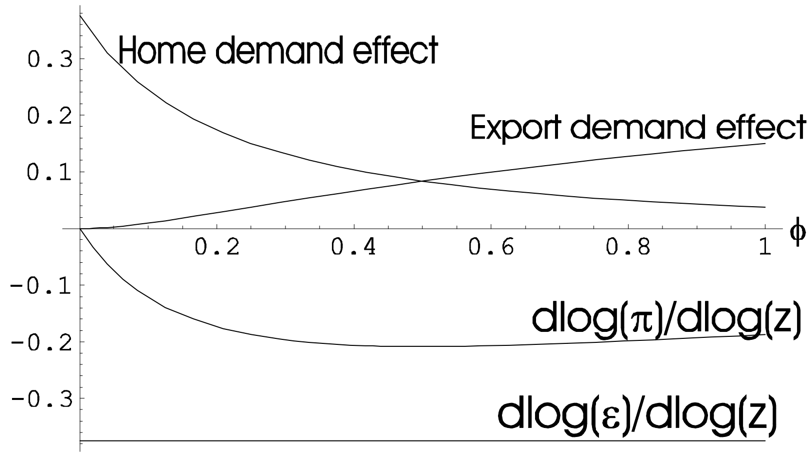

Figure 6-8: Splitting up of the elasticity of the tax base with respect to the home tax rate in 3 effects.

noticeable impact and the only remaining effect present, namely the price index effect will cause a gradual increase of the Nash rate when the trade costs further decline.

A social planner will set its optimal tax rate invariant of the trade freeness. This is again explained by looking at the two effects as discussed just now: the first effect, the price index effect will become invariant to the trade freeness and the second effect will cease to exist. This can easily be seen by looking back at the expressions of the price index 6.14 and the tax base 6.20. These expressions reduce for a social planner ($\epsilon = 1$, $z = z^*$, $s_n = s_E = \frac{1}{2}$) to $\alpha \cdot \frac{w}{a} \cdot (\frac{1+\phi}{2})^{1/1-\sigma}$ and γ respectively. As a consequence the price index effect $\frac{d\log(P)}{d\log(z)}$ is equal to $\frac{z}{1-z}$ and the tax base effect $\frac{d\log(\pi)}{d\log(z)}$ becomes zero. The latter can intuitively easily be understood since both (symmetric) regions are per definition always equally competitive. The first effect can graphically be restated as a homothetic shift of the social welfare function under trade freeness changes. The parabolic social welfare function in function of the tax rate z shifts upwards when the trade freeness increases without a horizontal shift. More intuitively this can be understood by realizing that a social planner internalizes the partial shifting of the welfare burden induced by a tax increase on the real income of people. Each time a government increases its taxes, a part of the burden, namely the proportion of imported goods in the foreign price index, is shifted on to the foreign country since they also become poorer in real terms. This effect no longer plays for a social planner.

We can conclude that for high values of trade costs the regional governments overestimate the positive effect of a tax reduction on the competitiveness of the own region. This is because governments neglect the fact that the foreign region will also lower its tax rates as a response. For low values of trade costs, this effect fades out and governments are now underestimating the negative effect that a tax increase has on the price index since they don't consider the side-effect of their own tax increase, namely a foreign tax increase. A social planner will internalize these effects and will as a consequence not change its tax rate to a changing level of trade freeness.

6.5 Conclusion

Tax rates set by governments in a model of social security competition without capital mobility behave like strategic complements. In other words, goods mobility suffices for a race to the bottom result. Social security competition is possible without the introduction of any form of mobility of factors of production. This stresses the equivalence of the several dimensions of globalisation.

Just as was the case in autarky, the behaviour of the governments in the static Nash game is steered by three effects. Any tax rise leads to one positive effect, namely higher unemployment benefits but also to two negative effects. Not only there is a negative effect on the employment but the regions are also faced with a loss in purchasing power of the people. It is the relative weight of these three effects that determine the value of the chosen Nash rates. Of course, higher values of the inequality aversion lead to higher unemployment benefits and labour taxation levels.

This behaviour can also be understood by looking at the effect that a foreign tax change has on the home region. We distinguished two channels. The first mechanism works through the price index. A tap drop in the south will decrease the southern gross wage which shifts the marginal costs downwards. Due to the mill pricing present in our model, the prices for the southern goods will decrease relative to the northern goods. The subsequent reduction in the price levels in the northern region will increase the efficiency of that region. Given the constant inequality-efficiency trade-off of the government, she wants to raise her taxes to increase the equality between the working and the unemployed. This mechanism leading to tax rates that are strategic substitutes is dominated by the second effect, the competition effect. The same drop of southern prices will decrease the northern sales and hence, given the zero-profit condition, also the northern tax base. So the unemployment will rise and the unemployment benefit will decrease. The only way a government can react to this is by also lowering its own tax rates. As a result, tax rates behave like strategic complements.

We also looked at the influence of some model parameters on the results obtained. The elasticity of substitution has a mixed effect on the Nash equilibria since a higher value of σ leads to higher tax rates set by the social planner but to lower tax rates at the regional level. Broadly spoken, the elasticity of substitution characterizes the strength of the competitiveness on the markets. As a result, the same tax rate change will induce a larger loss of competitiveness at the regional level. A social planner that internalizes these effect, will only see an increased efficiency to which it will respond by creating more equality between the unemployed and the labourers.

A second model parameter that interested us, was the share of firms s_n in a region. When a region exogenously gets a higher share of the firms, that region will increase its tax rates. The real income effect explained this result.

Lastly we also looked at the influence of the trade freeness on the reaction curves. As it turns out this behaviour is quite intricate. When trade costs decrease, starting with prohibitive trade costs, the optimal tax rates set by the governments will decrease but after a while they will increase again and at the high end of trade freeness they even will surpass the level of taxes set by a social planner. Decreasing trade costs will increase the purchasing power of people which will lead to higher taxation levels given the constant inequality-efficiency trade off of the governments. But on the other hand, higher trade freeness also makes the economy more susceptible: the tax base will respond in a increasingly manner to changes in the relative tax rates. This last effect is inherent asymmetrical in a model without capital mobility and fades out (in elasticity terms) at an intermediate value of trade freeness. This is because the two effects that a tax increase has on the tax base evolve differently in function of the trade freeness. The first effect, working via the reduction in the purchasing power of the consumers, becomes less important at a steady rate when trade freeness increases. The second effect, the export demand effect, increases less than the home demand effect decreases. The reason lies in the home bias of regions and in the fact that the share of firms in this set-up remains constant.

How promising the results may be that increased globalisation leads to less severe social security competition, we believe that the real impact of it remains limited. All the goods in our model are subject to trade. As a consequence, high levels of trade freeness, will become unrealistic since most goods in Western economies are non-tradable services.

Chapter 7

Two-country case with capital mobility

7.1 Locational equilibrium

7.1.1 Determining the steady states

Previously we looked at social security competition in a context of no capital mobility. In this section we broaden the model by introducing economic geography effects. As already explained in the motivation of the set-up in chapter 4, we assume that capital migrates to the other region as soon as it can get a higher nominal reward in that region. The owners of the capital don't move (a footloose capital setting) which is why we only have to look at the nominal capital reward, not the real reward of capital. In accordance with the standard NEG-models we use the following ad hoc migration equation for the interregional capital flows:

$$\frac{ds_n}{dt} = (\pi - \pi^*)(1 - s_n)s_n. \tag{7.1}$$

As explained in Baldwin ([10]), this formulation encompasses two desired characteristics of (capital) migration. Not only is the rate of migration proportional to the (nominal) capital reward gap, the last two terms on the right-hand side also indicate that the capital migration will not happen at once although all capital is identical. By modelling the capital flows in this way, we neglect (and simplify) the possible forward-looking behaviour of capital (owners).

Equation 7.1 shows that there are two types of long-run equilibria[1]. Interior equilibria are characterized by equal capital rewards in the north and the south ($\pi = \pi^*$). The second kind of equilibria are the core-periphery equilibria when all the capital is located in either region ($s_n = 0$ or $s_n = 1$). Note that the concept of equilibrium used here does not mean that all agents can't gain by unilaterally deviating from the equilibrium. It is merely a concept of a steady state, the only relevant long-run equilibria are the stable long-run equilibria.

We can rewrite the profit in each region by substituting 6.33 in the expressions 6.20 and 6.21 as follows:

$$\begin{aligned} \pi &= \gamma \frac{\epsilon(\phi\sigma\Delta + \frac{1}{2}(\Delta^* - \phi\Delta)}{\sigma\Delta\Delta^* - (\sigma-1)\epsilon s_n(\Delta^* - \phi\Delta)}, \\ \pi^* &= \gamma \frac{(\sigma-1)\epsilon s_n(\phi^2-1) + \sigma\Delta + \frac{1}{2}(\phi\Delta^* - \Delta)}{\sigma\Delta\Delta^* - (\sigma-1)\epsilon s_n(\Delta^* - \phi\Delta)}. \end{aligned} \tag{7.2}$$

Equating both expressions of (7.2) and substituting Δ by 6.14 and Δ^* by 6.15, we obtain a closed-form expression for the share of firms in the north:

$$s_n = \frac{\sigma\phi(1-\epsilon\phi) + \frac{1}{2}\epsilon(\phi^2-1)}{\sigma(\epsilon-\phi)(\epsilon\phi-1) - (\sigma-1)\epsilon(\phi^2-1)}. \tag{7.3}$$

This means that the model has the desired characteristic of having a closed-form expression of the share of firms while at the same time, it does not lose the circular causality as was the case in the footloose capital model.

In a next step we assess the locational choice in function of ϵ and ϕ where expression 7.3 is valid. By equating expression 7.3 to 0 and 1 respectively and solving for ϵ, it is easy to establish that internal solutions are only possible if and only if:

$$0 < s_n < 1 \Leftrightarrow \left[\sigma < \frac{1+\phi}{2\phi} \wedge \epsilon_0 < \epsilon < \epsilon_1\right] \quad \vee \quad \left[\sigma > \frac{1+\phi}{2\phi} \wedge \epsilon_1 < \epsilon < \epsilon_0\right]. \tag{7.4}$$

In this expression, ϵ_0 and ϵ_1 stand for:

$$\epsilon_0 = \frac{2\sigma\phi}{1+(2\sigma-1)\phi^2}, \qquad \epsilon_1 = \frac{1}{\epsilon_0}. \tag{7.5}$$

[1]In the NEG-literature one makes a distinction between short-run equilibria where s_n is fixed and long-run equilibria which are the steady states of migration equation 7.1.

To sharpen the intuition, we calculate the maximal allowed tax gap between the two regions in order to make an internal solution possible, whether it will be stable or not. The tax gap $\frac{1-z^*}{1-z}$ is given by $\epsilon^{1/(1-\sigma)}$ under the assumption of equal reference wages and is given in table 7.1. We also gave the border values for the competitiveness in brackets. We see that in general the regional tax rates can't diverge too much if an internal solution has to occur. Only for very small values of the trade freeness and the elasticity of substitution the allowable tax gap in an internal equilibrium can be quite considerable. This is an illustration of the strong agglomerative forces present in our model.

	$\phi = 0.1$	$\phi = 0.5$	$\phi = 0.9$
$\boldsymbol{\sigma = 2.5}$	63% ($0.48 < \epsilon < 2.08$)	16% ($1.25 > \epsilon > 0.8$)	4.0% ($1.06 > \epsilon > 0.94$)
$\boldsymbol{\sigma = 5}$	2.2% ($0.91 < \epsilon < 1.09$)	11% ($1.53 > \epsilon > 0.65$)	2.0% ($1.08 > \epsilon > 0.92$)
$\boldsymbol{\sigma = 7.5}$	4.2% ($1.31 > \epsilon > 0.76$)	8.2% ($1.6 > \epsilon > 0.6$)	1.4% ($1.09 > \epsilon > 0.91$)

Table 7.1: Maximal allowed tax gap for internal solutions.

Analogously we investigate the range of trade freeness wherein the share of firms lies between 0 and 1. We have to make a distinction between cases where the northern country has a competitive disadvantage ($\epsilon < 1$) and where it has a competitive advantage ($\epsilon > 1$). In both cases there are two zones of internal equilibria albeit they are not the same:

$$0 < s_n < 1 \Leftrightarrow 0 < \epsilon < 1 \wedge \left[\phi < \phi_{0A} \vee \{\phi_{1A} < \phi < \phi_{1B} \quad \wedge \quad \sigma > \frac{1 + \sqrt{1 - \epsilon^2}}{\epsilon^2}\} \right] \tag{7.6}$$

$$0 < s_n < 1 \Leftrightarrow \epsilon > 1 \wedge \left[\phi < \phi_{1A} \quad \vee \quad \{\phi_{0A} < \phi < \phi_{0B} \wedge \sigma > \epsilon^2 (1 + \sqrt{\epsilon^2 - 1})\} \right]. \tag{7.7}$$

In these expressions we defined the following parameters:

$$\begin{aligned} \phi_{0A} &= \frac{\sigma - \sqrt{\epsilon^2 - 2\epsilon^2\sigma + \sigma^2}}{2\epsilon\sigma - \epsilon}, & \phi_{0B} &= \frac{\sigma + \sqrt{\epsilon^2 - 2\epsilon^2\sigma + \sigma^2}}{2\epsilon\sigma - \epsilon}, \\ \phi_{1A} &= \frac{\epsilon\sigma - \sqrt{1 - 2\sigma + \epsilon^2\sigma^2}}{2\sigma - 1}, & \phi_{1B} &= \frac{\epsilon\sigma - \sqrt{1 - 2\sigma + \epsilon^2\sigma^2}}{2\sigma - 1}. \end{aligned} \tag{7.8}$$

Note that for $\epsilon = 1$, $\phi_{0A} = \phi_{1A}$ and $\phi_{0B} = \phi_{1B}$.

Again we give some numerical values for the introduced parameters. These are depicted in table 7.2. The zones of internal equilibrium are again very limited which illustrates the strong nature of the agglomerative forces in this model.

		ϕ_{0A}	ϕ_{0B}	ϕ_{1A}	ϕ_{1B}
	$\boldsymbol{\sigma = 2.5}$	0.10	>1	/	/
$\epsilon = \frac{1}{2}$	$\boldsymbol{\sigma = 5}$	0.05	>1	/	/
	$\boldsymbol{\sigma = 7.5}$	0.03	>1	0.25	0.28
	$\boldsymbol{\sigma = 2.5}$	0.25	0.25	1	1
$\epsilon = 1$	$\boldsymbol{\sigma = 5}$	0.11	0.11	1	1
	$\boldsymbol{\sigma = 7.5}$	0.07	0.07	1	1
	$\boldsymbol{\sigma = 2.5}$	/	/	0.14	>1
$\epsilon = \frac{3}{2}$	$\boldsymbol{\sigma = 5}$	0.21	0.53	0.06	>1
	$\boldsymbol{\sigma = 7.5}$	0.12	0.59	0.05	>1

Table 7.2: Values for ϕ_{0A}, ϕ_{0B}, ϕ_{1A}, and ϕ_{1B}.

7.1.2 Stability of the steady states

After establishing the zones of internal equilibrium, we are ready to analyze the stability of the found steady states by applying Krugman's informal stability test ([72]) which is, as proven by Baldwin ([8]), equal to the formal standard mathematical stability tests. An internal equilibrium is stable when a northward migration reduces the northern capital reward gap $(\pi - \pi^*)$ since the migrated capital would be better off if it had stayed in the original region. A core-periphery pattern is stable as soon as the level of the capital reward in the core exceeds the capital reward in the periphery. Mathematically this means that we should check the negativity of $\left.\frac{d(\pi-\pi^*)}{ds_n}\right|_{int}$ for internal equilibria and the sign of $\pi - \pi^*|_{s_n=1}$ for stable northern core solutions. The point where the former equals zero is called the break point, the point where the latter becomes negative is denoted as the sustain point.

In function of trade freeness

We start with the stability analysis in function of the trade freeness. The before mentioned first order derivative $\left.\frac{d(\pi-\pi^*)}{ds_n}\right|_{int}$ is calculated by substitution 6.14 and 6.15 in equation 7.2 and taking the first order derivative with respect to s_n:

$$\left.\frac{d(\pi - \pi^*)}{ds_n}\right|_{int} = \frac{4\gamma(\sigma\phi + \epsilon(-1 + \phi(\epsilon\sigma + \phi - 2\sigma\phi)))}{\epsilon^2(1 - \phi^2)(1 + (2\sigma - 1)^2\phi^2)}. \tag{7.9}$$

By equating the numerator of 7.9 to zero, we get a quadratic equation in trade freeness which has two roots as possible break points:

$$\phi_{B1} = \frac{\sigma(1+\epsilon^2) - \sqrt{4\epsilon^2(1-2\sigma) + \sigma^2(1+\epsilon^2)^2}}{2\epsilon(2\sigma-1)}, \tag{7.10}$$

$$\phi_{B2} = \frac{\sigma(1+\epsilon^2) + \sqrt{4\epsilon^2(1-2\sigma) + \sigma^2(1+\epsilon^2)^2}}{2\epsilon(2\sigma-1)}. \tag{7.11a}$$

Under the valid restrictions of $\epsilon > 0$ and $\sigma > 1$ it is easy to establish that $0 < \phi_{B1} < 1$ and that $\phi_{B2} > 1$. Since the sign of the quadratic term $(\epsilon\phi^2(1-2\sigma))$ in 7.9 is negative, stable internal equilibria only occur for values of trade freeness below ϕ_{B1}. This also means that we don't have to impose a no-black hole condition as is required normally in NEG-models.

The discussion of the sustain points in function of the trade freeness is more intricate since not only we have to make a distinction in function of the competitiveness ϵ, but also because we have to consider the core in the north and in the south separately. The difference between the capital rewards if $s_n = 1$ and $s_n = 0$ is respectively given by:

$$\pi - \pi^*|_{s_n=1} = \frac{\gamma(-1+\phi(2\epsilon\sigma + \phi(1-2\sigma)))}{2\epsilon\sigma\phi}, \tag{7.12}$$

$$\pi - \pi^*|_{s_n=0} = \frac{\gamma(\epsilon - 2\phi\sigma + \epsilon(2\sigma-1)\phi^2)}{2\sigma\phi}. \tag{7.13}$$

Equating both expressions to zero gives us four sustain points. We denote the sustain points for the northern core with ϕ_{SN1} and ϕ_{SN2}, the southern core sustain points are depicted by ϕ_{SS1} and ϕ_{SS2} :

$$\phi_{SN1} = \frac{1}{\epsilon\sigma + \sqrt{1+\sigma(\epsilon^2\sigma-2)}}, \qquad \phi_{SN2} = \frac{1}{\epsilon\sigma - \sqrt{1+\sigma(\epsilon^2\sigma-2)}}, \tag{7.14}$$

$$\phi_{SS1} = \frac{\epsilon}{\sigma + \sqrt{\epsilon^2(1-2\sigma)+\sigma^2}}, \qquad \phi_{SS2} = \frac{\sigma + \sqrt{\epsilon^2(1-2\sigma)+\sigma^2}}{\epsilon(2\sigma-1)}. \tag{7.15}$$

For equally competitive regions we see that ϕ_{SN1} equals ϕ_{SS1} and that ϕ_{SN2} coincides with ϕ_{SS2} and that both are equal to 1. For this situation, the core in the north and in the south becomes stable as soon as the trade freeness exceeds $\phi_{SN1} = \phi_{SS1}$.

For cases where the north has a competitive advantage over the south ($\epsilon > 1$), the northern core is stable for values lying between ϕ_{SN1} and ϕ_{SN2}. However, it is easily checked that the second northern sustain point ϕ_{SN2} always exceeds one, so we can simplify matters by stating that the northern core is stable as soon as the trade freeness becomes larger than ϕ_{SN1}. The square root in the denominator of 7.15 only gives cause to real solutions[2] for values of the elasticity of substitution higher than $\epsilon^2(1+\sqrt{\epsilon^2-1})$. It should come as no surprise that this condition on the elasticity of substitution coincides with the condition 7.7 for having a core in the south solution if $\epsilon > 1$. The higher the elasticity of substitution becomes, the larger the area (delimited by ϕ_{SS1} and ϕ_{SS2}) where the southern core is stable, becomes.

Lastly, if the south has a competitive advantage, we find that 7.13 is negative for values of trade freeness between ϕ_{SS1} and ϕ_{SS2} . Similar to the previous case, the second sustain point always exceeds one, as a result of what stable southern cores always occur for values of trade freeness exceeding ϕ_{SS1}. Expression 7.12 is only positive and real for values of trade freeness between ϕ_{SN1} and ϕ_{SN2} and for values of the elasticity of substitution higher than $\frac{1+\sqrt{1-\epsilon^2}}{\epsilon^2}$[3]. We conclude this discussion on the stability of the steady states in function of the trade freeness by noting that the stable core in the south (north) solution for values of $\epsilon > 1$ ($\epsilon < 1$) never can span the whole trade freeness range. Even for very high values of the substitution elasticity and almost evenly competitive regions, this stable region stays relatively small.

In function of the competitiveness

In order to determine the break points in terms of the competitiveness, we equate expression 7.9 to zero and solve for the competitiveness ϵ. There are, just as before, two possible solutions for the break points:

$$\epsilon_{B1} = \frac{1+(2\sigma-1)\phi^2 - \sqrt{1-\phi^2}\sqrt{1-(1-2\sigma)^2\phi^2}}{2\sigma\phi} \tag{7.16}$$

[2] The square root is also real if $\sigma < \epsilon^2(1-\sqrt{\epsilon^2-1})$, but this value for σ is always smaller than 1. Hence, we omit this.

[3] The square root in the denominator of 7.14 is also real if $\sigma < \frac{1+\sqrt{1-\epsilon^2}}{\epsilon^2}$, but this value is always smaller than 1.

$$\epsilon_{B2} = \frac{1 + (2\sigma - 1)\phi^2 + \sqrt{1-\phi^2}\sqrt{1-(1-2\sigma)^2\phi^2}}{2\sigma\phi}. \quad (7.17a)$$

The second root in the numerator of both expressions is positive if and only if the substitution elasticity lies between $\frac{-1+\phi}{2\phi}$ and $\frac{1+\phi}{2\phi}$. Since $\frac{-1+\phi}{2\phi} < 0$, σ has to lie between 1[4] and $\frac{1+\phi}{2\phi}$ in order to have non-imaginary values for ϵ_{B1} and ϵ_{B2}. Under this restriction, it is also easy to show that the first break point always lies between 0 and 1 and that the second break point lies in the region where the north has a competitive advantage over the south ($\epsilon > 1$). The sign of the quadratic factor in ϵ of expression 7.9 is positive as a result of which the internal steady states are always stable between the two break points as long as $\sigma < \frac{1+\phi}{2\phi}$.

Contrary to the previous section 7.1.2 the discussion of the sustain points is a lot easier. The solution in terms of the competitiveness of equating 7.12 and 7.13 to zero, leads to the following two sustain points for the core in the north and the core in the south solution respectively:

$$\epsilon_{SN} = \frac{1 + (2\sigma - 1)\phi^2}{2\sigma\phi}, \qquad \epsilon_{SS} = \frac{1}{\epsilon_{SN}}. \quad (7.18)$$

For values of $\epsilon > \epsilon_{SN}$ the northern core becomes stable, for values of $\epsilon < \epsilon_{SS}$ the south becomes a stable core. Both sustain points coincide when $\sigma = \frac{1+\phi}{2\phi}$ as could be expected.

7.1.3 The tomahawk diagram revisited

We now know how the locational equilibrium shifts when the trade costs shift or when the competitiveness changes between the two regions. We also know where which equilibrium is stable. By combining both results, we are able to draw two 'tomahawk' diagrams, one in function of ϵ, one in terms of ϕ.

We start with the tomahawk diagram in function of the competitiveness. Under the assumption that $\sigma < \frac{1+\phi}{2\phi}$ it is possible to show[5] that the first break point ϵ_{B1} comes before the start of the internal zone at ϵ_0 and that the second break point always lies at values of the competitiveness higher than ϵ_1. For values of $\sigma > \frac{1+\phi}{2\phi}$, the internal zone is always unstable. Since

[4] A Dixit-Stiglitz framework assumes that $\sigma > 1$.

[5] Analytical proofs are somewhat tedious but not difficult. In order not to burden the text too much, we omitted therefore the proofs of the different statements done in subsequent paragraphs. The proofs are available upon request.

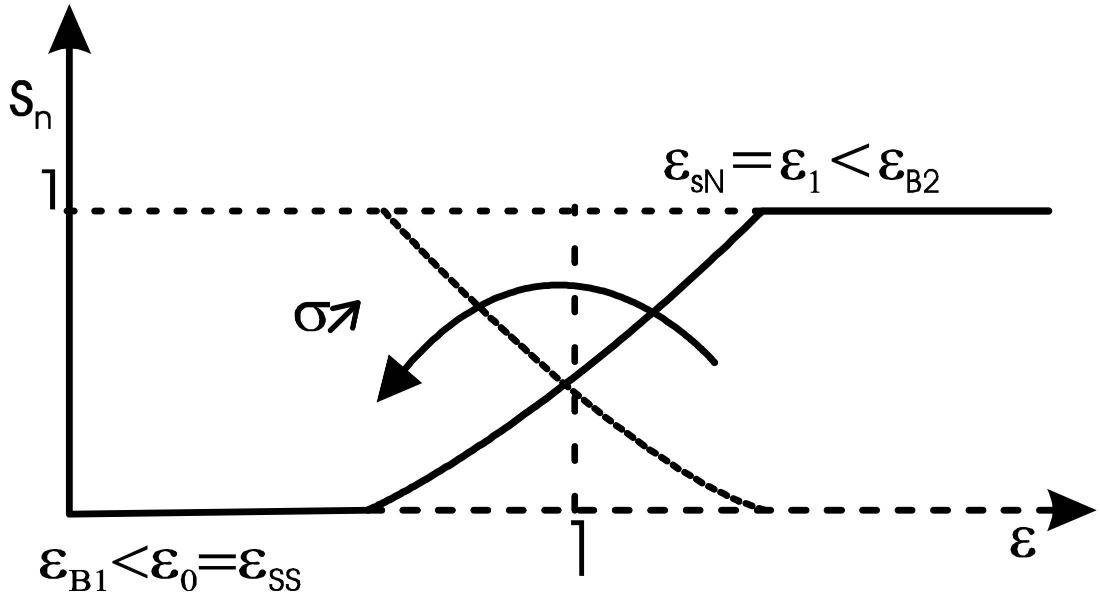

Figure 7-1: Tomahawk diagram in function of competitiveness.

ϵ_{SN} coincides with ϵ_1 and ϵ_{SS} with ϵ_0 we conclude that the core solutions are always stable. We can summarize the locational behaviour of the model in function of the competitiveness in diagram 7-1. In this diagram the solid lines represent the stable steady states, the dotted lines the unstable equilibria.

The integration of the results of the two previous sections is a little bit more complex for the behaviour in terms of the trade freeness since we have to make a distinction whether ϵ exceeds, is equal to or is smaller than 1. It is possible to show that ϕ_{B1} exceeds ϕ_{1A} when $\epsilon > 1$ and that $\phi_{1A} < \phi_{B1}$ when $\epsilon < 1$. When both regions have the same competitiveness, the first break point always coincides with $\phi_{OA} = \phi_{1A}$. The first zone of internal equilibria is as a consequence, regardless of the value of the competitiveness, always stable. The second zone of internal equilibria only occurs for values of σ that are high enough[6]. When the north is more competitive than the south, the second zone of internal steady states is always unstable since $\phi_{OA} > \phi_{B1}$ and $\phi_{OB} < \phi_{B2}$. The locational equilibrium is unstable for values of trade freeness that lie between ϕ_{B1} and between ϕ_{B2}. When the south has a competitive advantage, it is

[6]For $\epsilon < 1$, $\sigma > \frac{1+\sqrt{1-\epsilon^2}}{\epsilon^2}$, and for $\epsilon > 1$, $\sigma > \epsilon^2(1 + \sqrt{1-\epsilon^2})$.

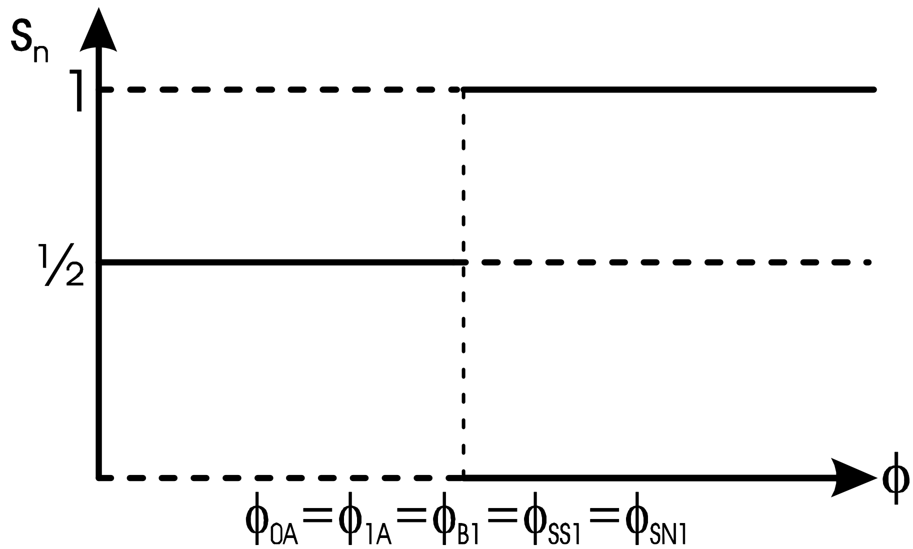

Figure 7-2: Tomahawk diagram in function of ϕ for $\epsilon = 1$.

again easy to show that the second zone of interior equilibria is always unstable ($\phi_{1A} > \phi_{B1}$, $\phi_{1B} < \phi_{B2}$). We now only have to look into the concurrence between the core-periphery zones and their stability. By realizing that, $\phi_{1A} = \phi_{SN1}$, $\phi_{1B} = \phi_{SN2}$, $\phi_{0A} = \phi_{SS1}$ and that $\phi_{0B} = \phi_{SS2}$, we can safely conclude that the core-in-the-south solution for $\epsilon \leqslant 1$ and $\phi > \phi_{0A}$ is always stable. The same holds for the core-in-the-north solution when $\epsilon \geqslant 1$ and $\phi > \phi_{1A}$. These results are again elucidated by plotting the tomahawk diagram. The first diagram 7-2 gives the situation when both regions are equally competitive, the following, figure 7-3 gives the case when the north has a competitive disadvantage and the last figure 7-4 represents the possibility where the north has a competitive advantage.

7.1.4 Discussion of agglomeration forces and properties of the model

Agglomerative and dispersion forces

There are two driving forces in this agglomeration model. The first one is the 'market access effect'. It describes the tendency of monopolistic firms to locate their production in the big market and export to the small markets. When the share of expenditures in a region increases,

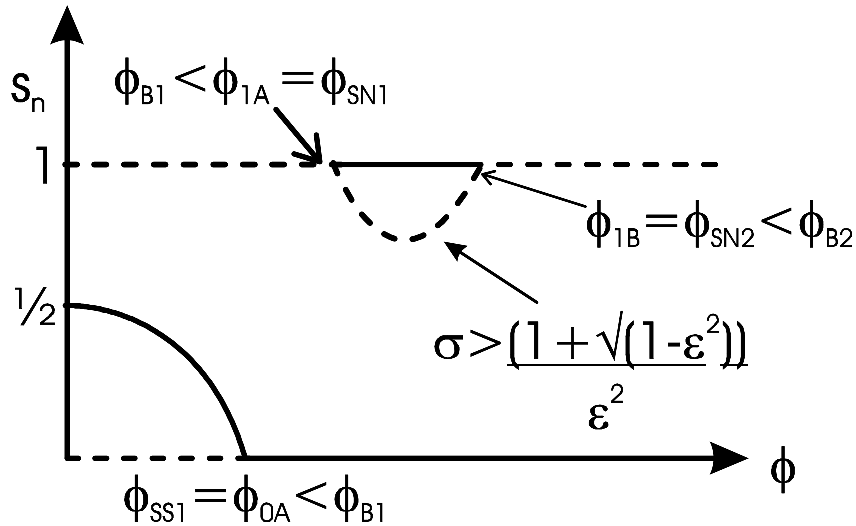

Figure 7-3: Tomahawk diagram in function of phi for $\epsilon < 1$.

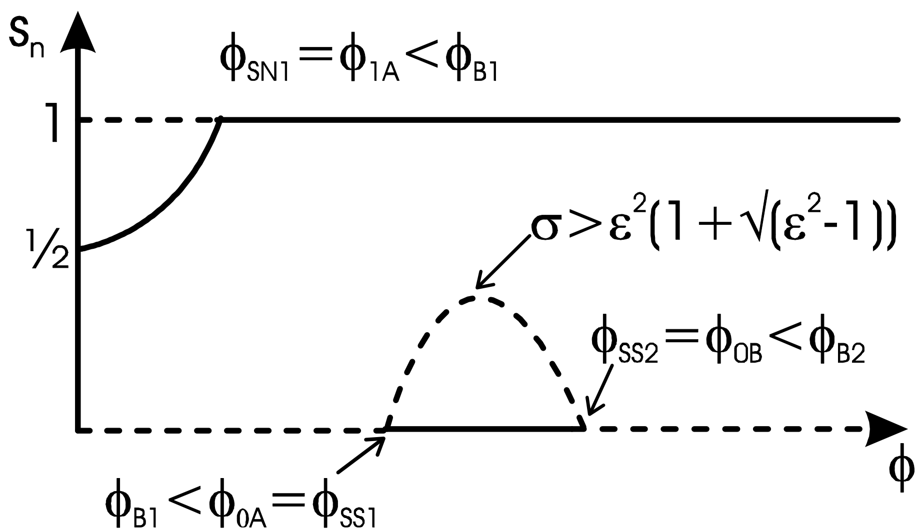

Figure 7-4: Tomahawk in function of ϕ for $\epsilon > 1$.

the sales of the firms located in that region also increases. As a consequence the operating profit of those firms also increases (the total labour cost to a firm didn't change). Under the zero-profit condition higher operating profits lead to a higher capital reward which will attract firms to locate in this region. The second force is not an agglomerative force, but a dispersive one. It reflects the fact that imperfect competitive firms have a tendency to locate in regions with relatively few competitors. A small movement of firms from the south to the north raises s_n. As a result Δ in 6.17 will rise while Δ^* will decrease. Under a constant share of expenditures and degree of competitiveness, this will lead to lower sales for a northern firm[7]. Owing to the simultaneous reduction of the operating profit, the northern capital reward has to decrease under the zero-profit condition. The resulting dispersion force is called the local competition effect or the market crowding effect. In many NEG-models a third force is also present, namely the cost-of-living effect. Since the driving force in our model is the nominal capital reward gap, not the real one, this effect is absent in our model.

Our model is analytically tractable enough to explicitly derive closed-form expressions for both forces in play. The agglomerative and dispersion force can be calculated by deriving the driving force $\pi - \pi^*$ at the internal equilibrium with respect to s_E and s_n respectively. Substituting 6.14 and 6.15 in equation 7.2 and taking the first order derivative with respect to s_n and s_E respectively gives:

$$\left.\frac{\partial(\pi - \pi^*)}{\partial s_E}\right|_{s_n,\, int} = \frac{8(\sigma-1)\phi((1+\epsilon^2)(1-\phi^2+2\sigma\phi^2) - 4\epsilon\sigma\phi)(\sigma\phi(1+\epsilon^2-2\epsilon\phi) - \epsilon(1-\phi^2))}{\epsilon^2(\epsilon-\phi(2\sigma-1))(1-\epsilon(2\sigma-1)\phi)(1-\phi^2)^2(1-(1-2\sigma)^2\phi^2)}, \tag{7.19}$$

$$\left.\frac{\partial(\pi - \pi^*)}{\partial s_n}\right|_{s_E,\, int} = \frac{4(\epsilon-\phi)(1-\phi\epsilon)(\phi\sigma(1+\epsilon^2-2\phi\sigma) - \epsilon(1-\epsilon\phi))}{\epsilon^2(1-\phi^2)^2(1-\epsilon\phi(2\sigma-1))((2\sigma-1)\phi-\epsilon)}. \tag{7.20}$$

It can be proven that under the conditions 7.4 for an internal equilibrium the agglomerative force is always positive while the second force is always negative. To illustrate both forces more clearly, we plotted 7.19 and 7.20 when $\epsilon = 1$. Note that we plotted the inverse of the negative dispersion force in order to compare the relative strength of both forces better. For low values

[7] Starting from symmetry ($s_n = s_e = \frac{1}{2}$, $\epsilon = 1$) the derivative of the sales with respect to s_n equals $-\frac{2(1-\phi^2)}{(1+\phi^2)}$, which is clearly always negative.

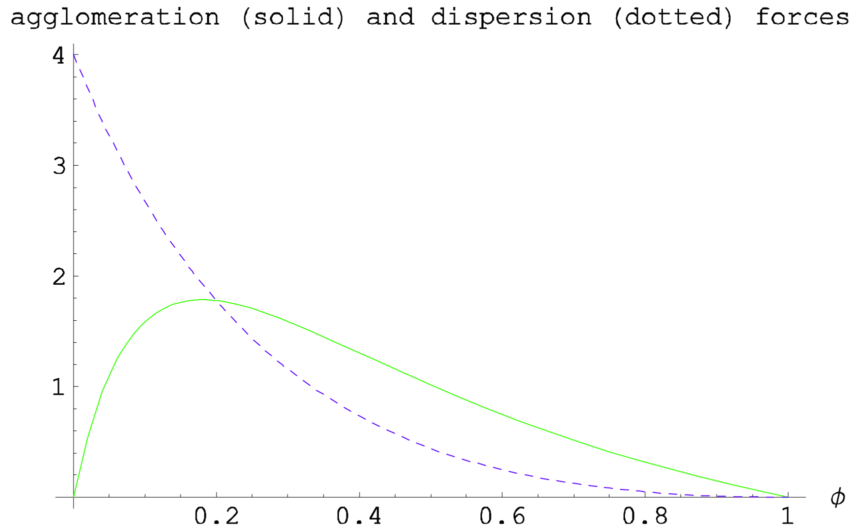

Figure 7-5: The agglomerative (solid) and dispersion (dotted) force ($\epsilon = 1$).

of trade freeness the dispersion force is still stronger than the agglomerative force and we end up in an interior steady state. For high values of the trade freeness, the core-periphery situation prevails. Since we reasoned from the interior equilibrium, the equality in strength of both forces coincides with the (first) break point. The fact that the dispersion force drops more sharply with trade freeness can be understood if one looks back at the expression of the (northern) sales 6.17. Lower trade costs mean that a larger share of the sales becomes independent of the location of the competitors while at the same time it becomes easier for a firm to increase its market share abroad.

Circular causalities

Unlike a standard footloose capital model, our model does have a cost-linked circular causality. An increase of capital (=firms) in a region will reduce the unemployment in that region and hence, increase the regions share of expenditure. This will make the region more attractive to further migrate capital to since the increased sales lead to higher capital rewards in that region. Thus, the main reason, why this model — although it has the same migrational behaviour as the model of Martin and Rogers — has circular causalities lies in the endogenous presence of unemployment via the reference wages.

Home market effect and magnification

We calculate the home-market derivative $\frac{ds_n}{ds_E}$. In order to do this we equate 6.20 and 6.21, substitute the expressions for Δ and Δ^* (given by 6.14 and 6.15 respectively) and solve for s_n. This leads to the following expression for the share of firms s_n in function of the share of expenditures s_E:

$$s_n = \frac{s_E \cdot \epsilon - \phi + (1 - s_E) \cdot \epsilon \cdot \phi^2}{(\epsilon - \phi) \cdot (1 - \epsilon \cdot \phi)}. \tag{7.21}$$

Taking the derivative of 7.21 with respect to s_E gives us the home-market derivative:

$$\frac{ds_n}{ds_E} = \frac{\epsilon(1 - \phi^2)}{(\epsilon - \phi)(1 - \epsilon\phi)}. \tag{7.22}$$

When both regions are equally competitive, this expression reduces to the standard FC-expression, namely $\frac{(1+\phi)}{(1-\phi)}$ from which it is clear that an exogenous change in the location of demand leads to a more than proportional relocation of industry to the enlarged region. When the south has a competitive advantage, the home market derivative is larger than 1 as long as the trade freeness remains smaller than ϵ. For values of $\epsilon > 1$, there can only be a home-market effect as long as $\phi < \frac{1}{\epsilon}$. It can be easily checked that these restrictions on the trade freeness are less strict than the restrictions we derived for an internal equilibrium (7.8). So we conclude that the home-market effect is always active for interior equilibria.

Secondly, by deriving 7.22 to the trade freeness, it is easy to show that the home-market derivative gets larger when trade costs decline. This is the home-market magnification effect of Baldwin ([7]) and can be captured by:

$$\frac{d^2 s_n}{ds_E d\phi} = \epsilon\left(\frac{1}{(\epsilon - \phi)^2} + \frac{1}{(1 - \epsilon\phi)^2}\right). \tag{7.23}$$

Freer trade makes industry become more footloose as could be expected.

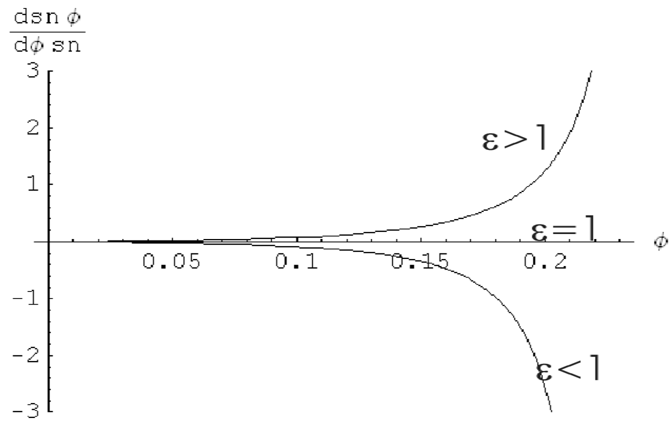

Figure 7-6: Delocation elasticity in function of trade freeness for three values of competitiveness.

Endogenous asymmetry and near-catastrophic agglomeration

A gradual lowering of the trade costs, starting from prohibitive trade costs, will only have a slight locational impact, with some of the industry moving to the region with the competitive advantage. However, as the level of trade freeness comes into the range of the break point, the delocation will go faster and faster. After the break point, all industry is agglomerated in the region with the competitive advantage. Since there is a gradual shift of stable locational equilibria in function of the trade freeness, full-blown catastrophic agglomeration is not possible between regions where one has a competitive advantage. All possible locational equilibrium states become possible between full symmetry and core-periphery. This behaviour can be captured by the delocation elasticity defined as the percent change in s_n with respect to a percent change in the trade freeness. This elasticity is found by deriving 7.3 with respect to the trade freeness and multiplying this result with $\frac{\phi}{s_n}$:

$$\frac{ds_n}{d\phi}\frac{\phi}{s_n} = \frac{\epsilon(1-\epsilon^2)\sigma\phi(1+(1-2\sigma)\phi^2}{(\epsilon - 2\sigma\phi + \epsilon(2\sigma-1)\phi^2)(\sigma\phi + \epsilon(-1+\phi(\sigma\epsilon + \phi(1-2\sigma)))}. \tag{7.24}$$

We plotted the delocation elasticity for equally competitive regions and for the case where one region has a slight competitive advantage ($\epsilon = 0.95/1.05$). We restricted the range of trade freeness to values where there is an internal equilibrium ($\phi_{SN1} = \phi_{SS1} = 0.23$ at $\sigma = 2.5$).

This figure also indicates that the delocation elasticity for equally competitive regions equals zero for values below the break point. If both regions are equally competitive, the symmetricum will remain the stable steady state for a large interval of high trade costs. In this case, a standard catastrophic agglomeration is evidently possible, which is still an important deviation from the Martin and Rogers set-up.

Locational hysteresis

For intermediate values of trade freeness and high enough elasticities of substitution multiple equilibria do exist. Both regions can sustain a core equilibrium at the same time. For instance, when the north has a competitive advantage a lowering of the trade costs makes the core-in-the-north solution stable starting from a stable interior solution. But in that range of trade costs where the agglomerative forces are the strongest (see figure 7-5) the core-in-the-south solution can become stable. Of course the competitive disadvantage of the south can't be too large and the agglomerative forces have to be strong (high values of σ). The range of values for the elasticity of substitution and the competitiveness where this is possible are depicted in graph 7-1. So our model does display locational hysteresis

This means that there is path-dependency in our model. It matters which starting point you have in a policy analysis.

Hump-shaped agglomeration rents

The agglomeration rents are defined as the loss that a capital unit would incur by relocating from the core to the periphery when full agglomeration is a stable equilibrium. These are given by:

$$\pi - \pi^*|_{s_n=1} = \frac{1 + \phi((2\sigma - 1)\phi - 2\sigma\phi)}{2\sigma\epsilon\phi}. \tag{7.25}$$

These rents are concave in trade freeness since the second order derivative of the profit gap with respect to the trade freeness is negative ($\frac{d^2(\pi-\pi^*)}{d\phi^2} = -\frac{1}{\epsilon\sigma\phi^3}$). It equals zero at the sustain point and reaches it maximum at $\phi = \sqrt{\frac{1}{2\sigma-1}}$. Accordingly, the agglomerative rents first increase after the sustain point and decrease towards complete trade freeness.

7.2 Internal equilibrium

Contrary to the two-country case without capital mobility, we are no longer able to explicitly derive the Nash tax rates in any scenario. Instead, we rely on simulations to describe social security competition under capital mobility. In this section we discuss the optimal behaviour of governments when the locational equilibrium is a stable internal equilibrium. In section 3 of this chapter we give the results for a stable core-periphery situation.

As before, we start with a short description of the effects through which a government's tax setting influences the social welfare. In a second step, we will discuss the reaction curves and the way the foreign tax rate influences the home tax rate. Finally we will analyze the effect of some parameters on the Nash equilibrium.

7.2.1 Benefit, unemployment and price-index effect

By focusing on internal equilibria, we have to restrict the freedom of action for a government since the tax gap endogenously determines the locational equilibrium. Each government can only choose a tax rate, given the foreign tax rate, such that 7.4 holds. In order not to limit the range of possibilities for each government too much, we opt for a low value of the elasticity of substitution σ $(= 2.5)$ and trade freeness ϕ $(= 0.05)$. This means in effect that the competitiveness may vary between 0.247 and 4.08 or otherwise said, that the north can undercut the southern tax rate by more than 150 per cent which creates more than enough space for social security competition. The fact that we are obliged to choose low values for the trade freeness is an indication that the model has very strong agglomeration forces.

A second consequence of looking at internal equilibria is the invariability of the capital reward. The expressions 6.20 and 6.21 are both equal to γ under 7.3. But at the same time, a new variability, namely via the share of firms in each region, is introduced. Without this second effect a foreign tax change would only have affected the home region via the price index, no longer via the tax base. It is not that difficult to check that, under the restrictions given by 7.4, the sign of the derivative of s_n with respect to z is negative.

This result simplifies the interpretation of the first order derivative of the social welfare function with respect to the tax rate. As before, we can distinguish three channels through which the northern tax rate affects the northern social welfare First, the unemployment, given by 6.28 increases since a higher tax reduces the share of firms s_n and also the term $(1-z)$. This will exert a negative influence on the social welfare. Secondly, higher taxes will decrease the share of firms in the home region and will increase the prices charged by the own firms. As a consequence the price index will increase and the purchasing power of the people will decrease. This again leads to a negative effect on the social welfare. In equilibrium both effects are in balance with the third effect, namely the benefit effect. It turns out that the combined effect of higher taxes on a reduced tax base still allows for a higher unemployment benefit. The price, unemployment and benefit effect can be consecutively written as:

$$\left.\frac{dSW}{dz}\right|_{b,u=cst} = \begin{cases} \frac{-1}{\Delta(z,z^*)} \cdot \left[\frac{s_n(z,z^*)\cdot\epsilon(z,z^*)}{1-z} - \frac{(\epsilon(z,z^*)-\phi)}{\sigma-1}\cdot\frac{\partial s_n}{\partial z}(z,z^*)\right] & (e=1) \\ -\frac{b(z,z^*)+CR}{\Delta(z,z^*)\cdot P(z,z^*)} \cdot \left[\frac{s_n(z,z^*)\cdot\epsilon(z,z^*)}{1-z} - \frac{(\epsilon(z,z^*)-\phi)}{\sigma-1}\frac{\partial s_n}{\partial z}(z,z^*)\right] & (e=\infty) \\ \frac{SW(z,z^*)\cdot(1-e)}{\Delta(z,z^*)} \left[\frac{s_n(z,z^*)*\epsilon(z,z^*)}{1-z} - \frac{(\epsilon(z,z^*)-\phi)}{\sigma-1}\frac{\partial s_n}{\partial z}(z,z^*)\right] & (e\neq 1,\infty) \end{cases} \tag{7.26}$$

$$\left.\frac{dSW}{dz}\right|_{P,b=cst} = \begin{cases} \delta\cdot\pi\cdot\left[s_n(z,z^*)-(1-z)\cdot\frac{\partial s_n}{\partial z}(z,z^*)\right]\cdot\log\left(\frac{b(z,z^*)+CR}{\frac{w_R}{1-\beta}+CR}\right) & (e=1) \\ 0 & (e=\infty) \\ \left(\frac{\delta\cdot\pi\cdot(P(z,z^*))^{e-1}}{1-e}\right)\cdot\left[s_n(z,z^*)-(1-z)\cdot\frac{\partial s_n}{\partial z}(z,z^*)\right]\cdot & \\ (b(z,z^*)+CR)^{1-e}-\left(\frac{w_R}{1-\beta}+CR\right)^{e-1} & (e\neq 1,\infty) \end{cases} \tag{7.27}$$

$$\left.\frac{dSW}{dz}\right|_{P,u=cst} = \begin{cases} \frac{w_T \cdot \delta \cdot \pi}{(b(z,z^*)+CR)\cdot(1-\beta)\cdot u(z,z^*)} \cdot \\ \left[s_n(z,z^*) \cdot (1 - \delta \cdot \pi \cdot s_n(z,z^*) + z \cdot \frac{\partial s_n}{\partial z}(z,z^*)) \right] \quad (e=1) \\ \frac{w_T \cdot \delta \cdot \pi}{P(z,z^*)\cdot(1-\beta)\cdot(u(z,z^*))^2} \cdot \\ \left[s_n(z,z^*) \cdot (1 - \delta \cdot \pi \cdot s_n(z,z^*) + z \cdot \frac{\partial s_n}{\partial z}(z,z^*)) \right] \quad (e=\infty) \\ \frac{(b(z,z^*)+CR)^{-e} \cdot (P(z,z^*))^{e-1} \cdot w_R \cdot \pi \cdot \delta}{(1-\beta)\cdot u(z,z^*)} \cdot \\ \left[s_n(z,z^*) \cdot (1 - \delta \cdot \pi \cdot s_n(z,z^*) + z \cdot \frac{\partial s_n}{\partial z}(z,z^*)) \right] \quad (e \neq 1, \infty) \end{cases}, \quad (7.28)$$

$$\text{with } \frac{\partial s_n}{\partial z}(z,z^*) \overset{7.3}{=} \frac{(\sigma-1)\cdot\epsilon\cdot(\sigma\cdot\phi^2 + (s_K - s_n)\cdot(1-\phi^2) - 2\cdot s_n\cdot\sigma\cdot\phi\cdot(\phi-\epsilon)}{(1-z)\cdot(\sigma\cdot(\epsilon-\phi)\cdot(\epsilon\cdot\phi-1)-(\sigma-1)\cdot\epsilon\cdot(\phi^2-1)}. \quad (7.29)$$

7.2.2 Reaction curves

The reaction curves of both regions are given for different values of the inequality aversion e in figure 7-7. When governments become more Rawslian-like, they opt for higher tax rates. Comparing these curves with the result of figure 6-2, two differences catch the eye. Firstly the reaction curves become a straight line for foreign tax rates that are high enough (function of the inequality aversion). Secondly, the chosen tax rate changes its behaviour from a strategic substitute to a strategic complement when the foreign tax rate further reduces from the point where the reaction curve simplified into a straight line.

We know from combining condition 7.4 and the tomahawk diagram 7-1 that stable internal equilibria can only occur for values of the elasticity of substitution that are smaller than $\frac{1+\phi}{2\phi}$(=10.5 for $\phi = 0.05$) and under the condition that the competitiveness lies between ϵ_0 and ϵ_1. Under the assumption that both regions have the same number of inhabitants — and hence have the same reference wage — one could easily rewrite this condition in terms of the tax rates z and z^*: $0 < s_n < 1 \Leftrightarrow 1-(\epsilon_1)^{1/(\sigma-1)}(1-z^*) < z < 1-(\epsilon_0)^{1/(\sigma-1)}(1-z^*)$. The straight lines

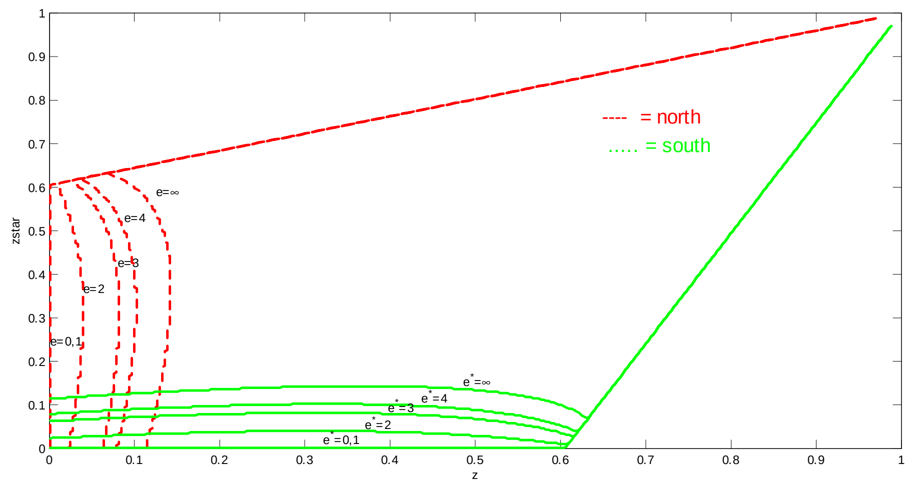

Figure 7-7: Reaction curves in function of e under capital mobility and $\phi = 0.05, \beta = 0.6$, $s_K = \frac{1}{2}$, $\sigma = 2.5$.

on the reaction curve diagram are nothing else than the representation of these limits in which the interior solutions are stable. Otherwise said, for high enough values of the foreign tax rate, a government would opt for a tax rate that is just low enough to attract all the industry within its borders.

To understand the shape of the reaction curves we consider the first order derivative of the (northern) social welfare function with respect to the southern tax rate. As before one could distinguish two channels: a price index effect and a competition effect. These are respectively given by:

$$\left.\frac{dSW}{dz^*}\right|_{u,b=cst} = \begin{cases} \left[\frac{\epsilon(z,z^*)-\phi}{(\sigma-1)\cdot\Delta(z,z^*)}\cdot\frac{\partial s_n}{\partial z^*}(z,z^*) - \frac{1}{1-z^*}\cdot(1-\frac{s_n(z,z^*)\cdot\epsilon(z,z^*)}{\Delta(z,z^*)}\right] & (e=1) \\ \frac{b(z,z^*)+CR}{P(z,z^*)}\cdot\left.\frac{dSW}{dz^*}\right|_{u,b=cst,e=1} & (e=\infty) \\ SW(z,z^*)\cdot(1-e)\cdot\left.\frac{dSW}{dz^*}\right|_{u,b=cst,e=1} & (e\neq 1,\infty) \end{cases} \tag{7.30}$$

$$\left.\frac{dSW}{dz^*}\right|_{P=cst} = \begin{cases} \delta \cdot \pi \cdot \frac{\partial s_n}{\partial z^*}(z,z^*) \cdot \\ \left[\frac{w_R \cdot z}{(b(z,z^*)+CR)\cdot(1-\beta)\cdot u(z,z^*)} - (1-z)\cdot \log(\frac{(b(z,z^*)+CR)}{\frac{w_R}{(1-\beta)}+CR}\right] & (e=1) \\ \frac{w_R \cdot \delta \cdot \pi \cdot z}{(1-\beta)\cdot(u(z,z^*))^2 \cdot P(z,z^*)} \cdot \frac{\partial s_n}{\partial z^*}(z,z^*) & (e=\infty) \\ \frac{\delta \cdot \pi \cdot (P(z,z^*))^{e-1}}{1-e} \cdot \frac{\partial s_n}{\partial z^*}(z,z^*) \cdot \left[(1-e)\cdot \frac{(b(z,z^*)+CR)^{-e}\cdot w_R \cdot z}{(1-\beta)*u(z,z^*)} - \right. \\ \left.(1-z)\cdot\left[(b(z,z^*)+CR)^{1-e} - (\frac{w_R}{1-\beta}+CR)^{1-e}\right]\right] & (e \neq 1,\infty) \end{cases} , \tag{7.31}$$

$$with \quad \frac{\partial s_n}{\partial z^*}(z,z^*) = -(\frac{1-z}{1-z^*})\frac{\partial s_n}{\partial z}(z,z^*) \; .$$

A tax increase abroad increases the import prices for the northern region (the term $\frac{1}{1-z^*}\cdot(1-\frac{s_n(z,z^*)\cdot\epsilon(z,z^*)}{\Delta(z,z^*)}$ in 7.30 if $e=1$) and, at the same time, will increase the share of home goods in the consumption basket of northern inhabitants (the term $\frac{\epsilon(z,z^*)-\phi}{(\sigma-1)\cdot\Delta(z,z^*)}\cdot\frac{\partial s_n}{\partial z^*}(z,z^*)$ in 7.30 if $e=1$). Under the condition of a stable internal equilibrium 7.4, it is possible to ascertain analytically that the effect via the increased import prices is always more than compensated by the effect that the increased share of domestic goods consumption has on the price index. The lower price index will increase the average income of the people but will not alter the inequality index (constant under equiproportional income changes). The only way the government can react to this situation under a constant equity-efficiency trade-off is by increasing the home tax rate. In other words, as soon as one introduces capital mobility in a model of social security competition, the price effect changes sign. When there was no capital mobility a foreign tax increase would have lead to a decrease in the home tax rate.

The second effect through which the southern tax rate affects the northern region is called the competition effect. As can be seen in expression 7.31 the only way the foreign tax rate

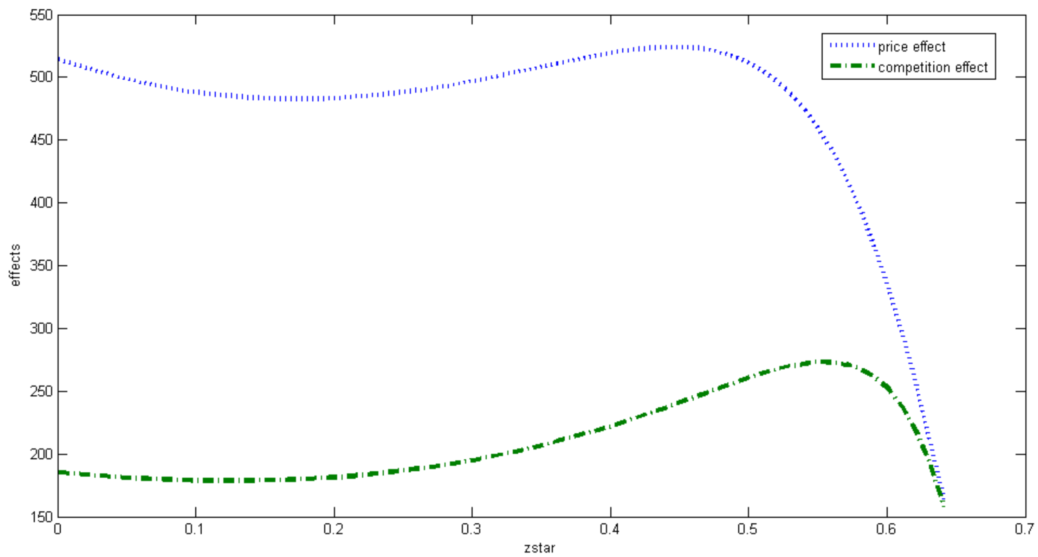

Figure 7-8: The effect of the southern tax rate on the northern social welfare function.

could influence the northern social welfare function is via the share of firms. It no longer works via the capital reward. A southern tax decrease will reduce, as long as there is a stable internal equilibrium, the share of firms in the northern region. This will, since the capital reward is constant[8], lead automatically to a decreased tax base. There are less people at work which leads under an unchanging tax rate to lower unemployment benefits for the unemployed. The net result is a deterioration of the efficiency and equity in the society. The government will react to this by lowering her own tax rate. This and the previous effect are given in figure 7-8 in function of the foreign tax rate. We assumed that $e = e^* = 4$ and that the home tax rate is equal to the Nash tax rate ($z = 0.089$).

The combined effect of both forces will lead to tax rates that are complements. The above graph also illustrates that the impact of a foreign tax rate change greatly diminishes for high values of the tax rate (near the $s_n = 1$-line). So the tendency to increase the home tax rate as a response to the foreign increased rate is weakened. At the same time, the secondary effect that a raise of the northern tax rate has on the northern social welfare function via the lower share

[8]Remember that the capital reward π equals $\frac{lw}{(\sigma-1)k}$.

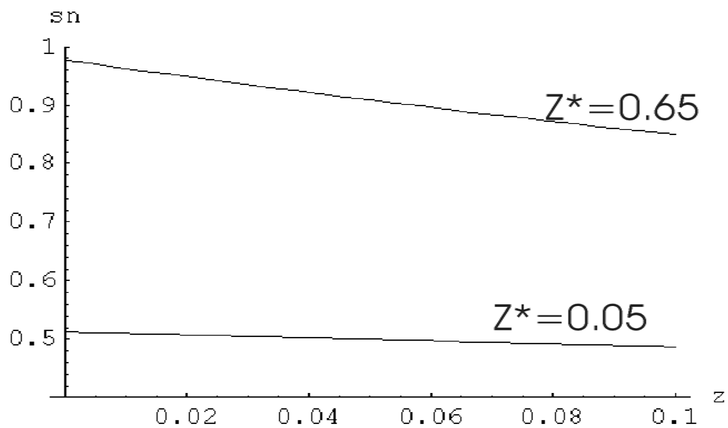

Figure 7-9: Effect of z on s_n for a low value of z^* and a high one.

firms s_n becomes more important. The increase in the price index and the loss in the tax base (higher unemployment, loss of firms) becomes larger . This is illustrated in figure 7-9 where s_n is given for a low value of z^* (= 0.05) and a high one ($z^* = 0.65$). The effect of the initial reaction towards a foreign tax increase is more than undone by the effect that that reaction has for high values of the foreign tax rate. More intuitively, it is more than worthwhile to reduce your tax rate for high values of the foreign tax rate since the reward you get in terms of the increased share of firms more than outweighs the initial loss in equity. The dominance of the s_n-effect explains why the northern tax rate behaves like a strategic substitute for high values of the southern tax rate.

To end this section, we compare the optimal Nash tax rates for the regions and the social planner with the Nash rate found under the same circumstances ($\phi = 0.05, \beta = 0.6, \sigma = 2.5$) in the model without capital mobility, and this for different values of the inequality aversion e. This is done in table 7.3.

s_n		$e, e^* = 0$	$e, e^* = 1$	$e, e^* = 2$	$e, e^* = 3$	$e, e^* = 4$	$e, e^* = \infty$
endogenous	$z = z^*$	**0**	0	0.02	0.07	0.09	0.13
	z^{SP}	**0**	0	0.11	0.16	0.18	0.22
exogenous	$z = z^*$	**0**	0	0.08	0.13	0.15	0.20
	z^{SP}	**0**	0	0.11	0.16	0.18	0.22

Table 7.3: Nash tax rates for the regions and the social planner in a model with and without capital mobility.

These numbers confirm the result that the regional social security competition is reinforced by introducing capital mobility. The regions will opt for lower Nash rates under capital mobility. Secondly the social planner in both situations will choose the same tax rate. This should come as no surprise since under the restriction that each region has the same tax rate, the share of firms in the model with and without capital mobility always equals one half. This is the case for a social planner. So again we can conclude that there are regulatory chill effects.

7.2.3 Influence of σ and ϕ

As a final step we discuss the impact of two parameters: the elasticity of substitution σ and the trade freeness ϕ. Note however that in the discussion of both parameters we have to account for the severe restrictions on these parameters for having a stable internal equilibrium. We start with the impact of a change of the elasticity of substitution.

		$e, e^* = 0$	$e, e^* = 1$	$e, e^* = 2$	$e, e^* = 3$	$e, e^* = 4$	$e, e^* = \infty$
$\sigma = 2.5$	$z = z^*$	0	0	0.025	0.069	0.089	0.129
	z^{SP}	0	0	0.107	0.157	0.179	0.221
$\sigma = 5$	$z = z^*$	0	0	0.022	0.044	0.053	0.075
	z^{SP}	0	0.151	0.261	0.301	0.321	0.351
$\sigma = 8$	$z = z^*$	0	0	0	0	0	0.016
	z^{SP}	0	0.206	0.311	0.344	0.357	0.383

Table 7.4: Regional and social planner Nash tax rates for different values of σ and the inequality aversions.

For a low value of trade freeness ($\phi = 0.05$), stable internal equilibria are possible as long as σ remains smaller than $\frac{1+\phi}{2\phi}$(=10.5 for $\phi = 0.05$). To illustrate the effect of the elasticity of substitution we give the Nash tax rates for a social planner and the regional government for different values of σ in table 7.4. As before, we see that the effect is mixed. Local governments will reduce their tax rates when σ increases but a social planner will increase its optimal tax rate. The elasticity of substitution characterizes the fierceness of competition on the goods market and thus also the agglomerative forces. Otherwise said, the change in the share of firms due to a shift in the tax rates becomes stronger for higher values of σ and as a consequence, the impact on the tax base will also be strengthened. This increased strength of the agglomerative forces explains the lower Nash rates for the local governments.

On the other hand, a social planner will internalize these effects and will in the end only be faced with the same situation an autarkic social planner has faced. Higher values for the elasticity of substitution mean that the economy becomes more efficient without altering the equity in the society. The social planner will amend this by increasing its tax rate. Note also that the optimal tax rates for the social planner are the same in the model with and without capital mobility for the same reason as discussed before.

The restriction imposed on the trade freeness is more severe than the one on the elasticity of substitution, as could be seen in table 7.2. For small deviations from the equicompetitiveness, the maximum allowed trade freeness (ϕ_{1A}/ϕ_{OA}) lies around 0.2 or smaller. The reason is again the strong nature of the agglomerative forces present in this model. As depicted in figure 7-10, the evolution in simple. A higher level of trade freeness means that the optimal Nash rate is lower. So we no longer have the concave effect as seen in the model without capital mobility. We can explain this by referring to the dominance of the effect of a change in the share of firms in the price effect and the competition effect. When the trade freeness increases, an identical change in the northern tax rate will lead to a much larger decrease in the northern share of firms. As a consequence, the government will restrain her optimal choice of taxation. The strength of this effect is captured by the elasticity of the share of firms with respect to the competitiveness[9]. This is depicted in graph 7-11. Since by definition the share of firms in each region equals one half for a social planner, this effect is absent in this case. As a consequence, the chosen tax rate will be constant in function of the trade freeness. More, it will be the same as the tax rate chosen by a social planner in a model without capital mobility.

7.3 Core-periphery situation

In this section we assume that the northern region is the (stable) core, the south is the periphery. This means that there is no industry left in the south and that the only income of that region stems from the transfer back of the remuneration for the southern capital employed in the north. People can still consume (northern) goods but the government is unable to levy any taxes since there are no wages paid to employees to levy them on. On the other hand, the northern region

[9] When the competitiveness increases, the northern tax rate decreases or the southern one increases.

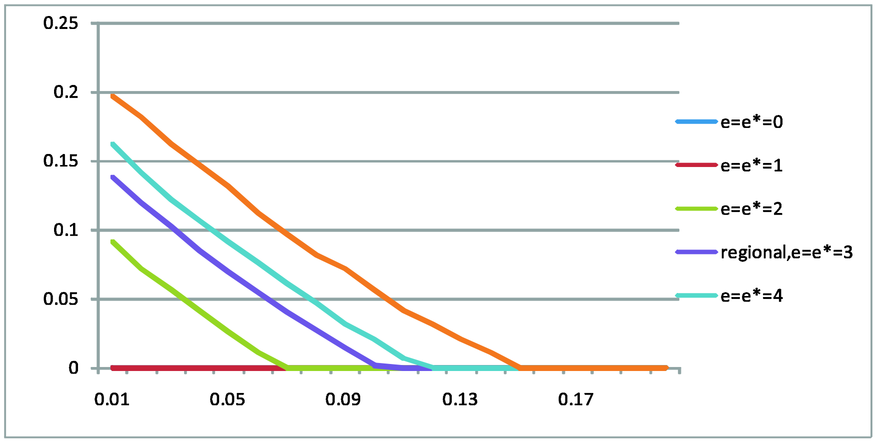

Figure 7-10: Influence of trade freeness on Nash rate for different values of the inequality aversion.

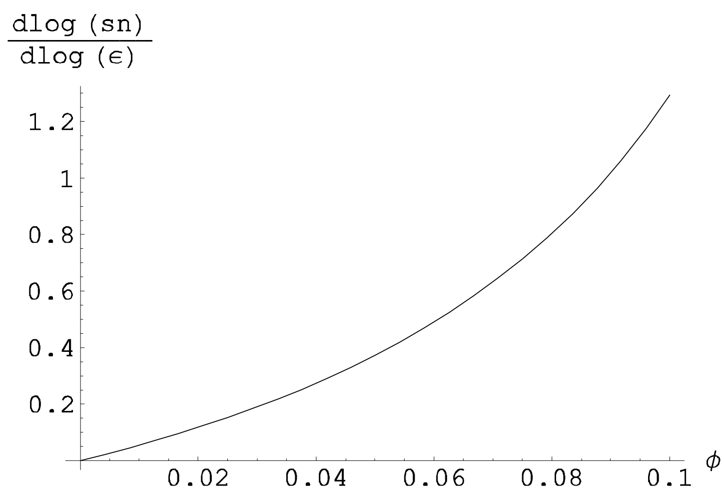

Figure 7-11: The elasticity of s_n with respect to ϵ in function of ϕ.

faces a very comfortable point of departure. It has all the industry, does not have to import any goods ($P(z) = \alpha\frac{w(z)}{a}$) and apparently can levy any tax it wishes. This resembles the autarkic case which we started with[10]. As can be easily shown, the social welfare of the core region becomes independent of the trade freeness and hence, the maximising government will choose its tax rate independent of the trade freeness.

To describe this scenario, we use – just as Baldwin and Krugman ([11]) did in their similar model – a three-stage tax game where the northern core sets its tax rate z in the first stage, the south sets its tax rate in the second stage, and migration and production occur in the third stage. We solve this game by backwards induction. The last stage yields an economic outcome that is described by the equilibrium condition laid out above, so we turn to the second stage. Clearly this structure maximizes the ability of the south to engage in fiscal competition.

In solving the second stage, it is important to realize that in our scenario the south is a destituted region with no industry left and residents (sur)viving on the reward to southern capital working in the north. It becomes impossible and senseless to determine the optimal southern tax rate since the southern social welfare will become invariant to the southern tax rate. In order to solve this problem and because we are in a non–cooperative setting, we assume that the south will opt for a zero tax rate to make it as difficult as possible for the northern core region[11].

In the first stage the north determines its optimal tax rate. However, the northern region is not that free as it first seems to set its tax rates. If it sets its tax rates higher than the agglomeration rents can allow for, it becomes profitable for a firm to relocate to the periphery. By looking back at the tomahawk diagram in function of the competitiveness, figure 7-1, this means that the competitiveness of the northern region has to stay above the value of $\epsilon_{SN} = \frac{1+(2\sigma-1)\phi^2}{2\sigma\phi}$, which clearly depends on the trade freeness. This corresponds with a certain maximal (northern) tax rate: $z < 1 - \frac{1-z^*}{(\epsilon_{SN})^{\frac{1}{1-\sigma}}}$. Using the result of the previous step, namely $z^* = 0$ further simplifies this expression. The concave (red) line on graph 7-12 represents this

[10]If we substitute s_n by 1 in the standard expressions, we arrive at the following formula's: $\Delta = \epsilon$, $\Delta^* = \epsilon\phi$, $P = \alpha\frac{w}{a}$, $P^* = \alpha\frac{w}{a}\tau$,
$s_E = 1 - \frac{1}{2\sigma}$, $\pi = \gamma$, $\pi^* = 0$, $u = 1 - (1-\beta)(1-z)$, $u^* = 1$, $b = \frac{w_R z}{\beta + z(1-\beta)}$, $b^* = 0$.

[11]Sensu strictu this assumption makes it unnecessary to stick to the three-stage limiting tax game as proposed by Baldwin and Krugman ([11]). In their model the south still had an influence on the social welfare via their tax setting.

sustain tax rate for the north: if the northern region sets its tax rate below this threshold, it will retain a stable core.

However, this value does not necessarily coincides with the tax rate that the northern social welfare maximizes. These tax rates are depicted for different values for the inequality aversion by the horizontal lines on the graph. Since the non-restricted optimalization mimics the autarkic behaviour, the (non-restricted) chosen tax rates are equal to the tax rates a social planner would choose in a model with (or without) capital mobility and at an internal equilibrium.

Since the northern region is always better off by remaining the core, the northern Nash rate is equal to the unrestricted tax rate if the sustain tax rate (the red line on figure 7-12) is higher than the unrestricted rate. When the reverse is true, the Nash rate is equal to the sustain tax rate. So imposing the restriction on the unrestricted tax rates lets us conclude that governments become more restricted when they have a higher inequality aversion. For instance, a Rawslian government will for any value of the trade freeness be restricted, while a government with an inequality aversion of 2 will only be restricted in its optimal choice for low and high values of trade freeness.

In the previous paragraphs we assumed implicitly that the northern core was stable. However, it could happen that for low values of trade freeness and the elasticity of substitution the northern core is always unstable. The only choice the northern government has in this scenario is abiding to a zero tax rate. In that way it can keep the core since any tax increase by the south would restore a stable northern core.

Thus, for intermediate values of the trade freeness, the chosen tax rates by the core region largely surpasses the Nash tax rates in an internal equilibrium and one could argue that there is no social security competition at all anymore, at least from the point of view of the northern region. Evidently, the southern region — but for low values of trade freeness also the northern region — is restricted to set its tax rates substantially lower than a social planner would do.

7.4 Conclusion

In this chapter we included a second dimension of globalisation into the model, namely capital mobility. This is done using the standard New Economic Geography formulation. However,

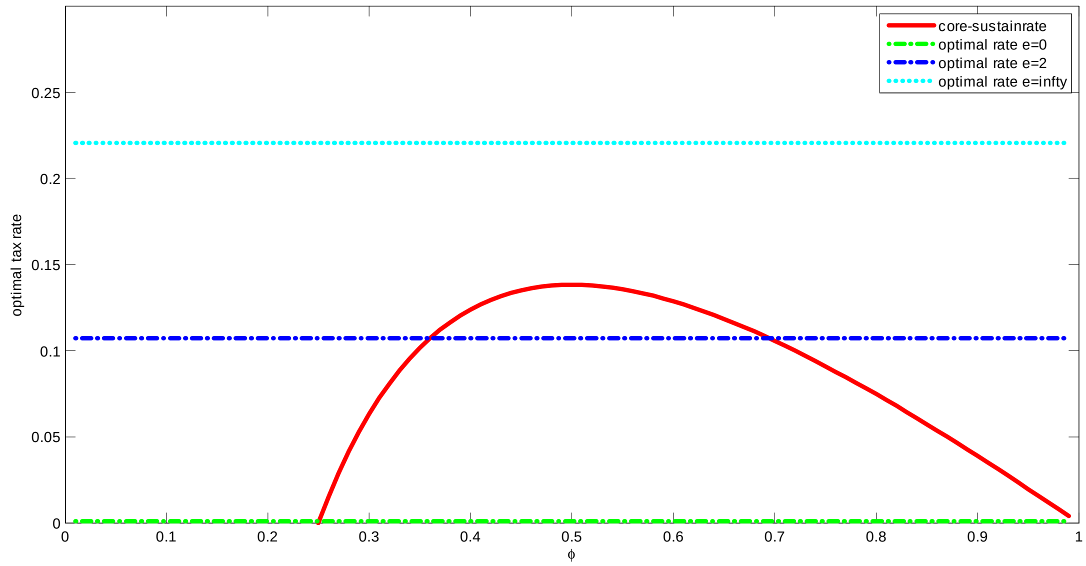

Figure 7-12: Unconstrained and core sustain tax rate for a core region for different values of the inequality aversion ($\sigma = 2.5$).

compared to the standard NEG-models, the properties of the locational equilibria and their stability in our model with endogenous unemployment become much more appealing. We are able to retain a closed-form expression for the migration variable which ensures a high degree of analytical tractability. But this analytical tractability does not come at a price as is normal the case in the NEG-framework. Almost all characteristics of the NEG-framework can be preserved. We have circular causalities, the possibility of a CP-situation in cases without complete trade freeness, etc. We also have locational hysteresis present in our model although not between an internal equilibrium and a core-equilibrium but instead between two core-situations. Thus, the introduction of efficiency wages leads to a footloose capital setting with most of the properties of a core-periphery or a footloose entrepreneur model.

The Nash tax rates set by governments under an internal equilibrium are lower than what the social planner would opt for. We arrive again at the race to the bottom result. The social security competition is even harsher compared to the case without capital mobility. As before, we looked at the two channels through which the foreign tax rate affects the home region.

Contrary to the previous model, the real income effect now also leads to tax rates that are strategic complements. The reason lies in the migration of firms that follows a foreign tax increase. The second effect, the competition effect, operates in the same way as in the model without capital mobility.

The second main difference between the model with capital mobility in an internal equilibrium with the model discussed in chapter 7 lies in the appearance of a limited zone where the tax rates behave like strategic substitutes. This limiting behaviour occurs when there is a large difference between the regional tax rates. In this zone where small tax changes can have a large delocation impact, it becomes more than worthwhile for the government to lower its taxes in order to attract more capital in a response to increased foreign taxes. In that way the home region nearly becomes a core region which reduces greatly the need to redistribute.

The elasticity of substitution plays the same role as in the model without capital mobility. Higher values of σ augment the chosen value of the tax rate by the social planner and intensifies the social security competition at the regional level. The trade freeness, on the other hand interacts in a different way than before. Lower trade costs now unambiguously lead to more intense social security competition with lower Nash rates since the effect of the constant share of firms present in the model of chapter 7 disappeared.

Besides looking at internal equilibria, we also investigated the behaviour of a government that has the core. We applied the three stage tax limiting game of Baldwin and Krugman. The agglomeration rents present in this setting can be taxed away by the government which attenuates the social security competition. However, the more a government cares for inequality, the less these rents suffice to finance the redistribution need. The government also faces a stronger restrictive environment for low or high values of trade freeness.

Chapter 8

A definite answer?

Since the beginning of the European integration process in the early 1950s, social downscaling concerns have been cropping up from time to time. In recent years this fear for the negative effects of globalisation pushed itself even more to the fore with the spurred expansion of the European Union. In this thesis we investigated the possible occurrence of this race to the bottom fear from a theoretical point of view.

The existing literature lacked real social security competition models. That is, models that have one or several dimensions of globalisation and a government that provides a social insurance against some social risks. However, there does exist some closely related (capital) tax competition literature where governments compete with each other for mobile factors of production in order to provide a general public good. We argued that the bottom line of this literature can be summarized in the following intuitive way: public goods are underprovided as soon as the beneficiary of the public good is not the payer of the public good and if the tax payer can evade taxation.

Recently a new strand in the tax competition literature emerged namely the New Economic Geography literature that encompasses tax competition. Although the race to the bottom result remains intact to a large extent, the introduction of this framework in tax competition leads to some interesting considerations. Not only are these models inherently richer from a theoretical point of view since they have besides the mobility of a factor of production also a second mechanism of globalisation, namely international goods trade. But secondly, they also incorporate agglomeration effects which seriously can attenuate or even abolish the race to the bottom result.

As a theoretical widening of the New Economic Geography models, we investigated also the dynamics of these models. This lead to some policy warnings. Although it has been proved by Robert-Nicoud that all different models in this strand are mathematical similar, that does not mean that the dynamics of the models are identical. Some set-ups like the footloose capital setting of Martin and Rogers lead to a much slower evolution towards the final stable locational equilibrium state. As a consequence, all concrete policy guidelines derived from a particular New Economic Geography set-up, optimally should indicate the time framework within a government has to take measurements.

A second extension in the New Economic Geography modelling we have undertaken lies in the creation of an analytical tractable NEG-model that has almost all the characteristics of the "difficult" models such as a core-periphery model of Krugman. In other words, the often mentioned trade-off between analytical tractability and richness of features is mitigated. Replacing the perfect labour market in the standard models with an efficiency wage mechanism lead to this result. Besides the reappearing of circular causalities and a home-market magnification effect in a borderline tomahawk diagram, the extension also allowed for an easy study of near-catastrophic agglomeration and a "bright lights, big city effect" of Anderson and Forslid in case of regional tax asymmetries.

The literature review of the tax competition models in a New Economic Geography and a neo-classical framework serves as a benchmark to see whether their results can be extended to a social security competition model. The main model assumptions in our attempt to falsify the race to the bottom result are threefold. We use a footloose capital set-up with only one sector (the differentiated goods sector) in which we introduce endogenous unemployment via efficiency wages and a government that provides an unemployment benefit by taxing the immobile factors. The governments interact in a static Nash game and determine their optimal reaction by maximising an Atkinson abbreviated social welfare function. The combined introduction of these three deviations from a first-best case leads to tax rates that are strategic complements between each other. In other words, we do expect social security competition to happen.

This result does not depend on the mobility of a factor of production. Even in cases where the only dimension of globalisation lies in the goods mobility, governments still opt to lower their taxes suboptimally low. The inclusion of capital mobility in this framework strengthens the race to the bottom results. In other words, these results give reasons to believe that all the different mechanisms are complementary and mutually reinforcing.

Due to the introduction of an Atkinson abbreviated social welfare function we are able to condition the race to the bottom result on the inequality-equity trade-off that a government has. The more a government behaves in a Rawslian way, the higher it will set its tax rates. In order words, shifts in the inequality aversion of a government have an impact that is as large as a change in the trade freeness can have. This linkage could be of importance in an empirical exercise since one could argue that the neo-liberal political revival from the 1980s onwards made governments more Benthamite. Of course one could wonder what is cause and what is effect.

The most important difference between the model with and without capital mobility lies in the influence that a change in the trade freeness has on the Nash equilibria. Under capital mobility, higher levels of trade freeness always lead to more intense social security competition. But, when capital is immobile, this result no longer holds. When trade costs decrease in the latter case, starting with prohibitive trade costs, the optimal tax rates set by the governments will decrease but after a while they will increase again and at the high end of trade freeness they even will surpass the level of taxes set by a social planner. In other words, there is a range where increased globalisation could lead to less severe or even non-detrimental social security competition. Although this result seems to be promising, we believe that the real impact of it remains limited. All the goods in our model are subject to trade. As a consequence, high levels of trade freeness, are perhaps a little realistic since many goods in Western economies are not traded.

In the cases where capital mobility lead to stable core-periphery equilibria, social security competition for the core region is – for a wide range of intermediate trade costs – seriously attenuated due to the agglomeration rents that accrue to the core region. This result is conditioned on the attitude that the government has concerning inequality and efficiency. The stronger the government cares for the poor, the more the government has to deviate from here optimal unrestricted tax rate in order not to lose the core.

While core regions can escape to a large extent the harmful effects of tax competition, our model indicates that social security competition becomes more threatening between regions that are not in a core-periphery situation. This would mean that tax competition is more enacted between the European core regions (West-Germany, Belgium, North of France, South of The Netherlands, London-Oxford, North of Italy,...) than between these regions and the periphery (Baltic states, etc.)

In conclusion, although the social security competition model we developed emphasizes a race to the bottom in general, the model is rich enough to already provide some attenuating factors such as the attitude of the government towards inequality and the presence of agglomeration rents. It could be interesting to extend the model further in this line of search. For instance, it could well be that the equilibrium concept used here has a considerable impact on the results. Instead of using a simple static Nash game concept (and the three-stage limiting tax game in a CP-situation), infinite games or cooperative game settings perhaps better reflect reality. Governments can cooperate (as they do in a European context) and they also realize that their actions cannot remain unnoticed by the foreign governments which could lead to tit-for-tat strategies.

Finally, the robustness of the model would be increased if we were able to show that the same results apply under other model specifications. Unfortunately this is not as simple as it seems. For instance, as said before, changing the Dixit-Stiglitz set-up to an Ottaviano-Thisse set-up already lead to unsurpassable parameter constraints. Finding other set-ups that confirm the result of the developed model will constitute a challenging task for the future.

Appendix A. Simulation of the dynamics of NEG-models

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A-1 The FC-model

The FC-model is the only model where all the endogenous variables can be expressed as explicit functions of the spatial distribution of economic activities. The lack of circular causality makes it fully analytically tractable. The basic equations of the model are given by:

$$\dot{s}_n = (\pi - \pi^\star)s_n(1-s_n) \tag{A-1}$$

$$\pi = bB\frac{E^w}{K^w} \tag{A-2}$$

$$\pi^\star = bB^\star\frac{E^w}{K^w} \tag{A-3}$$

$$B = \frac{s_E}{\Delta} + \phi\frac{s_E^\star}{\Delta^\star} \tag{A-4}$$

$$B^\star = \phi\frac{s_E}{\Delta} + \frac{s_E^\star}{\Delta^\star} \tag{A-5}$$

$$\Delta = s_n + \phi(1-s_n) \tag{A-6}$$

$$\Delta^\star = \phi s_n + (1-s_n) \tag{A-7}$$

$$s_E = (1-b)s_L + bs_K \tag{A-8}$$

The worldwide expenditures E^W and capital endowment K^W are normalized to 1 in the expressions for the northern and southern reward to capital π and π^*. In this and the following models b is a shorthand notation for $\frac{\mu}{\sigma}$. Intuitively B can be seen as a measurement for the bias in sales[1]. Δ can be interpreted as an indicator of the price index as the price index of a region

[1] One can show that the revenues R of a typically northern-based firm equal $\mu\frac{E^W}{n^W}B$. In this expression $\mu\frac{E^W}{n^W}$ can be interpreted as the amount of money spent by consumers per manufactured variety. If there are no trade costs ($\phi = 1$), B equals 1 and there is no bias in sales. If $B > 1$, the sales are biased toward the northern based

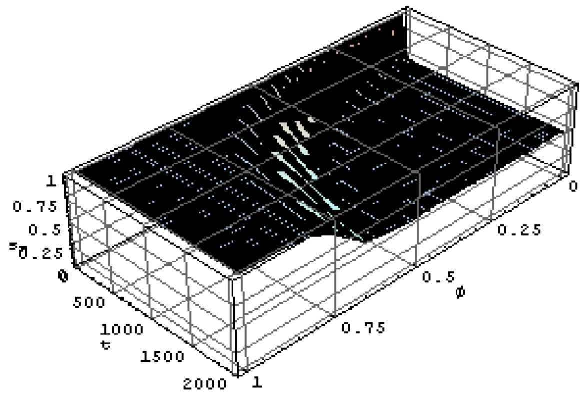

Figure A-1: Simulation of dynamics in symmetric FC-model ($s_n = 0.99$).

after normalizations is given by $P = \Delta^{\frac{-\mu}{\sigma-1}}$. In the relative market size condition A-8 s_L and s_K respectively represent the share of northern labourers and the share of capital ownership of the northern region. This equation is derived under the assumption that half of the capital used in each region belongs to the northern region. By assuming that capital earns the world average capital reward, we don't have to know the fractions of the northern (or southern) owned capital used in both regions. Contrary to the other NEG-models, the relative market size does not depend on s_n. This is the main reason for the analytic tractability of the model.

A-1.1 Symmetric case

We have a perfect symmetrical set-up. Each region has the same share of capital owners and labourers. As a consequence (see equation A-8) every region accounts for one half of the total expenditures. When trade is completely free, all possible locational divisions become equilibria. As soon as there are trade costs, two unstable equilibria (core and periphery solution) and one stable equilibrium (symmetricum) emerge.

Figure A-1 plots the share of north's industry in function of time and trade freeness. At $t = 0$, we impose that 99% of the worldwide capital is used in the north. The first thing that strikes us, is the strong ϕ-dependence of the dynamical behaviour: the lower the trade

firm. More details can be found in Baldwin et. al. ([6]).

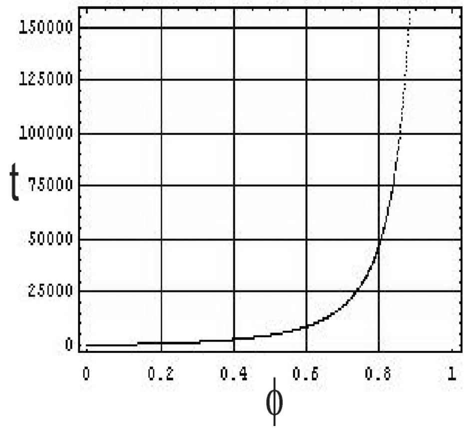

Figure A-2: Time necessary to reach equilibrium given that $s_n = 0.99$.

costs become, the longer it takes to deviate from the initial inequilibrium and the longer the transition toward the final equilibrium state takes. For this simulation we see that for values of ϕ above 0.7 the stable equilibrium is still not reached after 2000 time steps. The transition time moves asymptotically to infinity when trade costs become infinitely small.

To better depict this dynamical bifurcation behaviour, we calculate, for each possible trade freeness-level, the number of time steps it takes to reach equilibrium t_{equil}. This is depicted in figure A-2. The necessary number of time steps increases exponentially as trade costs diminish and tends asymptotically to infinity when ϕ is close to 1. With an R^2-value of 0.885, the trend can be best expressed as: $ln(t_{equil}) = 5.9696e^{0.0008\phi}$. Of course the coefficients differ with the initial condition.

The ϕ-dependence of the transition time and path can intuitively be understood by looking at the two driving forces in the NEG-models: the agglomeration and the dispersion force. It can be shown (see Baldwin et. al ([10])) that the dispersion force is larger than the agglomeration force for small values of trade freeness but drops more sharply than the agglomeration force when trade costs diminish. In the specific context of the FC-model where only one agglomeration force is present (no cost-of-living-effect), the intersection of both graphs occur when trade is completely free.

Hence as trade become more freely, the relative strength of the tendency toward a symmetrical equilibrium weakens compared to the agglomeration forces. This implies that it takes

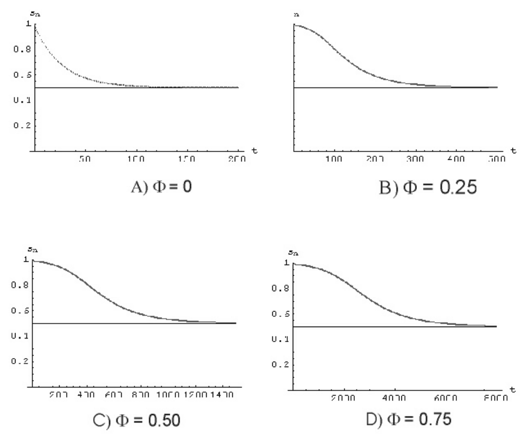

Figure A-3: Transition paths of symmetric FC-model ($s_n = 0.99$) in case a) $\phi = 0$, b) $\phi = 0.25$, c) $\phi = 0.5$ and d) $\phi = 0.75$.

longer before the system reaches its final equilibrium. When there are no longer any trade costs, the dispersion force becomes equally strong as the agglomeration forces, meaning that there can be no evolution at all anymore.

Figure A-3 depicts the shape of the transition process for a FC-model with a high initial northern share of firms and this for different values of trade freeness. We see that in all cases the system is characterized by a concave-convex shape with a long tail[2]. This means that the northern share of firms at first starts to decline progressively till the point of inflection is reached. After this point the transition starts to slow down. This shape naturally reflects the dynamical formulation of the model.

A-1.2 Asymmetric Case

Because the relative market size condition A-8 was derived under the assumption that the ownership of the capital employed in every regions is equally divided between northern and southern inhabitants, we can only vary the share of labourers in each region to make the model asymmetric. We simulate in figure A-4 a FC-model with the following set-up: $s_n = 0.01$ and

[2] If one on the other hand started with $s_n < 0.5$, the transition would be convex-concave with a long tail.

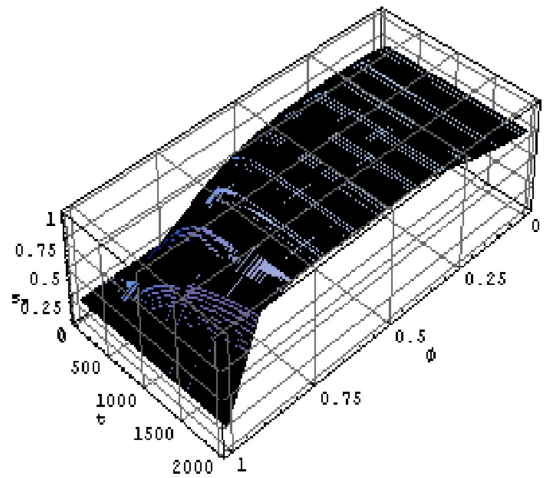

Figure A-4: Simulation of dynamics in asymmetric FC-model:$s_L = 0.75974$ and $s_n = 0.01$.

$s_L = 0.75974$. We chose this value for the share of northern labourers in order to have a northern market size s_E equal to 0.75. Different transition paths are depicted in figure A-5.

If there is no trade freeness, the share of firms in the north quickly rise to the value 0.75. This value equals the share of northern expenditure as predicted by the model (see Baldwin et. al. [10], p. 76). As trade costs start to decrease, the transition dynamics changes in two ways. The time necessary to reach the equilibrium state increases (398 steps for $\phi = 0$, 941 steps for $\phi = 0.15$, infinitely many steps for $\phi = \frac{1}{3}$[3] and 101915 steps for $\phi = 0.99$). Secondly the equilibrium value itself also increases till the value of 1 is reached at $\phi = \frac{1}{3}$ (e. g. $s_{n,equil} = 0.75$ at $\phi = 0$ and $s_{n,equil} = 0.838235$ at $\phi = 0.15$). The first evolution is already explained in the previous section. The second evolution is an illustration of the near-catastrophic behaviour of asymmetric FC-modelling[4]. The shape of the transition path is the mirror image of the symmetric case. Different initial conditions account for this behaviour.

Other simulations show that if one keeps the initial share of northern firms at the symmetricum and reduces the northern share of labourers slightly (e. g. 0.5%), no evolution at all

[3] At a break point the agglomerative force is as strong as the dispersion force. As a consequence it will take infinitely many steps to reach the final equilibrium. However the system will evolve fast to values close to the long run equilibrium after a few thousands steps as there is no other stable equilibrium.

[4] In Baldwin et. al. ([10]) one derives the analytical expression for the trade freeness level beyond which all industry is in the north ($\phi = \frac{1-s_E}{s_E}$). This is equal to 1/3 in our set-up.

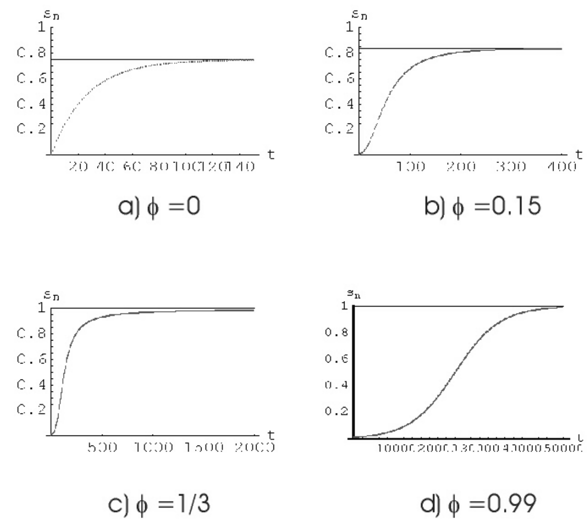

Figure A-5: Transition paths of asymmetric FC-model in case a) $\phi = 0$, b) $\phi = 0.15$, c) $\phi = \frac{1}{3}$ and d) $\phi = 0.99$.

occurs. Only when more than 5 % of the people move from north to south, one can distinguish a tendency toward the southern core solution at intermediate ϕ-levels.

Based on the previous graphs we conclude that the intrinsic dynamical behaviour of the asymmetric case is identical to the symmetric one. Differences that may arise between the two only stems from a different long run stability behaviour. This result could be expected as the migration equation does not change. In the following paragraphs we'll focus on assessing the impact of a realistic change in the share of labourers (or capital) on the transition time.

A-1.3 Influence of parameters μ and σ

We have used the same values for μ and σ as Brakman et. al. ([21]) did. Because, for instance, they regressed NUTS-data to estimate the value for the elasticity of substitution, different values can be assumed in other time frames or in other regions. Besides this empirical reason, it is also theoretically interesting to see which influence these parameters have on the dynamical behaviour.

To test the influence of both parameters we use the same set-up as in the symmetric case.

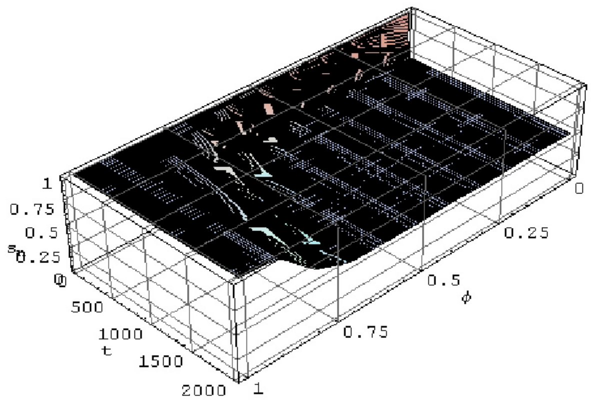

Figure A-6: Symmetric FC-model with $\mu = 0.9$ and $\sigma = 8$ ($s_n = 0.99$).

Figure A-6 simulates the dynamical behaviour under the assumption that $\mu = 0.9$. This means that people derive more utility from manufactured goods. Figure A-7 investigates the influence of a smaller σ ($\sigma = 4$), or otherwise stated the influence of the fact that manufactured goods become less substitutable.

We see in both cases a steeper transition. As a consequence, after 2000 time steps, the stable equilibrium is reached for lower values of trade freeness compared to the simulation done in paragraph A-1.1. This behaviour can be understood if one looks at the migration equation 3.2.2. Substituting A-2 and A-3 gives us the dynamical equation in function of b: $\dot{s}_n = b(B - B^*)s_n(1 - s_n)$. So increasing $b = \frac{\mu}{\sigma}$ augments the driving force and as a result, the transition is faster.

A-2 The CP- and FE-model

We discuss the CP- and FE-model together because both have the same migration equation and share the same source of agglomeration.

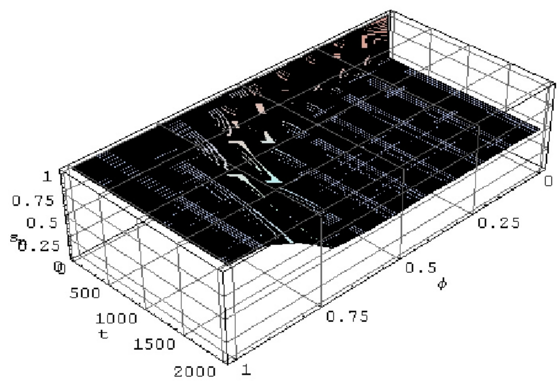

Figure A-7: Symmetric FC-model with $\mu = 0.3$ and $\sigma = 4$ ($s_n = 0.99$).

The basic (northern) equations of the CP-model are[5]:

$$\dot{s}_H = (\omega - \omega^\star) s_H (1 - s_H) \tag{A-9}$$

$$\omega = \frac{w}{P} \tag{A-10}$$

$$w = b \frac{E^w}{F n^w} B \tag{A-11}$$

$$B = (\frac{s_E}{\Delta} + \phi \frac{1 - s_E}{\Delta^\star}) w^{1-\sigma} \tag{A-12}$$

$$\Delta = s_n w^{1-\sigma} + \phi (1 - s_n)(w^\star)^{1-\sigma} \tag{A-13}$$

$$P = p_A^{1-\mu} (\Delta n^w)^{-a} \tag{A-14}$$

[5] The symbol a stands for $\frac{\mu}{\sigma - 1}$ in these expressions.

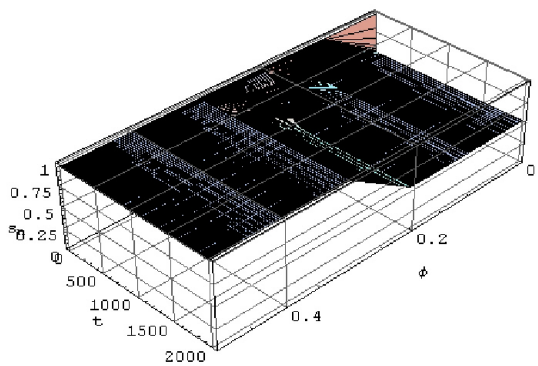

Figure A-8: Symmetric CP-model with $s_n = 0.99$.

$$s_E = (1-\mu)(s_L + \frac{wH^w}{w_L L^w} s_H) \tag{A-15}$$

We only give the expressions for the northern region as the southern formulas are isomorphic. Several variables are normalized in the literature: $F = 1$, $E^W = \frac{1}{\mu}$, $L^W = \frac{1-\mu}{\mu}$ and $p_A = w_L = n^W = H^W = 1$. These normalizations are discussed and motivated in Baldwin et. al. ([10]). They also prove the equivalence of s_H and s_n.

After normalizations, the FE-model differs only slightly in its formulations of some variables: the nominal wage w $(= bB)$, the bias in sales B $(= \frac{s_E}{\Delta} + \phi\frac{1-s_E}{\Delta^*})$, the indicator of the price index Δ $(= s_n + \phi(1-s_n))$ and the relative market size condition s_E $(= (1-b)s_L + bBs_H)$. As stated before, the FE-model was much more analytical tractable than the FC-model. This can clearly be seen by looking at equation A-11 and A-12. The nominal reward to the mobile factor is removed in the same expressions of the FE-model. As a consequence the nominal wage in this model can be expressed explicitly in function of the northern share of workers and the relative market size. The only intractability that remains in the FE-model lies in the relative market size condition. The circular causality is caused by introducing the term B in this expression.

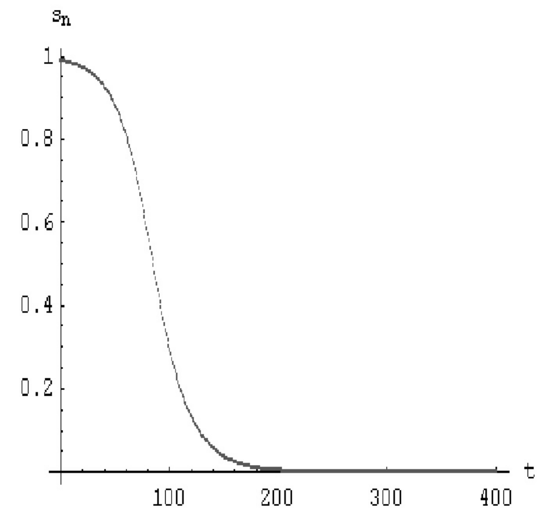

Figure A-9: Symmetric CP-model with $s_n = 0.99$: evolution at $\phi = 0.1$.

A-2.1 CP-model

As before we use the initial condition to generate the most interesting dynamics. The CP- and FE-model have, depending on the trade freeness, three different long run stable equilibria zones (see tomahawk-diagrams). This leads to the use of different initial conditions: $s_n = 0.99$ (or $= 0.01$) for ϕ-values between 0 and the sustain point[6] and s_n-values around the symmetricum for ϕ-values between the break point and 1.

The dynamical behaviour in the first zone ($\phi \in \left[0, \phi^S\right[$ is simulated in figure A-8 and A-9. The transition behaviour is similar to the FC-model. The transition path has the typical concave-convex form. The transition time increases as we come closer to the sustain point, but it takes never more than 1000 time steps, except for values very close to the sustain point as the evolution becomes asymptotically near this point. The explanation for both phenomena is already given in the previous section. Simulations done for values of trade freeness larger than the break point show that also in this region an analogue transitional behaviour occur. For instance at ϕ=0.60 and $s_n = 0.51$ it took 849 time steps to end up in the long run northern core solution.

[6] One can calculate the precise values for break and sustain point (Baldwin et. al. ([10]), p. 31): $\phi^B_{CP} = 0.263502$ and $\phi^S_{CP} = 0.234735$.

An interesting zone lies between the sustain and break point. In this zone multiple equilibria exist. Of course if one of the regions had all the industry (or half of the industry) initially, no evolution at all will be observed. The transition path and time will depend in this zone on the value of trade freeness and the initial condition. We illustrate this in table 8.1.

ϕ	0.23		0.24		0.25		0.26		0.27	
$s_n(0)$	to?	time	to?	time	to?	time	to?	time	to?	time
0.1	sym	2632	sym	4181	CP	2982	CP	1476	CP	1271
0.2	sym	2414	sym	3673	sym	7038	CP	2170	CP	1496
0.3	sym	2286	sym	3438	sym	6337	CP	3428	CP	1799
0.4	sym	2133	sym	3195	sym	5863	sym	24096	CP	2415

Table 8.1: Transitional behaviour between break and sustain point depend on initial condition and trade freeness.

The closer we get to the break point, the less we initially may deviate from the symmetricum and still have a long run symmetrical equilibrium. At $\phi = 0.27$ ($> \phi^B$) we will always evolve toward the CP-equilibrium. This can be interpreted as a clear illustration of the fact that, when trade costs decrease, the agglomeration force weakens less compared to the dispersion force. For instance, at$\phi = 0.26$ and $s_n = 0.4$ we need more than 24000 time steps before we reach the final equilibrium state. The dispersion force is in this case only a little bit stronger than the agglomeration force. Secondly it can be easily understood that the difference between the initial condition and the final equilibrium serves as a measurement of the time necessary to reach the final equilibrium.

Finally we assess the impact of a change in the share of northern labourers. The behaviour of the asymmetric CP-system is illustrated in simulation A-10. If one starts very close to the symmetricum and deviates the northern share of labourers with 0.5%[7], the outcome changes quite drastically compared to the symmetrical set-up[8]. For low values of trade freeness, the long run stable equilibrium is attained after a few time steps. This equilibrium occurs at increasingly lower values of s_n as trade costs continue to decrease (see figure 3-3). As soon as the break point is reached, the 0.5% reduction in s_L suffices to make the system evolve fast to the southern core

[7] Although a deviation of 0.5% may seem small, in reality it is large. For instance, this would mean a migration of around 60 000 people between Belgium and The Netherlands.

[8] This is also a big difference with the FC-model.

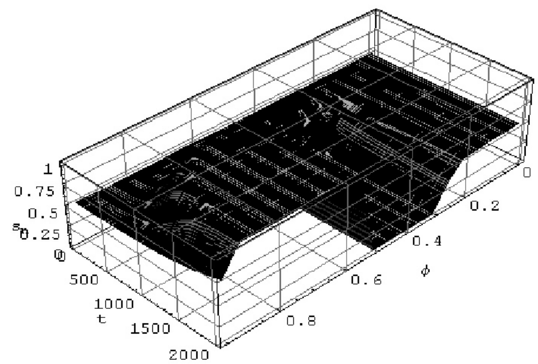

Figure A-10: Asymmetric CP-model with $s_n = 0.51$ and $s_L = 0.495$.

solution[9]. If we further increase the trade freeness, the lower share of labourers becomes less important than the initially higher share of firms. As explained before, the agglomeration force weakens when trade costs decrease (but not as fast as the dispersion force). As a consequence the tendency toward the southern core solution becomes less fierce and the initial advantage given to the northern region (a higher s_n) becomes important enough to generate a northern core solution. For very high values of trade freeness, the agglomeration forces are too small to have a CP-outcome, even after several thousands of steps. The shape of the transition path is similar to the previous cases. In general, the closer the initial condition of a region resembles its core solution, the higher the asymmetry in the labour force may be before the agglomeration force toward the other region overpowers the other forces.

A-2.2 FE-model

Although the FE-model resembles the FC-model closely, the dynamical properties differ considerably. This can be clearly seen if one duplicates figure A-8) for the FE-model. This is done

[9]Apparently it seems that a linear ϕ-dependence exists for the long run equilibrium values. This is caused by the discretization necessary to simulate the dynamics. For instance, figure A-10 is drawn with ϕ varying in intervals of 0.05. In reality the long run equilibrium values change as depicted by the asymmetric tomahawk diagram.

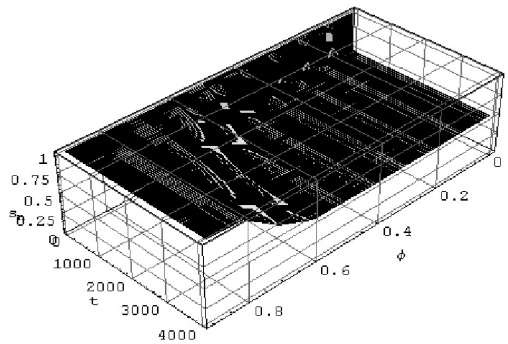

Figure A-11: Symmetric FE-model with $s_n = 0.99$.

in figure A-11.

The sustain and break point in the FE-model are characterized by higher trade freeness levels. They[10] respectively occur at ϕ equal to 0.851303 and 0.851461. After 4000 time steps the symmetrical equilibrium is still not reached for ϕ-values close to the sustain point. For instance at ϕ=0.80 it will take more than 40000 steps to attain the long run symmetricum (see A-4). This behaviour can evidently be explained by the weakened and closely matched forces at the high trade freeness level of the FE-sustain point.

At the same time, the transition time for values of trade freeness below the CP-sustain point is smaller for the FE-model than the FC-model. For instance, while in the FE-model it took only 999 time steps to attain $s_n = 0.5$ at $\phi = 0.2$ (starting at $s_n(0) = 0.99$), this takes 1371 steps in the CP-model. For high values of trade freeness the FE-model becomes slower than the CP-model (e.g. for $s_n(0) = 0.25$, $\phi = 0.95$,$T_{eq,CP} = 841 < T_{eq,FE} = 1186$). This difference in transition times can be explained if one looks at the cost functions of both models. In the FE-model the mobile factor is only used for a fraction of the total production cost. This means that for the same number of people that migrated interregionally, more firms and varieties are created in the FE-model compared to the CP-setting. This enhances the dispersion and cost-linked agglomerative forces in the FE-model. The demand-linked agglomerative force does

[10]see Baldwin et. al.([10]),p.100.

not diverge between the two modelling set-ups. The relative increase of the dispersion force in the FE-model versus the CP-model makes the transition faster toward the symmetricum and slower toward the CP-outcome[11].

Simulations done for asymmetric FE-models starting at $s_n = 0.51$ and $s_L = 0.495$ show that there is no evolution at all. In the CP-model with the same set-up we saw a clear tendency toward a northern core solution for relatively low levels of trade costs. Only for strong deviations ($s_L < 0.45$) in the northern labour share the tendency toward the southern core solution becomes important. For these large s_L-values the increased share of southern labourers enhances the southern agglomeration forces to such an extent that the southern agglomeration forces overpower the dispersion force in a region where the relative difference of both forces is very small in the symmetrical set-up (near the sustain and break point). For instance, at $\phi = 0.8$ and $s_n(0) = 0.51$ the FE-system attains the s_n-value of 0.19 after 2500 steps.

A-3 VL-models

In the following three paragraphs we discuss the differences between the VL-framework and the migrational framework of the CP-, FE- and FC-models.

A-3.1 FCVL-model

The defining equations of the FCVL-model are identical to the FC-equations except for the Δ-definitions and the relative market size condition[12]:

$$\Delta = s_n \Delta^{\mu} + \phi(1 - s_n)(\Delta^{\star})^{\mu} \tag{A-16}$$

$$\Delta^{\star} = \phi s_n \Delta^{\mu} + (1 - s_n)(\Delta^{\star})^{\mu} \tag{A-17}$$

$$s_e = (1 - \mu)s_L + b s_K + s_n \pi(\sigma - 1) \tag{A-18}$$

[11] This also explains the higher values for the break and sustain point in the FE-model.

[12] We slightly changed the relative market size formulation of Baldwin et. al. ([10]) to assess the impact of asymmetric regions.

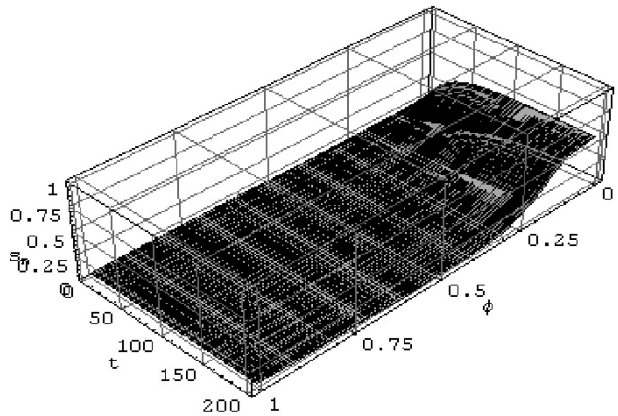

Figure A-12: Simulation of the dynamics in a symmetric FCVL-model with $s_n = 0.01$.

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Figure A-12 plots the share of north's industry in function of time and trade freeness. At $t = 0$, we impose that 99% of the worldwide industry is located in the south. For values of trade freeness below the sustain point ($\phi_S = 0.2922$) we see a rapid evolution toward the long run symmetrical equilibrium. As in the previous discussed models, there is a clear ϕ-dependence of the adjustment process: the lower the trade costs, the longer it takes to reach the long run equilibrium state. The data in the appendix once again show the clear influence of the sustain and break point (at $\phi = 0.2922$ and $\phi = 0.3145$ respectively). Given our initial condition there is practically no evolution after the break point. If one started at s_n slightly above 0.50, simulations show that there is no clear tendency toward the northern core solutions for higher values of trade freeness. Only when the initial advantage given to the region is quite large ($s_n(0) > 0.6$) a clear evolution toward the northern core is seen.

To better illustrate the transitional behaviour we draw the time evolution at$\phi = 0.2$ given an initial condition of $s_n = 0.01$ in figure A-13. The shape of the transition path is similar to the previous models. The identical form of the dynamic equation in the models explains this.

Figure (\ref{figuur17}) shows that the deviation in the share of labourers must deviate

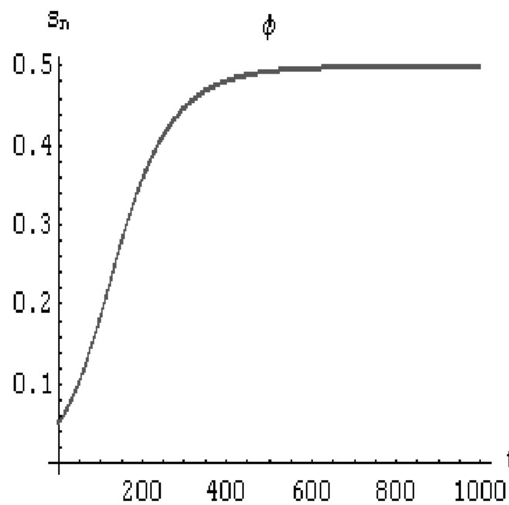

Figure A-13: Evolution at $\phi = 0.15$ of the symmetric FCVL-model starting from $s_n = 0.05$.

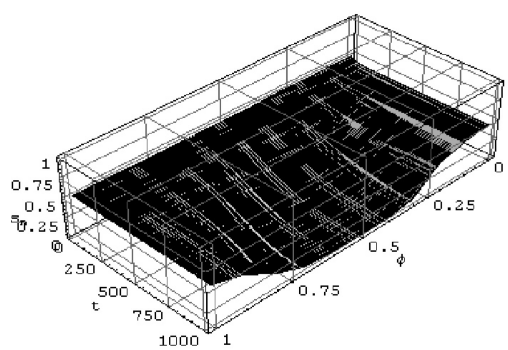

Figure A-14: Asymmetric FCVL-model with $s_n(0) = 0.51$ and $s_L = 0.45$.

considerably ($s_L < 0.45$) in order to change the outcome. On top of that we only see a tendency toward the southern core-solution in the region of trade freeness around the break and sustain point. There is no longer an evolution toward a northern core solution for high values of trade freeness as was the case in the CP-model. The reduced impact of a change in the share of labourers has to do with the different role labourers have in both models: in the FCVL-model it is not the share of labourers as such that is important but the fraction of that share that works in the imperfect competitive sector is. Similar simulations show that a deviation in the share of capital in each region has little or no influence on the dynamics. This can easily be understood if one looks at the relative market size condition A-18. The term with s_K is divided by σ compared to the s_L-term. In our context this means that the effect of a change in capital is 8 times less effective than a change in labourers.

A-3.2 CPVL-model

Probably the most intractable model of all discussed models is the CPVL-model. The system is defined as follows[13]:

$$\dot{n} = n\Pi \tag{A-19}$$

$$\dot{n}^\star = n^\star\Pi^\star \tag{A-20}$$

$$\Pi = \pi - \frac{P}{\sigma} \tag{A-21}$$

$$\pi = \frac{bB}{n^w} \tag{A-22}$$

$$B = P^{1-\sigma}(\frac{s_e}{\Delta} + \phi\frac{(1-s_e)}{\Delta^\star}) \tag{A-23}$$

$$P = (\Delta n^w)^{-a} \tag{A-24}$$

$$\Delta = \frac{n}{n^w}P^{1-\sigma} + \phi\frac{n^\star}{n^w}(P^\star)^{1-\sigma} \tag{A-25}$$

$$s_e = (1-\mu)s_L + \mu\frac{n}{n^w}B \tag{A-26}$$

[13] We only give the normalized northern equations as the southern are isomorphic. Note also that the expressions for the biases in the sales B and B^* differ from the equations in Baldwin et. al. ([10]), p. 196 as these formulas apparently have some typos. We also generalized the relative market size expressions to allow for regional asymmetries.

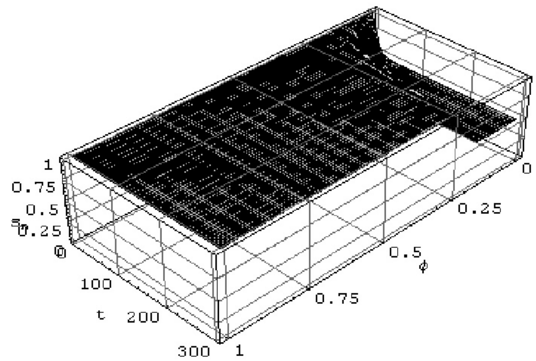

Figure A-15: Simulations of dynamics in symmetric CPVL-model with $n = 0.99$ and $n^* = 0.01$.

As in the CP-model the equations for the bias in sales$B$ and the price index Δ are recursively defined. On top of that the relative market size condition does not depend on the number of firms in the north n directly but via the sales bias B. This makes the model as a whole more intractable than the CP-model.

The dynamics of this model are illustrated in figure A-15. Just like the FCVL-model we see a rapid evolution toward the long run symmetricum if one started close to the northern core solution ($s_n(0) = 0.99$) for values of trade freeness below the sustain point. Secondly the same ϕ-dependence of the dynamical behaviour occurs as in all the previous models. Simulations done for initial values close to the symmetricum show that there still is an evolution for high values of trade freeness toward the northern or southern (depending on which region has the highest initial share) core solution. This tendency was lacking in the FE- and FC-model but present in the CP-model. It is possible to explain this phenomenon by referring to the relative low values of trade freeness at which the break and sustain point occur in the CP- and CPVL-model. Or otherwise stated, the existence of very strong agglomeration forces create this behaviour.

Figure A-16 plots the transition behaviour at $\phi = 0.1$ if one started near the northern core solution ($s_n(0) = 0.99$). The shape of the transition is similar to the previous models although the dynamical equation is different. It starts concave and ends convex with the point of inflection roughly in the middle. Again we see a very long tail.

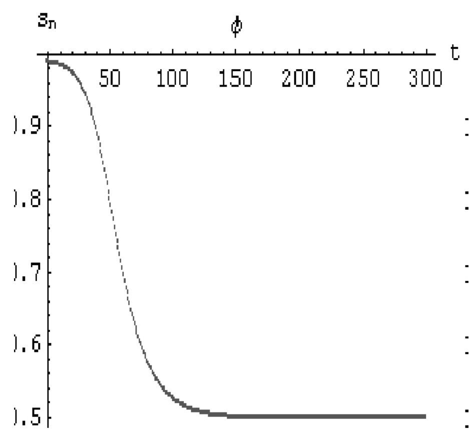

Figure A-16: Evolution at $\phi = 0.1$ of the symmetric CPVL-model starting from $s_n = 0.99$.

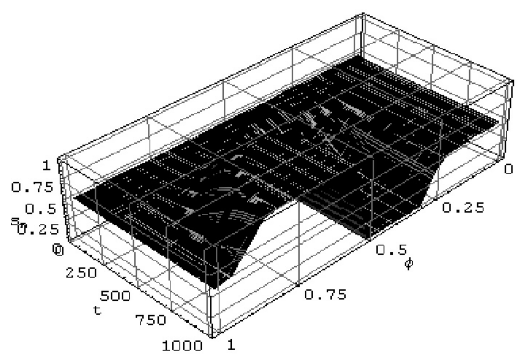

Figure A-17: Simulations of dynamics in asymmetric CPVL-model with $n = 0.51$, $n^* = 0.49$ and $s_L = 0.495$.

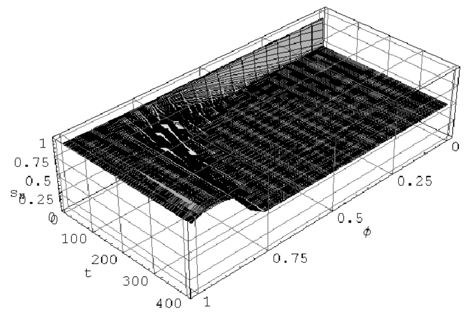

Figure A-18: Simulation of dynamics in symmetric FEVL-model with $n = 0.01$ and $n^* = 0.99$.

Lastly we want to briefly discuss the impact of regional asymmetries. This behaviour as depicted in figure A-17. This is almost an exact copy of the CP-case. This should come as no surprise as both models use the labourers in exactly the same way.

A-3.3 FEVL-model

The last model we discuss in this paper is the FEVL-model. We modelled this model using the following expressions:[14]

[14] Again we used the normalized equations for the northern region and generalized them slightly to introduce size asymmetries.

$$\dot{n} = n\Pi \tag{A-27}$$

$$\dot{n}^\star = n^\star\Pi^\star \tag{A-28}$$

$$\Pi = \pi - P \tag{A-29}$$

$$\pi = \frac{bB}{n^w} \tag{A-30}$$

$$B = \frac{s_e}{\Delta} + \phi\frac{(1-s_e)}{\Delta^\star} \tag{A-31}$$

$$P = (\Delta n^w)^{-a} \tag{A-32}$$

$$\Delta = \frac{n}{n^w} + \phi\frac{n^\star}{n^w} \tag{A-33}$$

$$s_e = (1-b)s_L + b\frac{n}{n^w}B \tag{A-34}$$

Figure A-18 represents the simulated dynamics of the symmetric FEVL-model in case we started from $s_n(0) = 0.01$. The evolution toward the long run symmetrical equilibrium is very fast. The break and sustain point occur at the same level as in the FE-model. Compared to the FE-model (figure A-11) the evolution is nearly a duplicate except for a different time scale. For instance, at ϕ=0.65 it takes 358 time steps in the FEVL-model to reach the symmetricum compared to 412 steps in the FE-model (at $s_n(0) = 0.95$). This difference also remains for values of trade freeness above the break point: at $\phi = 0.95$ and starting at $s_n = 0.95$ it took 3096 steps to reach the northern core solution in the FEVL-model while the FE-model requires 2707 time steps to reach the same solution. This illustrates the larger difference between the dispersion and agglomeration force in the VL-based models, although these differences remain relatively small.

This models exhibits the same differences with the CPVL-model as the FE-model did with the CP-model. For instance for low values of trade freeness (e.g. $\phi = 0.2$) the transition is fastest in the FEVL-model: only 35 steps are needed to reach the symmetricum starting from $s_n(0) = 0.99$ while the FCVL-model needs 472 steps. The reverse occurs for high values of trade freeness ($\phi = 0.9$). If the initial condition equals $s_n(0) = 0.9$, the CPVL-model needs 2503 steps to reach the northern cores solution while the FEVL-framework requires 3659 time steps. The relative reduction of the agglomeration force versus the dispersion force in the FEVL-framework lie at the basis of this feature.

Simulations show, as could be expected, that the influence of size asymmetries is similar to the FE-model. There is no noticeable influence of reasonable size asymmetries.

A-4 Transition times for different models

$T10\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.05$	$s_n(0) = 0.05$	6	10	1	2	6	12
	$s_n(0) = 0.15$	3	7	1	2	4	7
	$s_n(0) = 0.25$	2	6	1	2	4	5
	$s_n(0) = 0.35$	1	5	1	2	4	5
	$s_n(0) = 0.45$	1	5	1	2	4	5
$\phi = 0.15$	$s_n(0) = 0.05$	23	31	1	3	12	45
	$s_n(0) = 0.15$	9	18	1	3	7	20
	$s_n(0) = 0.25$	6	14	1	3	7	14
	$s_n(0) = 0.35$	4	12	1	3	6	12
	$s_n(0) = 0.45$	4	12	1	3	6	11
$\phi = 0.25$	$s_n(0) = 0.05$	49(CP)	27(CP)	1	4	22	232
	$s_n(0) = 0.15$	464(CP)	183(CP)	1	4	12	90
	$s_n(0) = 0.25$	141(sym)	175(sym)	1	3	10	57
	$s_n(0) = 0.35$	69(sym)	94(sym)	1	3	9	44
	$s_n(0) = 0.45$	53(sym)	75(sym)	1	3	8	39
$\phi = 0.35$	$s_n(0) = 0.05$	7	11	2	5	39	48
	$s_n(0) = 0.15$	10	14	1	4	20	71
	$s_n(0) = 0.25$	15	19	1	4	15	116
	$s_n(0) = 0.35$	28	30	1	4	13	218
	$s_n(0) = 0.45$	77	72	1	4	13	625
$\phi = 0.45$	$s_n(0) = 0.05$	5	10	4	7	67	25
	$s_n(0) = 0.15$	7	12	2	5	33	34
	$s_n(0) = 0.25$	11	16	2	5	25	50
	$s_n(0) = 0.35$	20	24	1	4	22	88
	$s_n(0) = 0.45$	54	53	1	4	20	241

Table 8.2: Time necessary to close 10% of gap between initial state and final equilibrium state.

$T10\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.55$	$s_n(0) = 0.05$	5	10	7	9	120	22
	$s_n(0) = 0.15$	7	12	4	7	58	29
	$s_n(0) = 0.25$	11	16	3	6	43	43
	$s_n(0) = 0.35$	19	24	2	5	37	75
	$s_n(0) = 0.45$	52	52	2	5	34	205
$\phi = 0.65$	$s_n(0) = 0.05$	6	11	15	16	231	23
	$s_n(0) = 0.15$	8	14	7	10	110	31
	$s_n(0) = 0.25$	12	18	5	8	80	46
	$s_n(0) = 0.35$	21	27	5	8	68	80
	$s_n(0) = 0.45$	59	58	4	8	63	219
$\phi = 0.75$	$s_n(0) = 0.05$	7	13	45	44	518	28
	$s_n(0) = 0.15$	9	17	22	23	245	39
	$s_n(0) = 0.25$	15	22	16	18	177	58
	$s_n(0) = 0.35$	24	33	13	16	150	101
	$s_n(0) = 0.45$	75	74	12	16	139	277
$\phi = 0.85$	$s_n(0) = 0.05$	11	18	6302	5632	1623	43
	$s_n(0) = 0.15$	16	23	2868	2640	766	59
	$s_n(0) = 0.25$	24	41	2014	1894	522	89
	$s_n(0) = 0.35$	42	47	1671	1593	465	158
	$s_n(0) = 0.45$	117	113	1537	1476	432	434
$\phi = 0.95$	$s_n(0) = 0.05$	31	39	44	39	16299	120
	$s_n(0) = 0.15$	44	50	62	55	7622	167
	$s_n(0) = 0.25$	67	71	94	83	5518	254
	$s_n(0) = 0.35$	120	119	169	149	4651	454
	$s_n(0) = 0.45$	333	313	468	410	4313	1257

Table 8.3: Time necessary to close 10% of gap between initial state and final equilibrium state.

$T50\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.05$	$s_n(0) = 0.05$	18	24	2	4	27	45
	$s_n(0) = 0.15$	10	20	1	4	25	34
	$s_n(0) = 0.25$	7	18	1	4	24	30
	$s_n(0) = 0.35$	6	18	1	4	23	29
	$s_n(0) = 0.45$	5	18	1	4	23	28
$\phi = 0.15$	$s_n(0) = 0.05$	70	71	3	5	50	150
	$s_n(0) = 0.15$	40	49	2	5	40	98
	$s_n(0) = 0.25$	30	41	2	5	37	80
	$s_n(0) = 0.35$	25	38	2	5	35	71
	$s_n(0) = 0.45$	23	36	2	5	34	68
$\phi = 0.25$	$s_n(0) = 0.05$	281(CP)	229(CP)	4	7	86	704
	$s_n(0) = 0.15$	1203(CP)	822(CP)	3	6	65	415
	$s_n(0) = 0.25$	605(sym)	583(sym)	3	6	57	317
	$s_n(0) = 0.35$	400(sym)	387(sym)	3	5	54	272
	$s_n(0) = 0.45$	338(sym)	330(sym)	3	5	52	254
$\phi = 0.35$	$s_n(0) = 0.05$	42	46	7	9	144	302
	$s_n(0) = 0.15$	55	56	5	8	104	405
	$s_n(0) = 0.25$	76	73	5	7	90	574
	$s_n(0) = 0.35$	115	105	4	7	83	891
	$s_n(0) = 0.45$	219	191	4	7	81	1747
$\phi = 0.45$	$s_n(0) = 0.05$	31	38	12	14	243	155
	$s_n(0) = 0.15$	40	45	9	11	172	195
	$s_n(0) = 0.25$	55	57	7	10	147	258
	$s_n(0) = 0.35$	82	78	7	9	135	375
	$s_n(0) = 0.45$	154	136	7	9	130	695

Table 8.4: Time necessary to close 50% of gap between initial state and final equilibrium state.

$T50\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.55$	$s_n(0) = 0.05$	30	38	23	23	428	136
	$s_n(0) = 0.15$	39	45	16	17	298	170
	$s_n(0) = 0.25$	53	56	14	15	252	223
	$s_n(0) = 0.35$	79	77	12	14	230	322
	$s_n(0) = 0.45$	149	133	12	14	221	593
$\phi = 0.65$	$s_n(0) = 0.05$	34	42	50	47	817	145
	$s_n(0) = 0.15$	44	50	35	24	565	180
	$s_n(0) = 0.25$	60	63	29	29	474	238
	$s_n(0) = 0.35$	89	86	26	27	432	344
	$s_n(0) = 0.45$	167	151	25	26	413	635
$\phi = 0.75$	$s_n(0) = 0.05$	44	51	157	141	1824	176
	$s_n(0) = 0.15$	56	62	108	98	1254	224
	$s_n(0) = 0.25$	76	78	90	83	1049	297
	$s_n(0) = 0.35$	113	109	82	76	952	432
	$s_n(0) = 0.45$	213	194	78	73	911	800
$\phi = 0.85$	$s_n(0) = 0.05$	68	74	21544	18888	5702	271
	$s_n(0) = 0.15$	88	91	14361	12635	3905	343
	$s_n(0) = 0.25$	119	118	11796	10401	3662	458
	$s_n(0) = 0.35$	177	169	10583	9344	2956	672
	$s_n(0) = 0.45$	333	305	10071	8898	2827	1251
$\phi = 0.95$	$s_n(0) = 0.05$	196	193	277	243	57186	757
	$s_n(0) = 0.15$	253	243	356	312	39113	968
	$s_n(0) = 0.25$	342	324	482	422	32637	1305
	$s_n(0) = 0.35$	508	474	714	625	29565	1928
	$s_n(0) = 0.45$	954	879	1342	1173	28268	3611

Table 8.5: Time necessary to close 50% of gap between initial state and final equilibrium state.

$T90\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.05$	$s_n(0) = 0.05$	31	45	4	6	80	111
	$s_n(0) = 0.15$	22	41	4	6	77	99
	$s_n(0) = 0.25$	19	39	4	6	76	95
	$s_n(0) = 0.35$	16	39	4	6	76	93
	$s_n(0) = 0.45$	15	38	4	6	76	92
$\phi = 0.15$	$s_n(0) = 0.05$	128	130	6	8	131	317
	$s_n(0) = 0.15$	96	105	6	8	120	260
	$s_n(0) = 0.25$	83	97	5	8	116	238
	$s_n(0) = 0.35$	77	93	5	8	114	228
	$s_n(0) = 0.45$	74	36	5	7	113	223
$\phi = 0.25$	$s_n(0) = 0.05$	785(CP)	671(CP)	10	11	210	1351
	$s_n(0) = 0.15$	1883(CP)	1416(CP)	9	10	187	1034
	$s_n(0) = 0.25$	1431(sym)	1371(sym)	8	10	178	918
	$s_n(0) = 0.35$	1188(sym)	1090(sym)	8	10	173	862
	$s_n(0) = 0.45$	1110(sym)	1018(sym)	8	10	171	838
$\phi = 0.35$	$s_n(0) = 0.05$	129	128	16	17	338	944
	$s_n(0) = 0.15$	151	145	14	15	295	1110
	$s_n(0) = 0.25$	162	170	13	14	278	1354
	$s_n(0) = 0.35$	232	211	13	14	269	1762
	$s_n(0) = 0.45$	351	309	12	14	268	2731
$\phi = 0.45$	$s_n(0) = 0.05$	97	102	27	26	558	493
	$s_n(0) = 0.15$	112	114	23	23	480	557
	$s_n(0) = 0.25$	133	130	22	22	450	649
	$s_n(0) = 0.35$	168	158	21	21	435	801
	$s_n(0) = 0.45$	250	224	21	21	428	1163

Table 8.6: Time necessary to close 90% of gap between initial state and final equilibrium state.

$T90\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.55$	$s_n(0) = 0.05$	95	101	51	47	968	433
	$s_n(0) = 0.15$	109	112	43	41	826	487
	$s_n(0) = 0.25$	130	128	40	38	770	564
	$s_n(0) = 0.35$	163	155	39	37	743	693
	$s_n(0) = 0.45$	242	219	38	36	730	999
$\phi = 0.65$	$s_n(0) = 0.05$	106	113	111	100	1833	459
	$s_n(0) = 0.15$	122	125	94	85	1554	517
	$s_n(0) = 0.25$	145	144	88	79	1446	601
	$s_n(0) = 0.35$	183	174	84	76	1392	739
	$s_n(0) = 0.45$	272	247	83	75	1368	1068
$\phi = 0.75$	$s_n(0) = 0.05$	136	141	349	307	4067	565
	$s_n(0) = 0.15$	157	158	294	260	3437	639
	$s_n(0) = 0.25$	186	182	273	241	3192	745
	$s_n(0) = 0.35$	235	222	263	232	3069	921
	$s_n(0) = 0.45$	348	318	258	228	3016	1338
$\phi = 0.85$	$s_n(0) = 0.05$	214	213	46532	40620	12670	857
	$s_n(0) = 0.15$	247	241	38609	33725	10867	975
	$s_n(0) = 0.25$	293	261	35535	31048	9915	1143
	$s_n(0) = 0.35$	368	346	34001	29711	9529	1420
	$s_n(0) = 0.45$	545	501	33334	29129	9361	2077
$\phi = 0.95$	$s_n(0) = 0.05$	618	587	873	764	126886	2392
	$s_n(0) = 0.15$	710	669	1002	876	106940	2736
	$s_n(0) = 0.25$	841	788	1166	1037	99173	3228
	$s_n(0) = 0.35$	1056	982	1488	1301	95286	4036
	$s_n(0) = 0.45$	1563	1442	2200	1924	93595	5947

Table 8.7: Time necessary to close 90% of gap between initial state and final equilibrium state.

$T100\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.05$	$s_n(0) = 0.05$	31	45	4	6	80	111
	$s_n(0) = 0.15$	22	41	4	6	77	99
	$s_n(0) = 0.25$	19	39	4	6	76	95
	$s_n(0) = 0.35$	16	39	4	6	76	93
	$s_n(0) = 0.45$	15	38	4	6	76	92
$\phi = 0.15$	$s_n(0) = 0.05$	128	130	6	8	131	317
	$s_n(0) = 0.15$	96	105	6	8	120	260
	$s_n(0) = 0.25$	83	97	5	8	116	238
	$s_n(0) = 0.35$	77	93	5	8	114	228
	$s_n(0) = 0.45$	74	36	5	7	113	223
$\phi = 0.25$	$s_n(0) = 0.05$	785(CP)	671(CP)	10	11	210	1351
	$s_n(0) = 0.15$	1883(CP)	1416(CP)	9	10	187	1034
	$s_n(0) = 0.25$	1431(sym)	1371(sym)	8	10	178	918
	$s_n(0) = 0.35$	1188(sym)	1090(sym)	8	10	173	862
	$s_n(0) = 0.45$	1110(sym)	1018(sym)	8	10	171	838
$\phi = 0.35$	$s_n(0) = 0.05$	129	128	16	17	338	944
	$s_n(0) = 0.15$	151	145	14	15	295	1110
	$s_n(0) = 0.25$	162	170	13	14	278	1354
	$s_n(0) = 0.35$	232	211	13	14	269	1762
	$s_n(0) = 0.45$	351	309	12	14	268	2731
$\phi = 0.45$	$s_n(0) = 0.05$	97	102	27	26	558	493
	$s_n(0) = 0.15$	112	114	23	23	480	557
	$s_n(0) = 0.25$	133	130	22	22	450	649
	$s_n(0) = 0.35$	168	158	21	21	435	801
	$s_n(0) = 0.45$	250	224	21	21	428	1163

Table 8.8: Time necessary to close 100% of gap between initial state and final equilibrium state.

$T100\%$		CP	CPVL	FE	FEVL	FC	FCVL
$\phi = 0.55$	$s_n(0) = 0.05$	95	101	51	47	968	433
	$s_n(0) = 0.15$	109	112	43	41	826	487
	$s_n(0) = 0.25$	130	128	40	38	770	564
	$s_n(0) = 0.35$	163	155	39	37	743	693
	$s_n(0) = 0.45$	242	219	38	36	730	999
$\phi = 0.65$	$s_n(0) = 0.05$	106	113	111	100	1833	459
	$s_n(0) = 0.15$	122	125	94	85	1554	517
	$s_n(0) = 0.25$	145	144	88	79	1446	601
	$s_n(0) = 0.35$	183	174	84	76	1392	739
	$s_n(0) = 0.45$	272	247	83	75	1368	1068
$\phi = 0.75$	$s_n(0) = 0.05$	136	141	349	307	4067	565
	$s_n(0) = 0.15$	157	158	294	260	3437	639
	$s_n(0) = 0.25$	186	182	273	241	3192	745
	$s_n(0) = 0.35$	235	222	263	232	3069	921
	$s_n(0) = 0.45$	348	318	258	228	3016	1338
$\phi = 0.85$	$s_n(0) = 0.05$	214	213	46532	40620	12670	857
	$s_n(0) = 0.15$	247	241	38609	33725	10867	975
	$s_n(0) = 0.25$	293	261	35535	31048	9915	1143
	$s_n(0) = 0.35$	368	346	34001	29711	9529	1420
	$s_n(0) = 0.45$	545	501	33334	29129	9361	2077
$\phi = 0.95$	$s_n(0) = 0.05$	618	587	873	764	126886	2392
	$s_n(0) = 0.15$	710	669	1002	876	106940	2736
	$s_n(0) = 0.25$	841	788	1166	1037	99173	3228
	$s_n(0) = 0.35$	1056	982	1488	1301	95286	4036
	$s_n(0) = 0.45$	1563	1442	2200	1924	93595	5947

Table 8.9: Time necessary to close 100% of gap between initial state and final equilibrium state.

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