Chapter 7

Summary and conclusions

7.1 Summary

Over time, two regularities may be observed in the world:

- *Economic activity is distributed unevenly on many scales.* There seems to be a force at work that pulls economic activity together, resulting in a system of cores and peripheries. Such a system may be observed at a worldwide scale, but also on the scale of countries and provinces.

- *On average, economies grow.* Technological advances, accumulation of capital, growing populations: for most of recorded history, world production has increased over time.

Chapter 2 illustrates these two trends with some data and then draws attention to the fact that, until recently, economic theory did not explain important aspects of either trend. Models of exogenous growth would describe the transition of economies to a steady-state growth path, but leave the determination of that path outside the model. In the end, productivity increases would come from technological improvements; their component in economic growth has been called 'a measure of our ignorance' by Abramovitz (1956).

Spatial models would describe the effect of a concentration on its *hinterland*, using the land rent gradient of von Thünen (1842) or the market potential function of Harris (1954). The occurrence of the concentration itself is explained by the Marshallian trinity of a shared labor market, the closeness of intermediate goods suppliers and pure external effects (Marshall 1920). The different sizes of these external effects, balanced against the congestion that discourages city growth, then explains the different sizes of cities (Henderson 1974). The assumption of pure, unobservable, external effects as the binding force in agglomerations, however, leaves the economist empty-handed when it comes to predicting the effect on cities of changes in transport costs or the occurrence of new industries.

In chapter 2 we explore two theories that provide new insights into these problems. Both theories make use of the monopolistic competition framework of Dixit and Stiglitz (1977), in which there are increasing returns on the level of the firm, as well as increasing returns to the number of firms (or, the number of varieties). These qualities of the model explain why there exist *complementarities* between firms, and these complementarities can be the source of agglomeration as well as growth. The two theories are the economic geography theory of Krugman (1991b) and endogenous growth theory of Romer (1986).

The beauty of the monopolistic competition model is that the owner of a single firm recognizes the fact that other firms complement his enterprise and uses this information in his decision, but no single firm can grow big enough to affect the size of the total 'complementarity'. Thus, it is a model where small actors, through their individual optimizations, bring about a macro-equilibrium with interesting qualities (Matsuyama 1993).

One such quality may be agglomeration; when there exist transport costs between different locations and individual firms value the complementarities of other firms, it is intuitive that there will exist an equilibrium in which all firms have moved to the same location. The channel through which these complementarities travel can differ between models: in paragraph 2.3.4 we identify the labor market, the market for intermediate goods and the R&D sector as possible media. The countervailing force to agglomeration in these models is local demand: even though being near other firms brings advantages, serving local demand from the peripheral region may be worthwhile. Another possible quality of the macro-equilibrium is lasting growth: when returns to variety imply that an increase in the number of firms makes all other firms more efficient, growth can be an equilibrium solution (paragraph 2.4).

Because both theories rest on the same foundation, prospects for a theory of growth *and* agglomeration are hopeful. In paragraph 2.5, several such theories are surveyed. The interplay between growth and location turns out to change the outcomes that are found in either literature by itself. Stable equilibria in static geography models turn out to be unstable in a dynamic context. On the other side, the rate of growth is influenced by the location pattern, which itself depends on initial values.

In chapter 3, we extend the economic geography model in which complementarities between firms exist on the market for intermediate goods. This type of model, introduced by Venables (1996b), explains agglomeration of economic activity when the population is not mobile between regions; this makes it suitable to investigate the differences in agglomeration between nations. In the original model, the simplifying assumption is made that firms use the output of *all* other firms as an intermediate input. We introduce an extension to the model, in which each firm can have its own input demand function, depending on its production process.

This extension introduces a wealth of possibilities into the model; there are infinitely many firms, and each of them can have a particular input demand function. Even with only two regions, it would be very hard to discuss every possible outcome of this model. We therefore proceed in two, simplifying, directions. For the remaining part of chapter 3, we adopt a number of simple, sweeping assumptions about the use of intermediate inputs by groups of firms. This allows us to asses the different ways in which differences in technology can affect the spatial equilibrium. We find that it is possible for two groups of firms to repel each other, when they do not use each other's output sufficiently. The externality that drives two unrelated sectors to different locations is their effect on local wages. In paragraph 3.3, we discuss how different technologies interact with location decisions if there is economic growth. Assuming a pattern of input demand that is consistent with technological progress, we show that in this model, firms locate according to their age: there exists a region in which firms use old technology and a region where new technology is introduced and used. When the number of firms increases, older firms in that region are to the *old* region.

