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An *n*-Sector Migration Simulation

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An n-Sector Migration Simulation

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Abstract

Workers, considering costs of migration, tend to migrate to sectors where they expect higher wages. In revers, firms trying to increase profits, migrate to sectors with lower wages. The result of their combined movement will determine wages in each sector. This inductive behavior model with various strategies for wage expectations yields patterns of migration in an n-sectors scenario.

Starting with a note on migration, this work analyses three influential papers on migration[1] and one on firm development[2]. It concludes with an agent based n-Sector Migration Simulation encapsulating ideas, concepts and approaches of stated papers.

[1] *Migration, Unemployment and Development: A Two-Sector Analysis* by Harris, Todaro; *The Costs and Returns of Human Migration* by Larry A. Sjaastad; *Potential Migration from Central and Eastern Europe into the EU-15 - An Update* by Brücker, Alavarez-Plata, Siliverstovs

[2] *The Emergence of Firms in a Population of Agents: Local Increasing Returns, Unstable Nash Equilibria, And Power Law Size Distributions* by Robert Axtell

Contents

1 Migration

1.1 Migration in 60,000 BCE

Human migrants started around sixty thousand years ago in Africa. Environmental changed vegetation and forced animals and the homo sapiens who feed on them to migrate. [Chan07]

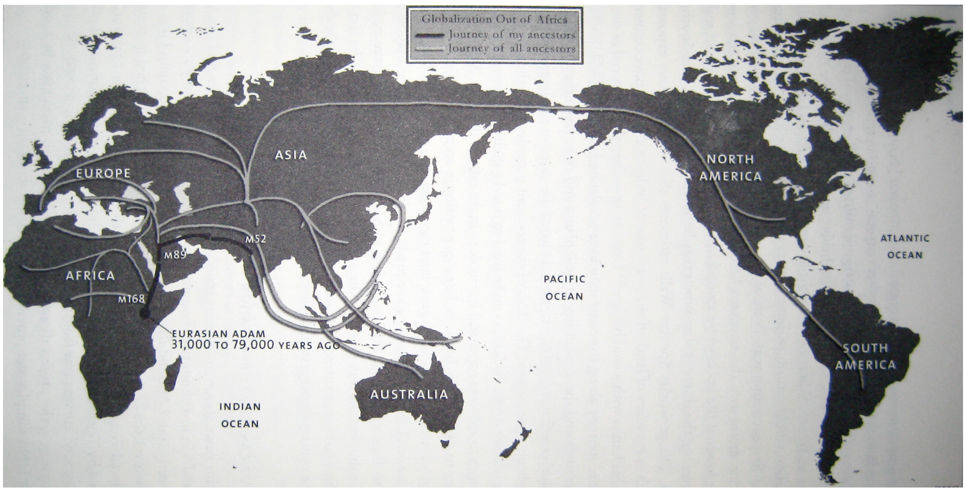

Figure 1: Out of Africa by the Genographic Project 2006

A global DNA survey by Genebase Systems tracked our ancestors and their early paths of migration. Starting in Africa our ancestors first moved to Central and Eastern Asia. From there over tausands of years the human species spread to Europe, Sibiria, North and than South America. Within fifty thausand years all five continents were occupied by humans.

Sixtythousand years, i.e. a snapshot in evolutionary terms, hardly changed our DNA, evolution slightly adopted skin color and body size to account for differences in temperature and sun exposer in various regions. But underneath we are all distant relatives. *Vasudhaiva kutumbakam*, "The whole world is a family." This aphorism from the Indian Panchatantra is worth keeping in mind while tinkering with migration.

The recent *International Migration Outlook* [OECD07] placed the number of foreign born, i.e. immigrants, at 200m world wide (that's legal plus an "educated guess" on illegal immigration). That sounds a lot, but it is really only 3% of the world population.

The reasons for people to migrate hardly changed since our great great ancestors left Africa to follow their supply of food. Resources and security still dominate migration today.

1.2 Motives for Migration

Formally we can identify three key motives for migration:

First, refugees and asylum seekers, defined as those escaping prosecution but often including anybody forced to flee, for example from a war.

Second, often underestimated, family reunification. One example can be seen in the data of US legal migration in 2005: Half of all legal US immigrants claimed to have relatives in the US.

And third and most prominently those who seek an (economically) better life.

As long as moving from a poor country to a rich one will increase income fivefold [Survey on Migration]. This motivator will persist.

The search for opportunities and prosperity is hands down the strongest force of migration. This thesis will focus on this economic motivator of migration.

It is generally the case (and data [OECD07] proves it) that young adults are most likely to migrate. They have a higher expected lifetime income differential than their older peers. The boundary with their home country is not yet as strong. Plus, they may be able to offer their children better opportunities as well.

1.3 Politics of Migration

Thru-out history migration resulted in wars and fights over territorial domination. More recently opinions against migration (particularly immigration) are driven by populist politicians trying to identify scapegoats for economic miseries.

While borders my fall inside the European Union, borders are rising on the outside. The political force almost universally, it seems, is to close borders and stop immigration.

Ironically, those countries who would benefit most from young working immigrants, i.e. aging countries like Japan and most of central Europe, are those who oppose it the most. Not everyone is opposed, but enough to drive politics in the direction of more selective immigration laws or in extreme cases outright opposal of everything foreign.

Many politicians who inveighed against immigration now get closer to political power. In France Jean Marie Le Pen in 2002 run an anti-immigration campaign and reached the run-off stage of the presidential election. Running an election campaign based on comments against immigrants, Jörg Haider's far-right party FPÖ joined a coalition government in Austria in 2000.

Both events steered controversy in and beyond Europe. Not so today, when hostility to immigration is spreading all over Europe. Britain's Gordon Brown asks for "British jobs for British workers", Nicolas Sarkozy follows Le Pen in his arguments to save jobs for the french. Across the Atlantic, the 2008 presidential election candidates talk about ever increasing border controls and cracking down on illegal immigration. No debate without clapping down on migrants stealing jobs from native Americans.

What is it that drives natives to oppose immigration? First it helps to group natives by income. Those well-off seem in general to benefit more from cheap labor provided by immigrants, while the poor feel the wage pressure particularly for low skill employment.

A second worry is that migrants will put a strain on public services and the tax system. Locals complain if clinics and schools are overloaded. Although migrants often make a large contribution to the public purse. When a foreign worker arrives, dominantly as a young adult, fully educated and in good health, he makes few demands on schools or clinics. If allowed (i.e. he is a legal immigrant) he will pay taxes on his income. Even illegal immigrants will contribute by paying value added tax on their consumption.

Immigrants as a whole, in the long term and counting the contributions of their children when they grow up and get jobs, are not a drain on public services. For rich countries with aging workforces in particular, gains from importing the young, the energetic and those willing to take risks comfortably outweigh the cost.

1.4 Emigration and Immigration

Migration always has two sides. To immigrate in one country one first has to emigrate from another. Ruffle 10% of the United Kingdom's population is foreign born. On the other hand, about 10% of UK born folks currently

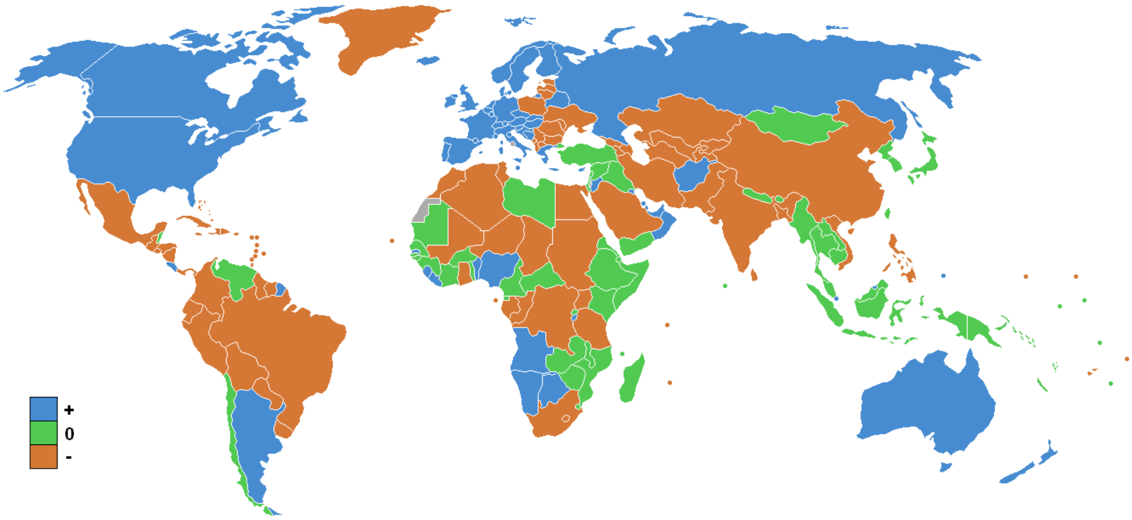

Figure 2: Net World Migration Rate: Immigration (+), Emigration (-) based on CIA factbook data, April 2006

life outside the UK.

On average, of course, the number of immigration equals the number of emigrants world wide. However, when a fast majority is leaving one place to migrate to another. Problems occur. On both sides (although the source country usually already has problems to cause emigration in the first place).

Benefits of Immigration

- Jobs: Frequently economic immigrants are highly motivated, entrepreneurial, go getters (after all, they made the jump). About a quarter of Silicon Valley's IT companies are founded by Chinese or Indian immigrants. Among them such as Sun Microsystems, Intel and Google. Bill Gates calculates, and respectable economists agree, that every foreigner who is given an H1B visa for America creates jobs for five regular Americans [Econ08].
- Talent: 40% of American PhDs in science and engineering go to immigrants. 70 of the 300 Americans who have won Nobel prizes since 1901 were immigrants [Econ08].
- Additonal tax income from legally employed immigrants.
- GDP growth, albeit not necessarily on a per capita bases.

Drawbacks of Immigration

- Lower wages for some native workers (less so in the long term).

Benefits of Emigration

- Higher wages for staying natives (less so in the long term).
- Remittance payments to poor or developing countries ($301.4bn worldwide in 2006 [IFAD06]).
- Back-flow of knowledge and business opportunities [BoST05].

Drawbacks of Emigration for source country Brain drain, the emigration of trained and talented individuals. Sometimes this "drain" can be offset by knowledge backflow. As South African President Thabo Mbeki asked for in his 1998 'African Renaissance' speech:

> *"In our world in which the generation of new knowledge and its application to change the human condition is the engine which moves human society further away from barbarism, do we not have need to recall Africa's hundreds of thousands of intellectuals back from their places of emigration in Western Europe and North America, to rejoin those who remain still within our shores! I dream of the day when these, the African mathematicians and computer specialists in Washington and New York, the African physicists, engineers, doctors, business managers and economists, will return from London and Manchester and Paris and Brussels to add to the African pool of brain power, to enquire into and find solutions to Africa's problems and challenges, to open the African door to the world of knowledge, to elevate Africa's place within the universe of research the information of new knowledge, education and information."*

2 A Two-Sector Migration Model

Harris and Todaro[HaTo70] found the conventional economic models with their singular dependence on the achievement of a full employment equilibrium through appropriate wage and price adjustments insufficient to explain migration to highly unemployed urban areas.

Their work is focused on tropical Africa rural-urban migration but can be seen more abstract as a poor to rich migration, with the added twist of unemployment in the urban area.

Clearly what is driving migration are not wage differentials per se, but more specifically the expected wage differentials between rural and urban employment.

I was drawn to this work while looking into migration patterns in the European Union, during and after the inclusion of 10 new countries of mostly lower wage eastern European countries. There like in Harris and Todaro, unemployment in the host countries particular Germany played a role.

The foundation of the model is that migration continues from rural to urban areas for as long as the expected wage in urban areas W_u^e is higher than in rural areas. Or as Harris and Todaro put it: *"prospective rural migrants behave as maximizers of expected utility."* As an added twist, urban wage has a lower sealing set by the government i.e. a minimum wage (a market intervention that causes unemployment).

After showing the model the authors analyse potential government policy to reduce unemployment, while keeping the minimum wage set. The economically more efficient solution of price flexibility is rejected as political impossible. The effects of partial wage subsidies (for example via direct government employment) and restrictions to free migration are analytically shown with their model.

Nether wage subsidies nor restrictions on migration can yield the desired result. But interestingly a combination of both measures can, under certain conditions, lead to the desired result.

2.1 The Basic Model

The basic model used by Harris and Todaro is a two-sector internal trade model with unemployment. The two sectors are the permanent urban and the rural. The urban sector produces manufactured goods, part of which is exported to the rural sector in exchange for agricultural goods.

The crucial assumption made by Harris and Todaro is that rural-urban migration will continue so long as the *expected* urban real income W_u^e exceeds real agricultural product W_A.

The following formulation of the model is an excerpt from Harris and Todaro's work.

Agricultural Production Function:

$$X_A = q(N_A, \bar{L}, \bar{K}_A), q' > 0, q'' < 0 \tag{1}$$

where,

X_A is output of the agricultural good,

N_A is the rural labor used to produce this output,

$\bar{L}$ is the fixed availability of land,

$\bar{K}_A$ is the fixed capital stock,

q' is the derivative of q with respect of N_A, its only variable factor.

Manufacturing Production Function:

$$X_M = f(N_M, \bar{K}_M), f' > 0, f'' < 0 \tag{2}$$

where,

X_M is output of the manufactured good,

N_M is the total labor (urban and rural migrant) required to produce this output,

$\bar{K}_M$ is the fixed capital stock, and

f' is the derivative of f with respect of N_M, its only variable factor.

Price Determination:

$$P = p\left(\frac{X_M}{X_A}\right), p' > 0 \tag{3}$$

where,

P, the price of the agricultural good in terms of the manufactured good, (i.e., the terms of trade) is a function of the relative output of agricultural and manufactured good when the latter serves as numeraire.

Agricultural Real Wage Determination:

$$W_A = P.q' \tag{4}$$

where,

W_A, the agricultural real wage, is equal to the value of labor's marginal product in agriculture expressed in terms of the manufactured good.

Manufacturing Real Wage:

$$W_A = f' \geq \bar{W}_M \tag{5}$$

The real wage in manufacturing, expressed in terms of manufactured goods, is equateed with the marginal product of labor, because to perfectly competitive producers. However Harris and Todaro assume the minimum wage $\bar{W}_M$ to be always above f'.

Urban Expected Wage:

$$W_u^e = \frac{\bar{W}_M N_M}{N_u}, \frac{N_M}{N_u} \leq 1 \tag{6}$$

where the *expected* real wage in the urban sector, W_u^e is eqaul to the real minnimum wage $\bar{W}_M$ adjusted for the proportion of the total urban labor force (permanent urban plus migrants, denoted as N_u) actually employed, N_M/N_u.

Labor Endowment (constraint):

$$N_A + N_u = \bar{N}_R + \bar{N}_u = \bar{N} \tag{7}$$

Equilibrium Condition:

$$W_A = W_u^e \tag{8}$$

Therefor migration will continue until the rural wage W_A reaches the expected urban wage W_u^e.

And so Harris and Todaro arrived at 8 equations and 8 unknowns X_A, X_M, N_A, N_M, W_A, W_u^e, N_u and P to solve the model fpr sectoral employment, the equilibrium unemployment rate and, consequently, the equilibrium, expected wage, relative output levels and terms of trade.

Derived Equilibrium Condition:

$$W_A = W_u^e$$
$$\Phi = W_A - W_u^e = 0$$
$$\Phi = P.q' - \frac{\bar{W}_M N_M}{N_u} = 0$$
$$\Phi = p\left(\frac{X_M}{X_A}\right).q' - \frac{f' N_M}{\bar{N} - N_A} = 0$$

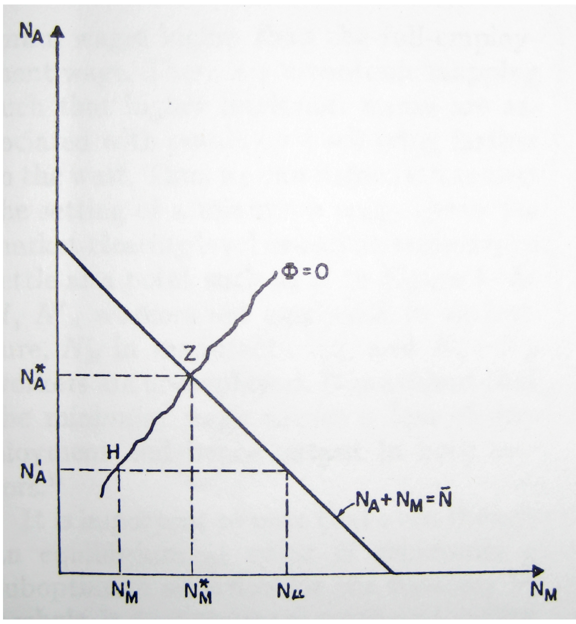

Figure 3: Equalibrium Condition

Since X_M and X_A are functions of N_M and N_A respectively, Φ is an implicit function of N_A and N_M which, for any stated minimum wage, can be solved for the equilibrium combination of agricultural and manufacturing employment. And from there the urban unemployment and commodity outputs can be determined.

As we can see in figure 3 there is a unique equalibrium $\Phi = 0$ for each minimum wage. The labor constraint is shown by the line $N_A + N_M = \bar{N}$. Because of this constraint any result above are is impossible. The intersection of the equalibrium with the constraint (i.e. point Z) shows the full-employement point. At this point $\bar{W}_M = f'$. However, with an increasing minimum wage $\bar{W_M}$ we move below point Z and unemployment increases.

Point H represents the equilibrium for a given minimum wage above the market-clearing level i.e. $\bar{W}_M > f'$. At H, N_A' workers are employed in agriculture, N_M' in manufacturing, and $N_u - N_M'$ workers are unemployed. Harris and Todaro therefor clearly showed that minimum wage causes a loss of employment and lower output in both sectors.

Harris and Todaro point out that, although point H represents a suboptimal situation, it does represent a rational, utility maximizing choice for individual rural migrants given the level of the minimum wage.

2.2 Government Policies

Having developed the model, Harris and Todaro work thru some possibly government policies and analyze the corresponding consequences. First they consider what will happen if the government tries to hire the unemployed. Second they look at how migration restrictions affect the outcome. And finally a combination of the two policies is analyzed.

2.2.1 Wage Subsidy

The above model showed us how unemployment is caused by a minimum wage above the market clearing level. The obivous government policy to improve this market failure, i.e. abolition of the minimum wage is not politically visable. But we can use the model to analyze wage subsidies as one political instrument to resolve unemployment.

The key point to consider with wage subsidies in this two sector model, is that the two sectors are intimately connected through labor migration (and therefor wage expectations).

If the government applies wage subsidies in the form of addinal employment in the urban area, than it will increase wage expectations W_u^e which will lead to higher immigration. Harris and Todaro show that more than one agricultural worker will likely migrate in response to the creation of one additional industrial job (with the set minimum wage).

The effect is further market distortion and depending on the parameters of the model the result can range from small welfare improvements to actual decreases in welfare. Not to mention that the government has to find a way to raise the money for the subsidies in the first place.

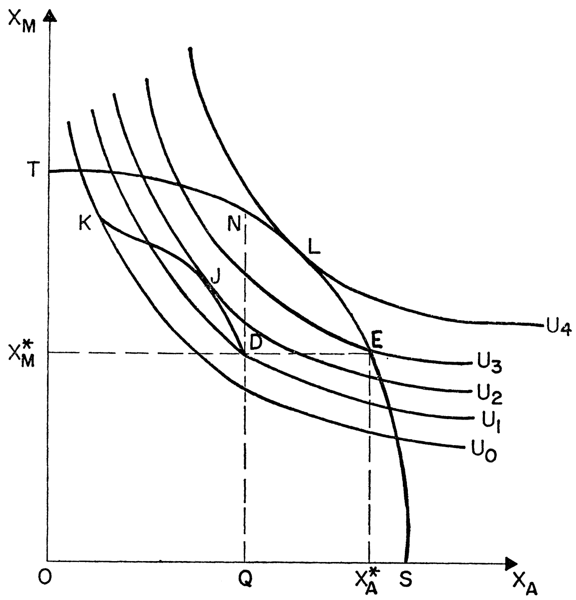

Figure 4: Aricultural and Manufactoring Output with shadow wages

2.2.2 Government Policy: Migration Restriction

Altought Harris and Todaro state *grave reservations about the ethical issues involved in such a restriction of individual choice*, they analyze the economic effects of migration restriction in the scope of their model.

In figure 4 we see the manufacturing output X_M and the agricultural output X_A and the the line TS representing the production possibilities for the agricultural sector when labor export is allowed.

With minimum wage such that industrial output is OX_M^*, prohibiting migration above the level required to produce that output will allow the economy to move production from point D to point E with an welfare improvement from U_1 to U_3.

However, the welfare will be unevenly distributed between urban and rural area. A lump-sum payment from urban to rural area, not considering the difficulties of carrying out such an payment, could distribute the welfare and make everyone better of.

We are however still short of the optimum that could be achieved with competitive wage determination, i.e. point E in figure 4. Lets try a combination of the above policies.

2.2.3 A Combination of Policies

As we saw above, one policy instrument fails to clear the single market failure, the wage level, of our model. The reason is that the wage performs two functions in this model. It determines both the level of employment in the industrial sector and via wage expectations, the level of migration from the rural to the urban area.

If wage subsidies decrease unemployment in the short run, they increase migration and offset the effect in the long run.

Restrictions of migration (alone) prevents the effect minimum wage has on unemployment but does nothing to increase the level of industrial employment.

In order to reach point L, a combination of both policies has to be applied. Wage subsidies must be set at a point equal to the difference between the minimum wage and marginal productivity. At that point $W_u^e = W_M$.

However, at that point individuals would still find it in their interest to migrate (since $W_M > Pq'$) and the point will not be attainable unless migration is restricted.

Even due reaching the optimal point L in figure 4 is depending on the parameters theoretically possible, the fiscal requirements of the requiered subsidies are substantial. Finding the right tax without again distorting the result is tricky. Harris and Todaro identify an urban land tax as the least problematic way to raise the required finances.

2.3 Adaptations for the n-Sector Migration Simulation

Harris and Todaro's model form the foundation for the simulation later in this work. However some adaptations will be required.

We will not consider minimum wages in our simulation. The manufacturing real wages are plainly $W_A = f'$, therefor we always reach full employment.

The expected urban wage will be based on the workers knowledge about previous wages in the respective sector. But more on this later when we dive into the simulation.

The equilibrium condition will consider travel costs α. Therefor $W_A = W_u^e - \alpha$. In other words, potential migrants only move if their current wage is lower than the expected wage subtracted by their migration costs.

This allows use to simulation more restrict migration policies (increase α) or more open policies (decrease α).

However, while Harris and Todaro focus their model on the equilibrium, the simulation considers the equilibrium as a rare special case and analyzes the movement around the equilibrium.

3 Firm formation and Agent-based Simulation

This section will follow Axtell's[3] work on firm formation [Axte05][4].

I will start with a theory on firms by Coase, than continue conceptually with Axtell's microeconomic model on firm formation and end with his agent based simulation and a collection of concepts adopted in the n-Sector Migration Simulation.

3.1 The Theory of the Firm

Axtell draws on the Coase's *"The Nature of the Firm"* [Coas37]. Since his model is at heart about firm size distribution, Axtell emphasises factors affecting firm size which are conveniently at the heart of Coase's theory as well.

Coase starts with by identifying the lack of a clear definitions of "the firm". Besides the dictionary definition of a *"business concern, esp. one involving a partnership of two or more people"* [Oxfo05], Coase is looking for definition that is manageable (in economic terms) and realistic.

In economics the allocation of factors of production between different uses is determined by the price. Inside a firm that is hardly the case. Although modern firm theory tries to mimic markets in the internal decision process [Robe04], the typical firm observed usually works in command and control structure without internal price allocation.

Why firms developed: Coase focuses on *transaction costs*: Markets are imperfect. Interacting agents face transaction cost. If A and B have to negotiate a contract every time they work together and if those negotiations are costly, it is only natural that they will try to set up a contract capturing more than one element of work. Perhaps exchanging a promised daily effort against a monthly payments.

Quoting Coase:

[3] Robert Axtell is a fellow at the Brooking Institution and a member of the Santa Fe Institute. His research focus is on dynamics and quantitative studies of human behavior.

[4] I first read Axtell's paper on firm formation in a lecture on *Information Economics* as an applied introduction to agent based simulation.

"A firm is likely therefore to emerge in those cases where a very short-term contract would be unsatisfactory. (...) The operation of a market costs something and by forming an organisation and allowing some authority (an "entrepreneur") to direct the resources, certain marketing costs are saved. The entrepreneur has to carry out his function at less cost, taking into account the fact that he may get factors of production at a lower price than the market transaction which he supersedes, because it is always possible to revert to the open market if he fails to do this."

Another approach to firm development is based on the theory of evolution. Axtell cites Nelson and Winter [NeWi82].

Axtell draws together various concepts from competing papers. He preserves the production function, albeit in a modified form. His model is written at the level of individual agents following incentives and intrinsic transaction costs. The general equilibrium approch is relevant when at each instant a coalition of agents compose a firm. And finally the way firms grow and decline, follows the spirit of evolutionary economics.

3.2 A Variable Effort Model of Firm Formation

Axtell's model of firm formation consists of a population of agents with preferences of income (derived from work) and leisure (time outside work). Agents face economics of scale, i.e. they have increasing returns to cooperations. Therefor, agents working together can produce more output per unit of effort than if they work alone. However, and thats the critical part: agents are not entirely cooperative. Since each firms output is divided equally among its workers, different preference functions yields different effort inputs among the workers in a firm. The bigger the firm the less one agents effort will reflect total firm output. Finally, agents who put in more effort, are punished by *free riders* (agents who put in no effort for their share of firm income).

During periods some agents may migrate between firms or start-up new firms.

Total effort level of a firm with N agents A is

$$E = \sum_{i=1}^{N} e_i \tag{9}$$

where $e_{i \in A} \in [0, 1]$

Firm output by effort E is

$$O(E) = aE + bE^2 \tag{10}$$

Provided that $b > 0$, firms enjoy increasing returns on effort. I.e. for a given effort level, cooperation yields higher output than working separately.

Total firm output is shared equally: at the end of each period each agent receives an equal share O/N of the total output.

Axtell uses a Cobb-Douglas preference function for income and leisure but a more general preference function yields conceptually equal results.

Agent i's utility based on his effort level e_i and preference Θ_i

$$U^i(e_i, \Theta_i, E_{\sim i}, N) = \left(\frac{O(e_i, E_{\sim i})}{N} \right)^{\Theta_i} (1 - e_i)^{1-\Theta_i} \tag{11}$$

where the firm output O is given by the agents input e_i and the input of the remaining agents in the firm $E_{\sim i}$ with $E = e_i + E_{\sim i}$.

Given the total effort level E and firm size N each agent can now maximize his utility

$$e_i^* = argmax[U^i(e_i, \Theta_i, E_{\sim i}, N)] \tag{12}$$

Figure 5 shows individual agent effort e_i^* as a function of the remaining firm effort $E_{\sim i}$ for a number of different preference levels Θ_i.

As expected, increasing total firm effort will decreases individual agent effort level for those who value leisure i.e. $\Theta < 1$. The lower Θ the quicker an agent will reach a level of zero effort input, he therefor becomes a free rider.

An equilibrium is reach once all agents compute their respective e_i^* using $E_{\sim i}^* = \sum_{j \neq i} e_i^*$ instead of $E_{\sim i}$.

Such an equilibrium is a Nash equilibrium, since once it is established no agent can make itself better off by working at some other effort level.

However this will miss the highest level of feasible utility. Clearly incentives in cooperation are imperfect aligned. The increasing returns of cooperation, could yield much higher utility if agents where trying to maximize their combined utility. However, from an individual agent's point of view, additional input is not rational.

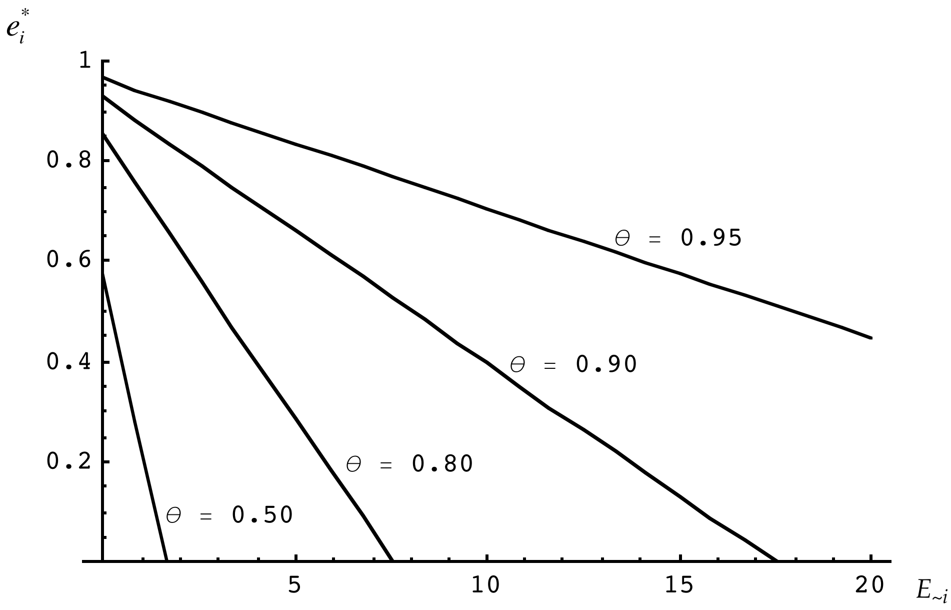

Figure 5: Dependence of e_i^* on $E_{\sim i}$

Axtell's Example of Nash equilibrium with free entry and exit

Four agents having preferences for income {0.6, 0.7, 0.8, 0.9} work together in a group in which a = b = 1. Equilibrium in such a group, from equation 5, corresponds to agents working with effort levels {0.15, 0.45, 0.68, 0.86}, respectively, producing 6.74 units of output. The corresponding utilities of the 4 agents are {1.28, 1.20, 1.21, 1.32}, respectively. If each of these agents were to leave the group to found their own firm they would, according to equation 8, put in effort levels {0.68, 0.77, 0.85, 0.93}, respectively, generating outputs of {1.14, 1.36, 1.58, 1.80} and total output equal to 6.07. Their respective utility levels would be {0.69, 0.80, 0.98, 1.30}.

That is, working together they make more output, with each agent putting in less effort and receiving greater reward. This is the essence of team production. Now say that an agent with income preference of 0.75 joins the group. The 4 original group members now adjust their effort levels to {0.05, 0.39, 0.64, 0.84}i.e., all work lesswhile total output rises to 8.41. The utility levels of the original agents become {1.34, 1.24, 1.23, 1.33}, respectively, meaning that all members benefit from the new arrival.

This new agent has an equilibrium effort level of 0.52 and utility level 1.23. It is individually rational for the newest agent to join since the utility it gets working alone is just 0.88. Next, imagine that another agent having preference for income of 0.75 joins the group. The new Nash equilibrium effort levels among the original 4 group members is then {0.00, 0.33, 0.61, 0.83}, while the two new agents each put in effort of 0.48. The total output rises to 10.09. The corresponding utility levels are {1.37, 1.28, 1.26, 1.34} for the original agents and 1.26 for each of the two agents having $\Theta = 0.75$. Overall, even though the addition of this sixth agent causes one of the first agents to free ridethat is, put in no effortthe net effect of this agent on the group is welfare-improving for all.

Finally, imagine that an agent having income preference of 0.55 arrives in the group. Such an agent will engage in free-riding and so will not effect the total effort or output levels, thus the individual effort levels of the extant group members will not change. However, since the output must be shared by one additional agent all utility levels fall. For the 4 original agents the new utility levels become {1.25, 1.15, 1.11, 1.17}. For the two agents having $\Theta = 0.75$, their utility falls to 1.12. Overall, the addition of this last agent reduces the welfare of all. Furthermore, it lowers the utility of the $\Theta = 0.9$ agent below what it can obtain working alone (1.17 versus 1.30). If agents may exit the group freely, this agent would find it rational to do so, causing all agents to readjust their effort levels. In the new equilibrium the three remaining original agents would now work with efforts {0.10, 0.42, 0.66}, respectively, while the agents having $\Theta = 0.75$ would put in effort of 0.55. The newest agent would free-ride. The new output level would be 7.52, yielding utility of {1.10, 0.99, 0.96} for the original three, 0.97 for the $\Theta = 0.75$ agents, and 1.13 for the free-riding agent. Unfortunately for the group, the ? = 0.8 agent now finds that it too can do betterutilities of 0.96 versus 0.98by leaving the group to work alone (or joining with the $\Theta = 0.9$ agent). This induces a further re-equilibration of the remaining group, so that the original two members work with effort levels of 0.21 and 0.49, respectively, the two $\Theta = 0.75$ agents put in effort equal to 0.61, and the ? = 0.55 agent rises out of free-ridership to work at the 0.04 level. The total output drops to 5.80. The utilities of the original two are now 0.99 and 0.90, respectively, 0.88 for the $\Theta = 0.75$ agents, and 1.07 for the newest agent. In this equilibrium the $\Theta = 0.75$ agents are essentially indifferent between staying in the group and moving off to work alone.

While the example above can be derived in a strictly inductive mathematical way, more dynamic settings of this mode can only be analyzed using simulation.

3.3 Agent based Simulation

Quoting Axtell:

> *"In agent-based computational models a population of data structures representing individual agents is instantiated and permitted to interact. One then looks for systematic regularities, often at the macro-level, to emerge from the interactions of the agents. The shorthand for this is that macroscopic regularities "grow" from the bottom-up. No equations governing the macro social structure are solved in multi agent computational modeling. Typically, the only equations present are those used by individual agent for decision-making. Nor are agents assumed to have complete information that they can costless process. Instead, agents social networks. that is through local interactions. This relatively new methodology facilitates modeling agents heterogeneity, non-equilibrium dynamics, local interactions and bounded rational behavior."*

In this model firms break and emerge, agents constantly readjust their effort level based on the (constantly changing) total effort level in a firm. There is no stable equilibria. The magic lies in the non-equilibrium dynamics.

The simulation is based on model described above. The total output function of the firm is slightly more general set at $O(E) = aE + bE^{\beta}$.

The agent follows his highest possible utility output when choosing where to work. However, his information is limited. He only knows firm output of firms where his friends v_i work. Axtell calls it his social network. Friends are assign randomly at the start of the simulation and do not change[5].

[5] At this point it was probably tempting to trow in some social network simulation with a dynamic v, simulating increasing connections among fluctuating workers.

Since each agents decision is based on the decision of all other agents, the order and periods when agents are activated to make their decision is critical.

The case of all agents being activated at once during a single period is known as uniform activation. Alternatively, agents are selected randomly for activation.

Axtell goes with random activation. Therefor some agents may get activated more often than others during each period. For example a population of A agents has $N < A$ (random) activations per period.

Initially each agent works alone. So at the start of a simulation with A agents there are A firms. As agents compare the utility of working together in their social network, firms will emerge due to the increasing returns of scale. The number of firms decreases, while their size increases. At some point the effort input of agents working in large firms has a smaller and smaller effect on their income. Slowly free riders will emerge. Putting in no effort, while talking the same share of output like everyone else[6]. Faster and faster agents will start emigrating until the firm dissolves and so drive the non-equilibrium dynamics of this simulation.

Model Attribute	**Value**
agents, A	1000
constant returns coefficient, a	1
increasing returns coefficient, a	1
increasing returns exponent, β	2
distribution of preferences, Θ	U[0,1]
sharing rule of firm output	equal shares
number of friends, v	2
agent activation	random
initial condition	all agents in singleton firms

Table 1: Configuration of computational model

3.3.1 Computational Implementation

Written in an object oriented programing language, Axtell encapsulates agents in objects. Each object, i.e. agent, has a state (a Firm where he is currently

[6]This of course is due to differently shaped utility functions. Θ is randomly set between 0 and 1.

employed, an effort level, an income and his utility) and a process of making decisions (stay in current firm, transfer to a another or start a new firm on his own).

Firms on the other hand will do little else than allocating their output to the agents associated with it.

Lets start with the structure of the class *Agent*[7]:

```
CLASS Agent
    Agent[] friend_list;
    float effort_level;
    float last_income;
    float last_utility;
    float wealth;
    Firm current_firm;
    METHOD compute_max_utility_level_in_firm(Firm);
    METHOD migrate_to_new_firm(Firm);
    METHOD create_new_firm();
```

The agent class starts with an array list of friends. Other agents who form the social network of this agent. Next we have data of the agents state: *effort level*, *income*, *utility*, *wealth*[8] and the firm this agent currently belongs to.

The methods allow an agent to compute his current utility, the effort level he would put in a given firm and let him start a new or move to different firm.

Additionally we have the class *Firm*:

```
CLASS Firm
    Agent[] agent_list;
    size;
    last_output;
    FUNCTION compute_total_effort();
    FUNCTION compute_output();
    FUNCTION allocate_income_to_agents();
```

A new firms object is created whenever an agent starts a new firm. Firms are deleted if they have no more agents who work in them. Each period all firms compute their total effort input based on the sum of all employed

[7]The following code samples are adapted to follow a more Java like style, but are conceptually identical to the pseudo-code provided by Axtell.

[8]The wealth of an agent, although not relevant for the simulation, is an interesting variable to follow.

agents individual effort levels. Next the output is calculated and allocated as shared income to all agents.

The *Main Program* finally brings the pisses together.

```
MAIN PROGRAM;
initialize agents;
initialize firms;
repeat for N periods:
    select M out of A agents at random;
    for each a of selected agents:
        a.compute_max_utility_level_in_firm(a.current_firm);
        for each v of a.friend_list
            a.compute_max_utility_level_in_firm(v.current_firm);
        a.compute_max_utility_level_in_firm(create_new_firm());
        a.migrate_to_new_firm(firm with highest utility);
    for each f of firms:
        if(empty(f.agent_list))
            del(f);
        else
            f.compute_total_effort();
            f.compute_output();
            f.allocate_income_to_agents();
```

First A agents and F firms are initialized[9].

Next the program loops thru N periods. Each period $M \leq A$ agents are selected randomly to reevaluate the firm they work in, the possibility of starting a new firm and the firms of their friends. Agents than choose the firm yielding the highest utility[10] and migrate if it exceeds the utility in their current occupation[11].

During each period agents bring in their set effort and firms share out the combined output. A firm is removed if all agents are emigrated. Therefor we always have $F \leq A$ firms.

The actual number of firms and their size over time is what Axtell highlights in his results below.

[9] Initially $A = F$ since at the beginning each agent works in a singleton firm.

[10] Based on their individual work leisure valuation.

[11] Migrating from one firm to another or starting a new firm imposes no costs on agents. Later, in the n-Sector Migration Simulation, this costs will be > 0 and will play an key role in the simulation.

3.3.2 Result of one representative Simulation

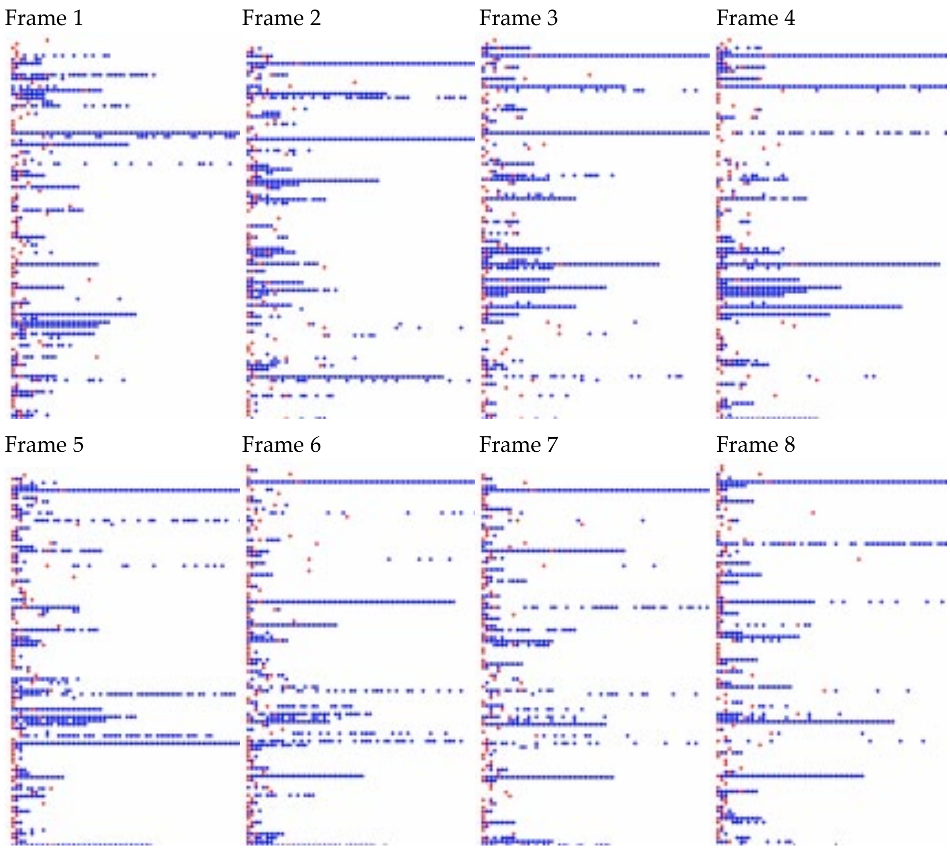

Figure 6: Snapshots from a typical firm formation process over 8 consecutive time periods (from $t = 1000$ till $t = 1007$); longer lines represent bigger firms.

Figure 6 shows a snapshot of 8 periods ($t = 1000$ till $t = 1007$) of a representative simulation based on the settings defined in Tabel 1. Initially all agents start in a single firm represented in figure 6 by one dot in the left most column. When agents migrate to another firm, their dot moves to the row represented by that firm. Agents migrate if they find it in their best intrest, i.e. utility improving, if they join a firm. As firms grow bigger, their lines grow to the right. Expanding firms face diminishing returns on effort input. Agents who value their leisure higher than their income will decrease their effort and life of the effort provided by other agents. The firm may still grow as additional agents join. However, at some point to much free riders will break the system as those who value income above leisure start to abandon the sinking ship.

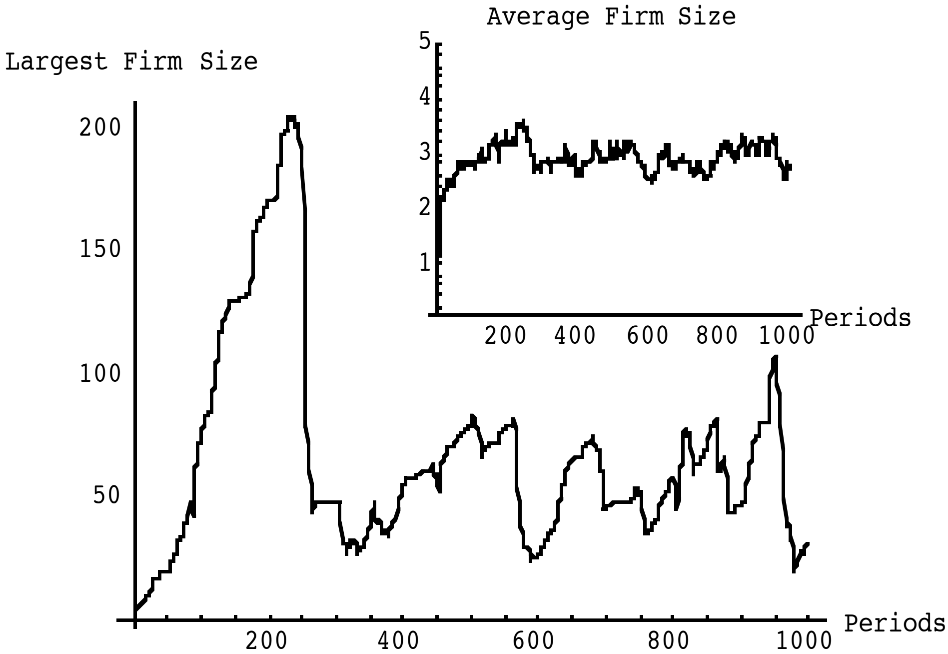

Figure 7: Typical time series for average firm size (inset) and largest firm size.

Figure 7 provides a telling view of average firm size (inset figure) and the size of the largest firm over time. The average firm size holds rather constant at about 3 to 4 agents per firm. The largest firm size has quite a fluctuation reaching up, at point $t = 250$, to an head-count of 200 (that's 20% of the entire agent population).

Axtell continues with analyzing effort level, output, income and utility. Average income follows a constant path while income in the largest firm fluctuates with a higher frequency but close to the path of firm size in figure 7. Occasionally income in large firms drops below average firm income. This is possible since, close to the end of a firms life cycle, agents who value leisure above income increasingly make up the majority of the firm.

That the income from a large firm may fall below the average income of the population is a natural result of a large firms ending life cycle. The utility however should and in figure 8 is (mostly[12]) above the average utility of the

[12]As utility levels decline, large firms reach the level of utility that is generally available in the population, agents leave for better opportunities. Occasional dips below the average level are possible because of a missing out in a randomly selected evaluation process, or because of a lack of lucky friends. Ether way some, agents may be trapped in failing firms

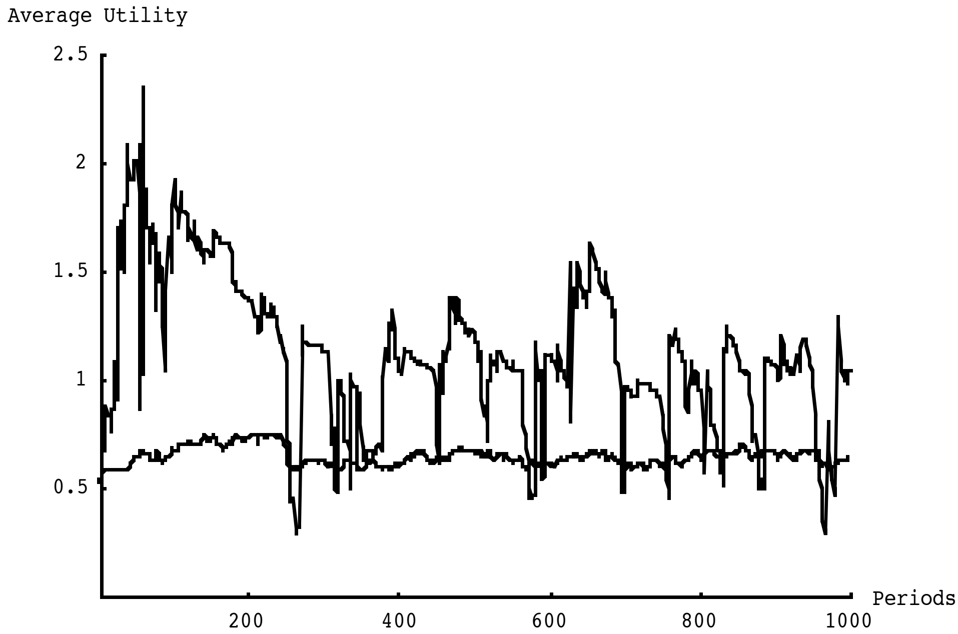

Figure 8: Typical time series for average utility in the population (thick line) and in the largest firm (thin line).

agent population.

Agents maximize their utility. The reason agents work with each other is the higher return from cooperation. More income for less work, clearly raises their utility. It would be exceptional (although possible) if agents in the largest firms received below average utility.

Figure 8 shows a typical time series for average utility in the population (thick line) and in the largest firm (thin line).

The data show in figure 6-8 is based on one sample run of the simulation. To get more robust results Axtell aggregates data of a large number of simulations and shows the derived results.

3.3.3 Firm Size Distribution in the Aggregate

Analyzing results of numerous simulation Axtell aggregates a firm size distribution following a power law. This distribution is one that can be observed across industries, regardless of measuring firm size by head count or by out-

and cannot immediately secure alternative employment.

put.

The probability of firm size s defined at $p(s)$ stated in a probability mass function:

$$p(s; \mu, s_0) = \left(\frac{s}{s_0}\right)^{-(1+\mu)} \tag{13}$$

where s_0 is a certain minimum size (in the case of this simulation $s_0 = 1$ since the minimal firm size is 1).

Over time simulations reach a rather stationary configuration, with a few large firms and progressively greater numbers of smaller and smaller firms. Aggregated data are shown in doubly logarithmic coordinates in figure 9.

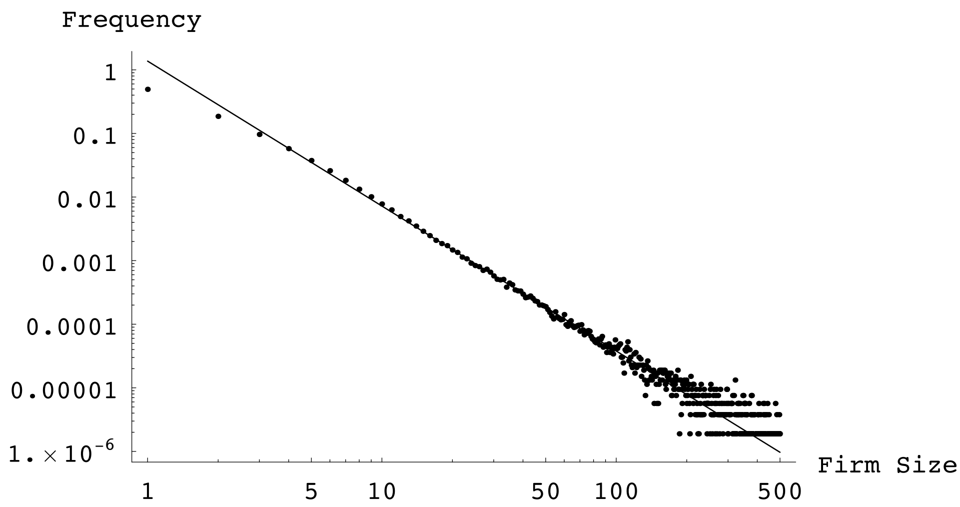

Figure 9: Stationary firm size distribution (probability mass function).

Axtell fits his data to an OLS and yields a firm size s proportional to $s^{-2.28}$ and a probability $p(s)$ of $\mu = 1.28$ (adjusted $R^2 = 0.99$).

Empirical data on firms follows this scaling. In particular Axtell quotes Simon and Ijiri [IjSi77] to report data on U.S. firms around 1955 to fit $\mu = 1.23$, while British firms fit a $\mu = 1.11$.

This is the essential result of Axtell's work. The connection of an explicit microeconomic model of endogenous firm formation with aggregate firm data and matching empirical data. A bridge between micro- and macroeconomics using an elegant agent based simulation.

The n-Sector Migration Simulation will closely follow his approach.

3.4 Adaptations for the n-Sector Migration Simulation

While preparing the n-Sector Migration Simulation, Axtell's work provided numerous ideas for the foundations of it's model as well as the computational implementation of the agent based simulation.

Adaptations of the Model: Roughly stated: If Axtell's *firms* are replaced with *sectors*, effort levels are omitted and costs of migrating included, we find a close resemblance between Axtell's model on firm formation (described above) and the n-Sector Migration Simulation described later on.

Adaptations of the Computational Implementation: Analog to chapter 3.3.1, I will analyze a pseudo code implementation of the n-Sector Migration Simulation to highlight similarities and contrasts to Axtell's implementation.
Again, lets start with the class *Agent*:

```
CLASS Agent
    Agent[] friends_list;
    boolean is_worker;
    double income;
    double savings;
    Sector current_sector;
    METHOD compute_income_in_sector(Sector);
    METHOD migrate_to(Sector);
```

Inspired by Axtell's implementation, an array list of friends, i.e. the social network, is used to simulate scarce information.

In the n-Sector Migration Simulation, each agent is ether worker or firm owner. Workers work for firm owners. Wages are endogenously set for each sector (firms in the same sector pay equal wages). Firm owner's income is negatively related to wages paid in their current sector.

Agents migrate to other sectors if they can expect higher income and can afford to migration (wealth > costs of migration).

Similar to Axtell's class *Firm* is the class *Sector*:

```
CLASS Sector
    Agent[] agent_list;
    int number_of_workers;
    int number_of_firms;
    float wage;
    FUNCTION calculate_sector_wage();
    FUNCTION allocate_income_to_agents();
```

Each sector has a list of agents. Ether worker or firm. Wages are negatively related to the number of worker and positively related to the number of firms in a sector.
Now, the *Main Program*:

```
MAIN PROGRAM;
initialize agents;
initialize sectors;
repeat for N periods:
    select M out of A agents at random;
    for each a of selected agents:
        a.compute_expected_income_in_sector(a.current_sector);
        for each v of a.friend_list
            a.compute_expected_income_in_sector(v.current_sector);
            if(highest income - migration costs > a.income)
                a.migrate_to(sector with highest income);
                a.wealth = a.wealth - migration costs;
        for each s of sector:
            s.calculate_sector_wage();
            s.allocate_income_to_agents();
```

During initialization all agents (workers and firm owners) are placed in sectors.

During each period a number of agents is selected to evaluate their expected income at their current sector (home) and other sectors know to their social network (given by their friends list). If they expect higher income outside, they pay the costs of migration and migrate.

Output Market Like Axtell I decided, for the time being, against the integration of a full market between firms (and sectors) determining prices and wages[13].

[13] Axtell's argues: *"Future work includes modeling the output market. There are two ways to interpret how output is converted into income in the present model. First, given that stationary distributions of income and output arise in the model, any market mechanism would yield an essentially constant price for the output good, treated here as a single homogeneous consumption good. Alternatively, imagine that agents have heterogeneous preferences over many goods, and that firms specialize in producing a single one of these goods. Then, as long as the economy is sufficiently large -as long as there are a large number of firms- all products will be made in more or less constant amounts and, given stable agent preferences, there will obtain an equilibrium vector of prices for these goods. While there are likely many interesting facets to actually building an output market, it is also the case that a powerful result of the present model is that through purely local interactions there develops long-range correlations -the power law size distributions have no characteristic scale, and therefore all sizes are present up through the finite size cut-offs. That is, by coupling the agents through the output market we would expect long-range correlations, but such internal structure arises spontaneously in the model even when the agents are not explicitly coupled globally."*

4 Costs and Returns of Migration

This chapter focuses on Sjaastad's *The Costs and Returns of Human Migration* [Sjaa62]. While we have so far dealt only with forces affecting migration, