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CAPITAL MOBILITY AND LABOR DEMAND IN
URBAN AGGLOMERATIONS DURING THE SUB-
URBANISATION PROCESS, AN ECONOMETRIC
APPROACH

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I. Introduction

It is the task of this paper to investigate the determinants of the change in the spatial distribution of productive capital and labor demand in the economic development process.¹⁾

Additionally it is the goal of this contribution to report some attempts to use econometric methods to test the empirical reliability of some of the hypotheses based on economic theory. Unhappily the notorious lack of consistent sets of regional economic data make the latter part of this paper an adventure. This introduction serves two purposes, one is to give a few selected references about capital and investment theory in the body of general economic literature. The second aim is to imbed this contribution into a framework of spatial analysis introduced in the CURB project (v.d. Berg, et al. 1981). Some of the (scant) literature dealing specifically with the spatial mobility of capital will be mentioned in an attempt to synthesize some of the different approaches.

In general economic theory, the problems of capital accumulation have provoked several famous controversies (for a survey, see e.g. Orosel and Weizsäcker, 1980; Harcourt, 1972, etc.). The issues raised ranged from the definition of capital, to the implications of neo-classical production theory, the "switching" and "reswitching" of technologies in the course of economic development, as well as the question of functional income distribution. The analysis presented in this paper remains more or less in the macro-economic, neo-classical (with a few glimpses of neo-Austrianism) paradigm, not necessarily by inclination but rather driven by the wish to derive an empirically testable model, which cannot be along "general-equilibrium" lines - which, according to Orosel and Weizsäcker, remains more or less unruffled by the ardent capital theory controversies. Besides this more pragmatic excuse, we have to take into account that it is not a capital theory

we are after but rather a theory of the spatial allocation of investment.

Standard non-spatial economic theory, both along neo-classical or Keynesian lines, relies basically on marginal productivity theory to explain the demand for labor and capital. Additional units of the production factors are demanded until the marginal cost of this expansion becomes equal to the value of the marginal product of the production factor. In such a static approach no frictions exist to keep firms from hiring and firing labor at any point in time and the optimal capital stock can be reached instantaneously. To derive a theory of investment - not of capital, such frictions had to be introduced (e.g. Jorgenson, 1971), either stemming from capacity bottlenecks in the investment good industry. (Lange, 1968) or from internal frictions. These are mainly due to organisational changes and production losses during the installation time of the new equipment (Treadway, 1969). Similar approaches were also utilized to derive the demand for labor (Scanlon et al., 1977). It is not the entire stock of labor that is up for decision at each period of time, but only a part of it ("Hiring and firing").

One of the most important driving forces behind necessary changes in the labor force and the capital stock are changes in demand for the goods produced ("accelerator models", e.g. Samuelson, 1939). Others are changes in the factor prices and the availability of new technology.

In the framework of spatial models these factors have to be re-interpreted and new aspects appear. The most important among these is the existence of different market areas varying in size and the differentials in factor prices over space. Profit opportunities hence vary over space and as a consequence factor mobility can be observed. Contrasting opinions about the direction of these factors flows have led to the creation of different schools of thought - "Myrdalians vs.

Neo-Classicists". Greatly simplified the thesis of the first can be summarized by saying: "Where there is lot, more is due to come", and the analogous reverse (cumulative processes), the latter expects a tendency towards a spatial equilibrium (see e.g. Richardson, 1973).

Let us next turn briefly to the general theory of urban development, to put the present contribution into a more general context (see v. den Berg et al., 1981; Drewett and Schubert, 1980).

The basic hypothesis of the work quoted in the close connection between economic development as a whole (GNP growth, etc.) and urbanization. Corresponding to the phases of economic development as a whole (industrialization, tertiarisation, etc.) there are phases of urbanization (centralization, suburbanization, etc.). Urbanization follows a "life-cycle" in which the distribution of population and production units, etc. over the urban system changes. Each phase of urbanization is characterized by a catalogue of economic & social problems, typical policy targets and measures (expenditures, etc.) and instruments of urban development planning.

Three groups of agents are distinguished whose interdependent decisions drive the urban development processes: Households, production units and governmental agencies. Three types of activities are analyzed which are essential:

- working
- living
- communicating (traffic, etc.)

The basic hypothesis is that all actors try to close the gap between desired levels of their goal variables and the actual levels. These options are summarized in the form of potentials, open to the actors in the area of living and working where actions farther away from the place of residence are worth less to the actor. The usual spatial "discount-factor" is influenced by the capacity of the communi-

cation system and its relative state of congestion. There is a trade-off selection between these potentials defining the "welfare-functions" of these agents.

The decisions made to improve the welfare levels of the urban agents cause changes in the distribution of households, production units and infra-structure over the intra-urban as well as the inter-urban system (migration, etc.). The constraints and thus the actual welfare levels of all parties concerned change again which leads to reconsiderations and new reactions by all agents (see figure 1).

The discrepancy between the actual and the desired level of the goal variables are perceived as "urban problems". Reactions to these problems then become real "expenditures". But all of these reactions change the system - so they are "input" variables into the urban transformation process.

There are, of course, a number of exogenous variables which influence the actual welfare levels of the urban agents. One of the fundamental variables changing the restrictions under which welfare maximization takes place, is the national (or international) economic "growth propensity". There is obviously a simultaneous relationship between national growth and local growth - it becomes "embodied" by the local economic decisions taken. Within the project, however, this simultaneity is not investigated.

This continuous feedback process described is broken into discrete "stages of urbanization" to be better able to illustrate the varying characteristics of each stage.

3 stages can be distinguished in the full life-cycle of urban development

(a) Urbanization

At the beginning of the industrialization process the already existing towns are the optimal locations for industries. Migration

The Behavior of Actors in the Urban Development Process

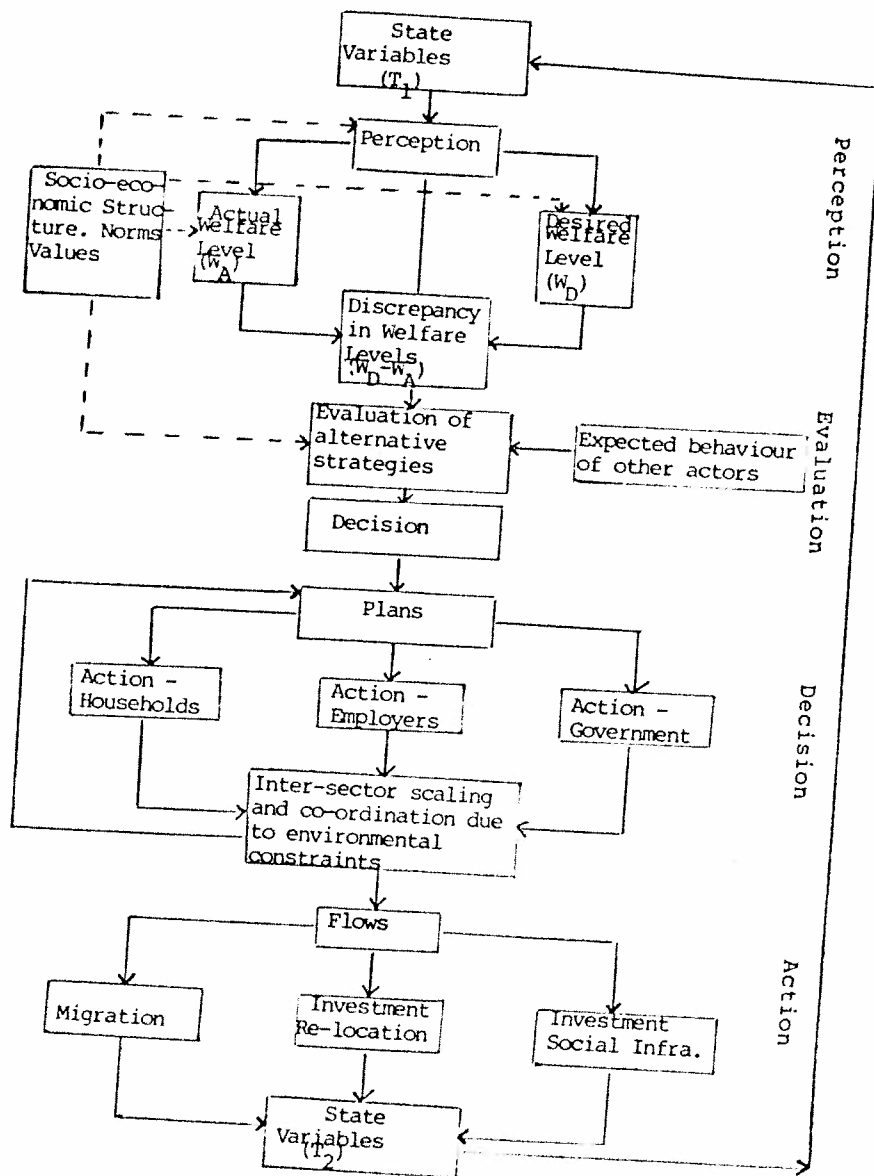


Figure 1
(Source: Drewett & Schubert 1980)

W_D ...Desired welfare level
 W_A ...actual welfare level
 $T_{1,2}$...time period

from the hinterland to the cores where the jobs and the higher incomes can be found results in increased population in the urban places. Interactions take place primarily between core and hinterland.

(b) Suburbanization

Urban population growth is slowing down. The urban structure is consolidating and the quality of urban facilities is improved. Interactions are still primarily intraregional. Economic exchanges between regions increase (exports & imports of goods and services increase).

Shifts of urban population and -lagged-of production units to urban rings leads to urban sprawl.

(c) Desurbanization

The big agglomerations lose population, the former hinterlands (particularly the small urban places) now become the destination of migration of people as well as of firms.

As population and economic activities change over space growth in one spatial category must imply decline in another, *cet. par.* Looking at different size classes within the national urban system, we must find one category "urbanizing" the other "desurbanizing", etc. This implies that various stages of this process can be observed within the urban system of even one country.

Let us next turn briefly to more formal models of the spatial mobility of capital. An article by Rahman (1963) in the quarterly *Journal of Economics* and a comment by Intriligator (1964) led to a controversy about the possibility of a "switch" of investment. Takayama (1967) states that: "...if the (regional) productivities are the same, we should invest all the fund in the region where the saving rate is higher. In this case, there is no switch...". The important theme, pricked up in the following sections of the paper,

is the importance of regional differences in the relevant decision variables (productivities, etc.).

A similar discussion utilizing empirical evidence was later published in the *J. of Regional Science* (Engle, 1975), focusing on the disequilibrium issue. Other analytical studies attempting econometric tests of the theoretical models are the most recent development (La Bella, 1978; Schubert and Hampapa, 1979; Bade, 1981, etc.). (An early attempt, based on a very simple model was made by Peaker, 1971).

The basic approach used in this paper is very similar to a study by v. Rompuy and de Breuyne (1977). The maximization of the market value of a multiregional firm is the objective, the maximization of this value yields a set of simultaneous, non-linear investment functions on the sectoral level, where the dependent variable in the regressions is the share of sectoral, regional investment in the total national investment.

In this contribution we intend to take a closer look at the "welfare level" of the urban firm and define it more formally. Furthermore the goal variables and constraints of the decision problem will be scrutinized. A micro economic decision model applying optimal control theory is applied to derive investment plans in the home region as well as shifts of capital to other regions. The determinants for the variations in the level of investment expenditures and simultaneously labor are investigated and empirically testable hypotheses are derived.

2. The investment and location decision at the level of the firm.

2.1. The constraints of the decision problem.

The purpose of investment in the framework of this analysis is to create or expand productive facilities. To be able to produce goods and services, production factors are necessary and a specific technology of production has to be chosen. In this study only the production factors capital (K), labor (L) and land area (A) are considered. The levels of these stocks required can be changed by means of flows, i.e. investment (I), hiring and firing of labor (H), and expansion (E) of the land area at each time period. Specific combinations of these factors represent "technologies", by means of which the goods and services (Y) can be produced. As our analysis is eventually concerned with "value added" only, we will not explicitly consider "flowing capital" (raw materials, etc.).²⁾

The efficient combinations (i.e. yielding maximum output), assuming that there are infinitely many of them, can be represented by a production function. A fact sometimes neglected in economic analysis is that changes in the stocks of the production factors cause internal frictions which often imply temporary losses of productivity. The installation of new machines takes time in which productivity suffers, new labor has to be trained to acquire the specific skills necessary, it usually takes time to find the extra labor required, the expansion of a productive facility on new land takes time in which production is partly even impossible, etc. These "production detours" (Böhm - Bawerk, 1889; Hicks 1973) imply that a "production sacrifice" has to be made now, to be able to reach higher production in the future. These considerations lead us to the formulation of the following production function:

$$Y_t = f(K_t, L_t, A_t, I_t, H_t, E_t) \quad (1)$$

where

$f_K, f_L, f_A \geq 0$ and $f_I, f_H, f_E \leq 0$ (the $f_{K,L,\dots}$ denoting partial derivatives).

To simplify the analysis we will assume, that the productivity losses, due to changes in the productive capacity last only one period, i.e. Y_t does not depend on:

$$\int_{I_{t-\tau}}^{\tau} \int_{H_{t-\tau}}^{\tau} \int_{E_{t-\tau}}^{\tau}$$

Let us first look at the various investment possibilities of a firm located in region r at time t . The following table represents an overview of some initial conditions and strategies. K_t^{rr} represents the existing capital stock in the region r at time t . K_t^{rn} stands for the productive capital in region r owned by the firm resident in r . I_t^{rr} is the volume of investment goods placed in other regions at time t . All variables are measured in real terms.

Investment strategy	Capital stocks at the beginning of period t	Capital stock at the end of period t
<u>new investment:</u> $I_t^{rr} \geq 0, I_t^{rk} \geq 0$	$K_{t-1}^{rr} = 0, K_{t-1}^{rk} = 0$	$K_t^{rr} = I_t^{rk}; K_t^{rk} = I_t^{rk}$
<u>extension or reduction of present capacities:</u> $I_t^{rr} \geq 0, I_t^{rr} \leq 0$	$K_{t-1}^{rr} \geq 0, K_{t-1}^{rk} \geq 0$ (0 for at least one region)	$K_t^{rr} \text{ \& } K_t^{rk} \geq 0$
<u>relocation:</u> $I_t^{rr} \leq 0, i_t^{rr} = -K_{t-1}^{rr}$	$K_{t-1}^{rr} > 0, K_{t-1}^{nr} = 0$	$K_t^{rr} = 0; K_t^{nr} = i_t^{rn} \geq 0$
<u>closure:</u> $I_t^{rr} = -K_{t-1}^{rr} < 0$	$K_{t-1}^{rr} > 0$	$K_r^{rr} = 0$

If we let investment take on positive and negative values (disinvestment) all possible strategies are taken into account. Using an interregional accounting framework, we can keep track of all the investment expenditure originating in region r and indicate to which regions it goes (I_t^{rr} being the investment made in the home region).

from region r ,	1	3	3	...	r ...	total investment emanating from region r
to region .	I_t^{r1}	I_t^{r2}	I_t^{rr}	...	I_t^{rr}	$I_t^{r\cdot}$

Similarly we can construct an account of investments arriving in region r .

to region r	total investment arriving in r				
from region .	I_t^{1r}	I_t^{2r}	I_t^{3r}	...	I_t^{rr} ...
					$I_t^{\cdot r}$

Pooling this information for all regions yields an interregional investment flow table (similar to an input-output table, see e.g. Klaassen and Molle, 1981 a), on the level of the individual firms. We will make use of this accounting framework again when we turn to the macro economic situation.

Investment causes a change in the capital stock, i.e. the "internal production-conditions" of the firm are different now because of a decision taken in the past. The decision maker has to take dynamic stock-flow conditions into account:

The net change of the capital stock is equal to gross investment minus replacement. Assuming that capital depreciates at a constant rate δ and measuring time continuously we obtain:

$$\frac{dK_t^{rk}}{dt} = \dot{K}_t^{rk} = I_t^{rk} - \delta K_t^{rk} \quad (2)$$

(where k is the index set of all regions concerned).

To produce goods, labor and land are required besides capital (see (1)), hence analogous dynamic constraints have to be observed for labor and land as well:

- The net change of the labor employed is equal to the number of laborers hired and fired minus the number of laborers leaving the firm (because of retirement, change of job, accidents, etc.).

$$\dot{L}_t^{rk} = H_t^{rk} - \delta L_t^{rk} \quad (3)$$

where δ is the labor turnover rate.

Similarly we have that:

- The change of the land area required for production is equal to the additional land purchased ("expansion").

$$\dot{A}_t^{rk} = E_t^{rk} \quad (4)$$

At each period the potential investor has a certain budget (S_t^r) at his disposal which he can use for investment purposes. This amount can be used in different regions, the sum of all regional investments cannot exceed his total investment fund.

$$I_t^{r1} + I_t^{r2} + \dots + I_t^{rr} + \dots = \sum^k I_t^{rk} \leq S_t^r \quad (5)$$

To keep the analysis simple, we postulate that the labor turnover rate (δ) as well as the rate of capital depreciation (δ) do not vary over the regions.

2. 2. Revenues, costs and profits.

Profits at each period of time (π_t) are defined as revenues minus costs.

As we are only considering a one-product firm, which can sell its single products at a given price p_t^r , total revenue from the sales of the goods produced in several regions are:

$$\pi_t = p_t^1 y_t^{r1} + p_t^2 y_t^{r2} + \dots + p_t^r y_t^{rr} + \dots = \sum_k p_t^k y_t^{rk}, \quad (6)$$

where y_t^{rk} represents the production volume of a firm located in k and controlled from r .

The price level p_t^r signalizes the demand for the product to the multiregional firm. It depends on the disposable income in the region r as well as a part of the demand arising for this product in other regions into which it is imported. We will turn to this question in more detail in the "macro-approach" section, below.

Expenditures have to be made to pay for the factors used in the production process, the sum of which yields the total cost. Let us start with capital and investment expenditures. Investment goods are usually bought in a very large market (the world or the national market) in which prices are usually very uniform. We suppose then, that the aggregate investment good I_t can be purchased at a uniform price q_t . This implies a total sum to be spent for investments located in several regions, the amount of which is:

$$\begin{aligned} \text{Total investment goods' cost} &= q_t (I_t^{r1} + I_t^{r2} + \\ &\dots) = q_t \sum_k I_t^{rk} \end{aligned} \quad (7)$$

For the already existing capital stock at time t opportunity costs have to be considered (or if the money was all borrowed, debts have to be paid back). Let the interest rate (r_t) again be uniform over the national system, thus implying that the financial markets in a country are "regionally integrated". (This assumption further means that money capital is perfectly mobile in a national economic system). The multi-regional firm then encounters total capital costs of:

$$\begin{aligned} \text{Total capital cost} &= r_t q_t (K_t^{r1} + K_t^{r2} + K_t^{r3} + \\ &\dots + K_t^{rr} + \dots) = r_t q_t \sum_k K_t^{rk} \end{aligned} \quad (8)$$

Besides these "direct costs", there are the indirect costs of transferring investment to other locations and the transaction costs of

investment in general.

There are many components of these costs, let us just mention a few, such as the cost of information, which especially for a new investment in a different region, can be quite substantial. Empirical studies, based on surveys (Klaassen & Molle 1981) have shown, that for this reason only very few locations are investigated closer to check whether an investment there would be worth while. In the case of a relocation there are the costs of the physical transfer to be reckoned with, etc. We postulate hence, that the total transaction costs of investment is positively related to the total volume of the investment and to the distance of the region of destination from the region of origin.

$$\begin{aligned} \text{Transaction cost of investment} &= TA(I_t^{rk}, d_t^{rk}) \\ &+ TA(I_t^{r2}, d_t^{r2}) + \dots + TA(I_t^{rr}) + \dots = \\ \sum^k TA(I_t^{rk}, d_t^{rk}); (TA_{I_t^{rk}}, TA_{d_t^{rk}} \geq 0) \end{aligned} \quad (9)$$

New labor often has to be trained to acquire the necessary skills, there are filing fees, social security expenses, etc. (Scanlon and Holt, 1977). To keep the model as simple as possible, these costs are the same for hiring and for firing (with a negative sign), i.e. savings of the same amount will accrue (which in reality is usually not the case).

$$\begin{aligned} \text{Sum of wages} &= W_t^{1r1} L_t^{r1} + W_t^{2r2} L_t^{r2} + \dots W_t^{rrr} L_t^{rr} + \dots = \\ &\sum^k W_t^{rk} L_t^{rk} \end{aligned} \quad (10)$$

$$\begin{aligned} \text{Frictional cost} &= C(H_t^{r1}) + C(H_t^{r2}) + \dots C(H_t^{rr}) \\ &+ \dots = \sum^k C(H_t^{rk}) \end{aligned}$$

The land required for production causes 2 types of cost, the opportunity cost for holding land (like for a capital asset), which again we set equal to the current market rate of interest (r_t) and the sum to be paid for the extra land acquired (l_t^k being the land price).

$$\begin{aligned} \text{Total land cost} &= r_t (l_t^1 A_t^{r1} + l_t^2 A_t^{r2} + \dots l_t^r A_t^{rr} \\ &+ \dots) + l_t^1 E_t^{r1} + l_t^2 E_t^{r2} + \dots l_t^r E_t^{rr} + \dots = \\ &r_t \sum^k l_t^k A_t^{rk} + \sum^k l_t^k E_t^{rk}. \end{aligned} \quad (11)$$

Collecting terms, we can now compute the total profit of a multi-regional firm at time t .

$$\begin{aligned} \pi_t^r &= \sum^k (p_t^k Y_t^{rk}) - q_t \sum^k I_t^{rk} - r_t q_t \sum^k K_t^{rk} - \\ &\sum^k TA^k(I_t^{rk}, d_t^{rk}) - \sum^k W_t^{rk} L_t^{rk} - \\ &\sum^k C^k(H_t^{rk}) - r_t \sum^k l_t^k A_t^{rk} + \sum^k l_t^k E_t^{rk} \end{aligned} \quad (12)$$

2.3. The changes in demand for capital and labor.

Given all the constraints, costs and dynamic consequences of investment decisions the decision maker has to make a careful cost-benefit analysis to find out how much, where and when he should invest. What criterion should he use to judge whether any of the strategies mentioned above seems worth while and which one, or what mixture thereof he should choose? Maximizing the profits at time t only would result in a policy of no change at all, as there would

only be losses in the period he takes the action in, the "detours" pay off only in the long run, so future profits have to be taken into account. But future profits are highly uncertain, so they are worth less now and should be discounted. Let ρ be the rate of discount of future earnings, so that the present value (V_t) of the expected profits is:

$$V_t = \int_0^T e^{-\rho t} \pi_t dt,$$
 where T represents the planning horizon of the decision maker.

This present value then represents the "spatial welfare function" of a multiregional firm mentioned in section 1. Note that all the prices and costs for all future periods have now become uncertain and perfect information about them is not available - so that all these variables have to be interpreted as expected values. Further we notice that this cost-benefit analysis is made in each period, and plans are revised and new ones made as expectations about the future and information about alternative locations change. What we want to model then is, how investment and location plans come about and what the determinants of changes in the levels of investment and labor demand in different regions are. Furthermore we want to demonstrate that the demand for capital, labor and land is planned simultaneously and that one is dependent upon the other. The production and investment plans we try to determine in this analysis will contain the optimal levels of investment in different regions and simultaneously, the demand for labor and land by a multiregional firm. (The demand for land will not be analysed in detail in the framework of this paper). The variables the decision maker can control in each period of time are investment (I_t^{rk}), hiring and firing (H_t^{rk}), land acquisition (E_t^{rk}) and the volume of production (Y_t^{rk}). The stock variables K_t^{rk} , L_t^{rk} and A_t^{rk} are the consequences of his past decisions, they represent the state variables.

The question then is, what levels of the control variables have to be realized in a given period to maximize the present value of the expected future profits arising from these controls.

To solve this kind of cost-benefit analysis we will make use of optimal control theory and the Pontryagin Principle (Pontryagin et al., 1962).

Let us first write out this cost-benefit analysis as an optimal control problem:

$$\text{Maximize } V_t = \int_0^T e^{-\rho t} \pi_t dt \quad (\text{see Equation 12}),$$

given the following constraints: $y_t^{rk} = f^k(K_t^{rk}, L_t^{rk}, A_t^{rk}, I_t^{rk}, H_t^{rk}, E_t^{rk})$ (see (1))

$$\dot{K}_t^{rk} = I_t^{rk} - \delta K_t^{rk} \quad (\text{see (2) })$$

$$\dot{L}_t^{rk} = H_t^{rk} - \delta L_t^{rk} \quad (\text{see (3) })$$

$$\dot{A}_t^{rk} = E_t^{rk} \quad (\text{see (4) })$$

$$\sum^k I_t^{rk} \leq S_t^r \quad (\text{see (5) })$$

$$K_t^{rk} \geq 0$$

$$L_t^{rk} \geq 0$$

$$A_t^{rk} \geq 0$$

$$y_t^{rrt} \geq 0$$

The control variables I_t^{rk} , H_t^{rk} and E_t^{rk} can be positive or negative, the production volume cannot become negative.

The stock variables K_t^{rk} , L_t^{rk} & A_t^{rk} cannot become negative, either. For simplicity's sake we let $T \rightarrow \infty$.

The Pontryagin Principle applied to an economic problem (Arrow,

1968) applied to this problem, states:

(a) the sum of the marginal effects of a change in the control variables has to be equal to the scarcity prices (λ^k, ψ) of the relevant stock variable at each period (control conditions), where the scarcity price measures the marginal contribution of the relevant stock variable of the present value.

$$-q_t - TA_{I_t}^{rk} + p_t^k f_{I_t}^{rk} + (\lambda_t^k + \psi_t) = 0, \quad (13)$$

where λ^k is the "shadow price" of capital in region k and ψ is the "shadow price" of the investment budget available.

$$\text{Further: } -w_t^k - c_{H_t}^{rk} + p_t^k f_{H_t}^{rk} + \mu_t^k = 0 \quad (14)$$

where μ_t^k is the "shadow price" of labor, and

$$-l_t^k + p_t^k f_{E_t}^{rk} + \phi_t^k = 0; \quad (15)$$

where ϕ_t^k signals the scarcity of land in region k .

(b) As stocks accumulate (or diminish), their scarcities change, so do, hence, their shadow prices. One part of this change is caused by discounting the future, the second part consists of the gap between marginal costs and revenues caused by a change in the stocks³).

$$\dot{\lambda}^k = \rho \lambda_t^k + r_t q_t + \lambda_t^k \delta - p_t^k f_{K_t}^{rk} \quad (16)$$

$$\dot{\mu}^k = \rho \mu_t^k + w_t^k + \mu_t^k - p_t^k f_{L_t}^{rk} \quad (17)$$

$$\dot{\phi}^k = \rho \phi_t^k + l_t^k (1+r_t) - p_t^k f_{A_t}^{rk} \quad (18)$$

Given "well-behaved" problems, (for a discussion of second order conditions and stability see: Brock and Scheinkman, 1977), following these rules will lead to optimal production, location, investment, etc. plans. The indicated rules represent a system of simultaneous equations

which, in principle, can be solved to yield the optimal levels of I_t , H_t & E_t in all locations.

Let us next look at the nature of the solution. To do so, we first compute the total "shadow cost" of stock changes in one region, i.e.

$$\lambda_t^k + \mu_t^k + \phi_t^k = (l_t^k + w_t^k) + q_t + p_t^k (f_{I_t^{rk}} + f_{H_t^{rk}} + f_{E_t^{rk}}) - \psi_t + (TA_{I_t^{rk}} + C_{H_t^{rk}}) \text{ from (13) (14) (15)}$$

Let us next compare these total shadow costs between 2 regions, the region of origin r and destination k .

$$\begin{aligned} (\lambda_t^r - \lambda_t^k) + (\mu_t^r - \mu_t^k) + (\phi_t^r - \phi_t^k) = \\ (l_t^r - l_t^k) + (w_t^r - w_t^k) + \left[p^r (f_{I_t^{rr}} + f_{H_t^{rr}} + f_{E_t^{rr}}) - p^k (f_{I_t^{rk}} + f_{H_t^{rk}} + f_{E_t^{rk}}) \right] + (TA_{I_t^{rk}} - TA_{I_t^{rk}}) + \\ (C_{H_t^{rr}} + C_{H_t^{rk}}) \end{aligned} \quad (19)$$

Similarly we can compare the changes in these differences in the shadow costs:

$$(\dot{\lambda}^r - \dot{\lambda}^k) + (\dot{\mu}^r - \dot{\mu}^k) + (\dot{\phi}^r - \dot{\phi}^k) = \quad (20)$$

$$(\rho + \delta) (\lambda_t^r - \lambda_t^k) - (p_t^r f_{K_t^{rr}} - p_t^k f_{K_t^{rk}}) +$$

$$(\rho + \delta) (\mu_t^r - \mu_t^k) + (w_t^r - w_t^k) +$$

$$(p_t^r f_{L_t^{rr}} - p_t^k f_{L_t^{rk}}) + \rho (\phi_t^r - \phi_t^k) +$$

$$(1 + r_t)(l_t^r - l_t^k) - (p_t^r f_{A_t^{rr}} - p_t^k f_{A_t^{rk}})$$

(from (16), (17) & (18)).

To simplify, let Δ stand for the difference between the levels of a variable in region r and k . If we now combine the information

in (19) & (20) we arrive at the following expression:

$$(\Delta \dot{I} - (1+r + \rho) \Delta I) + (\Delta \dot{W} - (\rho + \gamma + 1) \Delta W) + \quad (21)$$

$$\Delta(p f_K) + \Delta(p f_L) + \Delta(p f_A) = \Delta \dot{T}A + (\rho + \delta) \Delta T A -$$

$$\Delta(\dot{p} f_I) - \Delta(p \dot{f}_I) + (\rho + \delta) \Delta(p f_I) - \Delta \dot{C}_H +$$

$$(\rho + \gamma) \Delta C_H$$

- (see appendix A).

The right hand side of this equation contains terms in investment and hiring and firing flows.⁴⁾ This equation can in principle be solved for these variables. A few general remarks about these solutions can be made.

- There is a functional dependence between the demand for investment and hiring and firing.

- Regional differences in the current values of goods and land prices, wages, different productivities as well as the changes in the expected price variables play a role in the determination of investment and employment plans

- as investment (and hiring and firing) at time t also depends on the change of investment, cyclical behaviour is possible (second order differential equations).

In order to be able to attempt an empirical test of the claims just made, further, more specific assumptions have to be made.

2.4. Functional forms and further restrictions.

Let us first postulate that the production function can be divided into two components, a positive and a negative part, the former being defined on the set of stocks, the latter on the flows. To simplify even further, suppose the frictions leading to losses in production are directly proportional to the level of the change of the production

factors.

$$y_t^k = F(K_t^{rk}, L_t^{rk}, A_t^{rk}) - a(I_t^{rk} + H_t^{rk} + E_t^{rk}) \quad (22)$$

in this special case the marginal frictions are constant and the same for all flows, i.e. equal to $-a$. As this is a constant, the change over time equals zero.

$$(f_{I_t^{rk}} = f_{H_t^{rk}} = f_{E_t^{rk}} = -a \text{ \& } \dot{f}_{I_t^{rk}}, \dot{f}_{H_t^{rk}} = \dot{f}_{E_t^{rk}} = 0).$$

Let the transaction costs of changing the capital stock be the square of the volume of investment and multiplicatively related to the distance between the region of origin and destination of a capital transfer. To facilitate the analysis we also postulate that these costs are always equally high, independent of whether it's the first investment in a new region or a subsequent one, which is certainly only an exception).

$$TA(I_t^{rk}, d^{rk}) = b(I_t^{rk})^2 g(d^{rk}). \quad (23)$$

As mentioned above $d^{rr} = 0$, in this case let $g(0) = 1$.

The costs of changing the labor force change with the square of the level of change.

$$C(H_t^{rk}) = c(H_t^{rk})^2, \text{ hence } C_{H^{rk}} = 2cH_t^{rk} \quad (24)$$

Taking into account all these restrictions, (21) can be rewritten to yield (leaving out the time subscripts):

$$\begin{aligned} x^{rk} = & (\Delta \dot{I} - (1+r+\rho)\Delta I) + (\Delta \dot{W} - (\rho+\mu+1)\Delta W) - \\ & a\Delta(\dot{p}) + a(\rho+\delta)\Delta(p) + \Delta(pf_K) + \Delta(pf_L) + \\ & \Delta(pf_A) - 2c\Delta \dot{H} + 2c(\rho+\mu+1)\Delta H - 2b(\dot{I}^{rr} - \dot{I}^{rk}g \\ & (d^{rk})) = 2b(\rho+\delta)I^{rr} - \left[2b(\rho+\delta)g(d^{rk}) + k\frac{\partial g}{\partial d^{rk}} \cdot g(d^{rk}) \right] I^{rk} \\ & = B^{rr}I^{rr} - B^{rk}I^{rk} \end{aligned} \quad (25)$$

We have not yet utilized the constraint (5), indicating that the sum of all investments emanating from region r cannot exceed the investment fund available in r (if budgets are restrictive, this constraint will hold with an equality).

It can be shown (see appendix B), that the simultaneous system of equations

$$\begin{aligned} x^{rk} &= B^{rr} I^{rr} - B^{rk} I^{rk} \text{ and} \\ s^k &= \sum_r I^{rk}, \end{aligned} \quad (26)$$

These solutions will have the same features as mentioned above (i.e. regional differences count etc.) in addition it can be shown that the investment funds available in the region of origin have an influence on the level of those investments. It is also obvious from (24) that investment location will be inversely related to the distance between the region of origin and destination. If this distance is measured in travel time or in "mental maps", then accessibility can change, and this change will also matter.

3. From the individual investor to regional investment.

3.1. Aggregation and interregional accounts.

What is the total volume invested in each region and how much labor is demanded?

To answer this question, we must turn to the accounting framework mentioned above. The following table records all investments made by all the firms in a region. Summing up along the rows of this matrix yields all investments emanating from a given region, summing along the columns shows all the "arrivals" in a region. Leaving out time subscripts and adding a firm index (n) left of the variable name results in the following table 1.

regions	1	2	..etc.	Total investment emanating from region r by firm n
	firms	firms		
	1_{I11} 2_{I11} \vdots n_{I11}	1_{I12} 2_{I12} \vdots n_{I12}		$\sum_k 1_{I1k}$ $\sum_k 2_{I1k}$ \vdots $\sum_k n_{I1k}$
sum over firms	$\sum n_{I11} = I^1$	$\sum n_{I12}$		$\sum_k \sum n_{I1k}$
2	1_{I21} 2_{I21} \vdots n_{I21}	1_{I22} 2_{I22} \vdots n_{I22}		$\sum_k 1_{I2k}$ $\sum_k 2_{I2k}$ \vdots $\sum_k n_{I2k}$
sum over firms	$\sum n_{I21} = I^2$	$\sum n_{I22} = I^2$		$\sum_k \sum n_{I2k}$
etc.				
total investm. arriving in region k	by firm $\sum_k 1_{I k1} \dots \sum_k n_{I k1}$ $\sum_k 1_{I k2} \dots \sum_k n_{I k2}$			Total investment (over all regions and firms).
	over all firms $\sum_k I^{k1} = I^1$ $\sum_k I^{k2} = I^2$			

Table 1: Interregional Investment Flows.

Aggregation can, of course, follow different lines. We could aggregate firms belonging to specific economic sectors, where the decision problem is fairly homogeneous, i.e. the relevant prices, costs and technologies are more or less the same. As an econometric analysis on the regional sectoral level is, at least at the moment, not possible, the aggregation is over all firms belonging to the industrial sector.

Can we now use the micro model developed in the previous section to determine which changes in the regional system will cause changes in the investment activities of a region?

Aggregating the volumes of investment in a given region over all firms is feasible - the aggregation of the right hand side (see (24)) poses more problems. We will not go into the details of this aggregation problem, which can generally only be solved under very special circumstances (see e.g. Green, 1964); let us suppose a consistent aggregation function can be found to be able to proceed with the analysis.

On the aggregate, regional level we expect investment expenditures in a given region to be the sum over all investments arriving in the region (leaving out time subscripts), i.e.:

$$I^k = I^{1k} + I^{2k} + \dots I^{kk} + \dots \quad (27)$$

Each of these investment flows (I^{rk}) can then be shown to depend on the differences ("push and pull" factors) in the regional characteristics, the total investment fund available in the region of origin, labor demand as well as the distance between the regions. (Appendix C shows how the information in (24), (25) and (26) as well as the assumption of the existence of a consistent aggregation function can be utilized to arrive at regional, macro-economic investment and labor demand functions).

$$I^r = A_0 + \vec{A}_1 \left(\sum^k \vec{x}^{rk} \cdot \frac{1}{h(g(d^{rk}))} \right) + A_2 \sum^k (s^k \frac{1}{h(g(d^{rk}))}) \quad (28)$$

$$i_{LD}^r = B_0 + \vec{B}_1 \left(\sum^k \vec{x}^{rk} \cdot \frac{1}{s(g(d^{rk}))} \right) + B_2 \sum^k (s^k \frac{1}{s(g(d^{rk}))})$$

where \vec{A}_1 , \vec{B}_1 and \vec{x}^{rk} are vectors, the latter containing the differences of regional characteristics;

i_{LD}^r is the labor demand in region r , by qualification i and I^r the regional investment level.

As outlined in section 1, decision makers have to change their plans when the variables affecting their "welfare levels" alter. This, of course, is always the case in a dynamic process like economic and urban development. As mentioned above, the very actions taken by the various decision makers in one period, change their "environment" in the next period, so that a continuous revision of plans becomes necessary.

How will changes in the determining factors affect the volume of investment and labor demand? Given the assumptions of the decision model most of these sensitivities are intuitively obvious.

Is it possible to test the empirical validity of the hypotheses by using statistical evidence? It is this question to which we turn in the next section.

4. A testable, econometric model of regional investment and labor demand.

4.1. Data and their limitations.

The most important data source for the empirical analysis are the annual surveys on a sample basis of the chambers of commerce (collected since 1972). Information on wages - by several qualification categories, employment - for the same qualifications, total production - in value terms, and gross investment expenditures. The 1971 census provided us with data on population density and total area by county.

The average travel times between the regions were taken from a study by Stöhr and Tödtling (1981).

4.2. Towards and operational model.³⁾

Unfortunately a straight-forward estimation of the parameters of (28) were not possible for several reasons.

- (a) Data for all the variables were not available, so some proxies had to be found or the variable had to be skipped.
- (b) The comparatively small number of observations (17 urban counties, 20 suburban counties) limited the sheer number of variables to be used in the regressions.
- (c) Some of the functional forms derived in the theoretical model were intractable from the estimation point of view and hence had to be simplified.
- (d) Econometric problems (e.g. multicollinearity, etc.) led to slight changes in the model specification.

The results reported in the next section are thus only of a very tentative nature, further work in this respect would be highly beneficial.

Let us next briefly discuss some of the steps towards a model specification that could be used for a regression analysis. To reduce the number of variables we first had to leave out all the dynamic changes in (28), such as differences in the change of price differences, investment changes, etc. This decision was made, as these changes could not be computed for all of them, due to the lack of data.

Let us first turn to the price variables.

- No information was available on the county basis on "average" land prices. As these magnitudes are clearly related to the density of urban land use (e.g. Alonso, 1964), the 1971 population density figures were used as a proxy.

- Wage rates for several labor qualification categories were available. Aggregation into 2 groups, i.e. graduates of obligatory and vocational schools (blue collar workers) and high school and university graduates (white collar workers) became necessary, as the number of variables in the regression had to be limited.
- No figures on regional prices for goods were at our disposal, so a different approach was taken.

Consider a demand function for goods:

$$P_t = p(Y_t, DY_t)$$

where p_t ... price of the good,

Y_t ... quantity demanded

DY_t ... disposable income.

At the regional scale, the total quantity sold is divided into the regional sales and exports. Both of these components depend on the income in the regions concerned. We further hypothesized that the expected value of the volume of sales to other regions decays with distance from the producing region, so that income in more remote regions turns less into effective demand for the goods produced in the region r . Unfortunately data of regional incomes on the county level do not exist, only production values, so these were used in the computations of the "regional income potentials", which were used instead of prices in the regressions.

- The value of the marginal products of the production factors were replaced by the average products. In the case of the two labor productivities the regional net production values were divided by the number of persons employed in the region.
- To find at least an approximation for the value of the marginal product of capital, the regional investments from 1971 to 1975 were discounted (using the same method and discount rates as Prucha, 1978, for the estimation of the national capital stock)

and summed. Again the value of the average production was computed by dividing the GRP by this quasi-capital stock. The land productivity figures were obtained by dividing the GRP by the land areas of the urban and suburban counties.

- As no data on regional investment funds are available, we assumed that they are proportional to the GRP and hence used this variable in the regressions (as was to be expected, there was high colinearity between this variable and the "regional price" variable, so that only one of them - the "price" variable, was finally used).

As a next step the matrix of pairwise regional differences in these variables was calculated. These differences should then be weighted by a term containing the distance - measured in travel time - (taken from Stöhr and Tödtling, 1981) and its change over time (as mentioned above, the change over time-terms in equation (28) had to be skipped). These weighted differences have to be summed over the regions, see (26). The parameters of this weighting function should be estimated in the regressions. As this non linear estimation problem poses several problems we took a slightly different route.

A priori weights in the distance-decay function were varied in a computer program for the calculation of "potentials" and these "regional difference potentials" were tried in the regressions, the best results decided which weights were finally chosen. For all variables, except the "income potential" high distance elasticities yielded the best fits - as was to be expected for a cross-section taken in the suburbanization phase.

- Another specification problem arises with the "regional differences in hiring and firing" (see equation (21)), as there are no observations on this variable as such. Only total employment can

be found in the statistics. (For the relation between these two variables, see (3)).

We were interested to what extent the parameters between urban cores and rings differed, in 1975, the year for which cross-section information was available, it was the rings of the agglomerations that had become the dynamic regions of industrial activity due to the suburbanisation of manufacturing firms. The following table gives an overview of the regression results. (The adjusted R^2 were all over 0.9, the values in parentheses are the t-values). The independent variables listed under (a) are the potentials of the pairwise regional differences of these variables (PD). (See table 2).

It should be mentioned, that in some regressions the land price difference potential proxy was significant, but these parameters were highly unstable, so they were finally left out. This is particularly regrettable as case studies on the micro scale have shown the importance of differences in land prices and entrepreneurial relocation decisions.

Similarly the wage rate differences potentials turned out to be significant in some runs but due to the parameter instability they were finally discarded.

A few general remarks should be made first. The investment Equations come fairly close to the theoretically derived form. The land productivity variable turned out to be insignificant in most runs, this being perhaps due to the use of the total area of the county in the denominator, instead of only the area used for manufacturing purposes - but these figures were not available for all counties concerned. Similarly the "regional price" variable proxies were apparently too far away from the original idea, this parameters were highly unstable. The orders of magnitude of most

Variables: dependent	Investment		demand for blue collar workers		demand for white collar workers	
	core	ring	core	ring	core	ring
(a) PD: capital: productivity	-9.2332E+4 (-4.21)	-1.7700E+4 (-1.03)	1050.9 (7.36)	75608 (4.70)	823.2 (4.85)	252.3 (4.79)
blue-collar workers: productivity	-22.60 (-1.02)	-18.83 (-4.18)	-4.56 (3.77)	-2.95 (-7.14)		
white-collar workers: productivity	443.71 (1.71)	248.06 (7.10)			0.358 (1.97)	-0.0045 (-3.1)
land: productivity			-1.10E-2 (-7.46)	-7.136E-3 (-1.73)		
wages of blue collar workers	8629.0 (2.39)	2912.4 (1.71)				
wages of white collar workers	6234.9 (2.41)	731.1 (1.08)				
"land prices" "incomes"	-0.103 (-3.14)	-7.04E-3 (-0.68)	2.90E-4 (6.79)	1.18E-4 (3.15)	4.390E-3 (4.05)	1.356E-4 (0.95)
employment: blue-collar workers	74.84 (3.92)	11.14 (2.91)			-0.15 (-4.25)	1.667E-3 (0.62)
employment: white collar workers	74.84 (3.92)	-36.82 (-3.8)				
(b) invest- ment			7.62E-3 (4.22)	1.28E-2 (7.88)	7.03E-3 (3.96)	1.831E-3 (3.89)
constant	3.45791E+5 (3.15)	1.96734E+5 (5.72)	3.954E+3 (4.94)	1.705E+3 (2.67)	7.03E-3 (-1.11)	5.61E+2 (3.85)

Table 2: Some regression results

of the parameters in urban core and ring areas are more or less the same, although there are differences.

The labor demand equations contain a smaller set of significant variables than the investment equation. The mutual dependence between different qualification levels it seems is a one way street, the demand for blue collar workers, does not depend on any variable pertaining directly to the group of white collar workers. The dependence of labor demand on investment and the capital productivity variable is highly significant. Higher investment has a positive effect (capital widening?) on the collar worker demand in cores and rings.

The demand for white collar workers does depend on the demand for blue collar workers, at least in the core areas of urban agglomerations. Again productivity differences play an important role in the labor demand decisions.

Concluding one can say that the empirical evidence presented is, due to the data deficiencies and the estimation problems encountered, not to be taken as a very strong argument in favor of the theoretical concept. We feel, however, that after experimenting with the Austrian data using some of the more common specifications encountered in the literature (see section 1), the approach just outlined fares rather well.

Footnotes

- 1) The author thanks P. Hampapa for being able to use parts of an earlier version of this paper. G. Maier's, J. Baumann's and P. Hampapa's help with the empirical work are gratefully acknowledged. Comments by C. Bartels, P. Nijkamp, L. Hordijk, J. Paelinck, A. Anderson, J. Parr, W. Blaas, D. Keil, M. Luptacik, G. Feichtinger, R. Drewett and W. Stöhr helped to improve the present paper. Unfortunately the author is still responsible for all the remaining flaws and errors.
- 2) This assumption implies a neglect of the "Weberian" type of location problem, focusing on the question of industry is to be placed where? It is only the total productive capacity of the region which is considered here.
- 3) This research was supported by the Austrian Fund for the Advancement of Scientific Research ("Forschungsförderungsfonds"). It was carried out in the framework of an interregional labor market study of Austria.

Appendix A

Equation (20) contains the differences in the values of the co-state variables λ , μ and ϕ . We can now use the "control variable optimality conditions" (13), (14) and (15) to substitute. After some simple transformation we obtain equation (21).

Appendix B

The system of simultaneous equations in (26) has the following structure:

$$\begin{bmatrix} B^{11} - B^{12} & 0 & \dots \\ B^{11} & 0 - B^{13} & 0 \\ B^{11} & 0 & 0 - B^{14} & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 1 & 1 & \dots \end{bmatrix} \begin{bmatrix} I^{11} \\ I^{12} \\ I^{13} \\ \vdots \end{bmatrix} = \begin{bmatrix} X^{12} \\ X^{13} \\ X^{14} \\ \vdots \\ S^1 \end{bmatrix} \quad \text{etc.}$$

The coefficient matrix can be shown to have a non-vanishing determinant.

The coefficients B^{rk} contain the weighting functions defined on the distance between r and k .

Appendix C

In (27) we can substitute for the I^{rk} using (24), (25) and (26). As the B^{rk} in (25) contain the distance weight function multiplicatively (see (23)), we have to multiply X^{rk} in (25) by a function of the inverse of $g(d^{rk})$.

(27) tells us to sum over the I^{rk} , thus we arrive at a weighted sum of the regional differences in profit relevant characteristics, as well as the differences in the levels of regional hiring and firing, again weighted, by an inverse function of distance. This formulation is very similar to the concept of a "potential" in regional science.

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