The other direction in which we simplify the initial extension of chapter 3 is by letting go of the concept of 'continuous sectors' in chapter 4. If we assign each firm to one of a fixed number of sectors and stipulate that all firms in a sector demand the same intermediate inputs, we can contain the number of possible specifications. More precisely, under this assumption the demand for intermediate inputs can be summarized by an input-output (IO)-matrix of limited size. Thus when the number of sectors is N, the characteristics of intermediate-input demand are given by a parameter of dimension $N \times (N - 1)$.[1] We present a full set of solutions in the case where $N = 2$ and there are two regions. Under those circumstances, there are four types of equilibrium (paragraph 4.3). We find that there exist a number of parameters in IO-space where the stability of these different equilibria switches. This means that a small change in technology can cause a dramatic change in the type of equilibrium that obtains. This disproportionate effect of a changing parameter has been shown before in the case of transport costs (Krugman 1991a). We show that it also applies to parameters in the production technology.

Next, we direct our attention away from the theoretical properties of geography models and turn to the estimation of their parameters in chapter 5. Paragraph 5.2 surveys earlier attempts to validate, estimate and parametrize these models in the literature. We discuss three approaches in detail: validation of the models by measuring the home market effect, estimation of parameters with the use of a spatial wage structure and the

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[1]Since the columns of a matrix of input shares must sum to one, the dimension of this parameter is lower than the number of entries in the matrix, N^2.

art of parametrizing applied general equilibrium models.

In the rest of the chapter, we attempt to estimate a spatial wage structure with data on American states. We start by replicating the methodology of Redding and Venables (2001), who use data on world incomes and distance, in paragraph 5.5.1. Our dataset has the advantage of pertaining to regions of a single country, which eliminates error due to institutional differences or trade barriers between countries. The dataset is also smaller and we expect less variation between the observations. Our results confirm the conclusion of Redding and Venables that the model has reasonable explanatory power. However, we find that on the scale of US states this power is substantially less than when the model is applied to a sample of countries worldwide.

A problem with the methodology used to obtain these parameter estimates is the following: the model that you get when inserting these estimates does not necessarily agree with the original observation as a state of equilibrium. That is, if we are interested in finding a model that explains the data as good as possible, the parameter estimates obtained in this way are not necessarily the best. We introduce another methodology which might improve on this result in paragraph 5.5.2. In this paragraph, we search over a grid of parameters, computing the full general equilibrium solution for each parameter-candidate. The estimate is the parameter in which that solution deviates as little as possible from the data. Monte Carlo methods are used to generate standard errors for these estimates. We use a model, thus specified, to evaluate a number of counterfactuals and find the (spatial) effects of a localized change in wages and a drop in transport costs in paragraph 5.6.

With the last paragraph, we have entered into the field of policy evaluation. Now that we have formulated an understanding of geographical patterns in activity and found a way to estimate and calibrate a model to the present situation, we can run counterfactuals as a tool to evaluate the effects of policy. An exercise of this nature is the subject of chapter 6. In this chapter, we use the results of our previous work to specify a model of the Dutch economy with 548 regions and 14 sectors. Intermediate good demand for each sector is specified by an input-output matrix, which may differ between regions. We use this model to evaluate the construction of a railway between Amsterdam and Groningen in 2020. We find that, due to our neglect of the labor market in this model, we have to deal with an instability: left unchecked, the model agglomerates all activity in one location. We opt for a first-step approximation, in which we take some of the feedback out of the model.

7.2 Conclusions

In this thesis we look at economic geography models from a number of angles. We started by placing the theory in a context of preceding theories, both earlier work on spatial economics and other children of the monopolistic competition 'revolution.' Next, we looked at the theoretical properties of these models, especially when we allow firms to have different demand functions for intermediate goods. We estimated the model using a dataset on US states, and computed a number of counterfactuals. Finally, we used the theory to conduct a policy evaluation exercise concerning the construction of a railroad.

From the first chapter, we learn that there exist a large number of progenitors to the current crop of economic geography models. The models themselves are direct descendants of the earlier waves of MC-based innovation in the areas of industrial organization, international trade and economic growth. However, many of the concepts that these models formalize have been known and used for a long time by other theories, albeit in a less formal manner. Examples of some of these concepts are the gravity equation and the market potential function. An advantage of the formal microeconomic underpinning that the 'new' theory provides is that they may now be used in computations of consumer welfare, and embody explicit assumptions about economic behavior.

Expanding the model with varying types of intermediate demand, as we did in chapters 3 and 4, shows just how much the standard models depend on their simplifying assumptions. Relaxing one such simplifying assumption opens up a whole gallery of new models with different types of equilibria. Because solving these models often requires the use of numerical methods, it is complicated to map all possible outcomes after the change.

Nonetheless, we can draw some useful conclusions from the extensions in chapters 3 and 4. The models in chapter 3 show that it is possible to separate the agglomerating and dispersing forces that operate between firms. By specifying a particular input demand function, we can eliminate the attraction between two groups of firms and observe that they move to different locations. The dispersing force is the local wage rate; this is reminiscent of the practice of multinational enterprises to relocate their manufacturing to low-wage countries. The same model can be used to show that in a growing economy, it is possible that all innovative firms locate in the same region, leaving the other region with the older manufacturing processes. Which region gets the innovative firms is decided by history, and cannot easily be changed. This outcome can be used to argue against subsidies that would help 'backward' regions attract innovative firms in the hope of creating jobs. Unless these firms are relatively independent of other firms using related technology, these subsidies will have no lasting effect.

The models in chapter 4 illustrate that the spatial equilibrium in economic geography models indeed depends on the technology that is used in production, and the different demand functions for intermediate inputs. It goes further by showing that a gradual change in these functions does not, in general, change the equilibrium except at a few crucial values. That is, there exist situations in which a small change in the input-output parameters can have catastrophic consequences. This is not unlike the property of standard core-periphery models to be sensitive to the level of transport costs at particular break- and sustain points. We offer a map of the boundaries between different equilibria in IO-parameter space.

The empirical exercises in chapter 5 show that the economic geography model with intermediate goods is a reasonable description of the level of wages in, and the direction of trade between American states in 1997. We use two methods of estimation, one of which has been used before on a sample of countries worldwide (Redding and Venables 2001). We find that applying the same model to a (smaller) sample of US states leads to less conclusive results. In particular, the effect of the surrounding geography on one state's wages are hard to measure. This may be the effect of a dataset that is smaller and contains a few dominating regions.

We introduce a new estimation procedure that takes into account the general equilibrium properties of the model. Using this procedure, we find parameter values that indicate increased sensitivity to distance and the presence of a shared border, relative to the first estimation. The standard errors (computed using Monte Carlo methods) cast some doubt on the reliability of these estimates, however.

With the parametrized model of the United States, we run two counterfactuals involving changes in the (central) state of Illinois. We show that a fall in local wages sets off a chain of events, redistributing demand toward Illinois and its neighboring states, who enjoy cheaper inputs. For those neighbors however, the total result turns out to be negative as they also face a drop in demand from Illinois. Next, we simulate a fall in transport costs between the neighboring states of Illinois and Indiana. This benefits the affected states, who with their cheaper products help the surrounding states as well. But again these neighbors are worse off in the end, this time because national demand is shifted away from them, towards Illinois and Indiana. The different ways in which these changes in the economic environment impact the rest of the country are easily tracked and quantified with our model, showing its use a policy evaluation instrument.

Our exercise in chapter 6 shows the results of a policy evaluation for which a large-scale economic geography model was built. The model has a number of shortcomings, but did a reasonable job in tracking and quantifying the effects of six infrastructural projects. We found that the most ambitious plan would lead to a shift of about 8,000 jobs, gained at both ends of the new line. Furthermore, consumers in the North are better off

because their access to services offered in the (more agglomerated) West has improved.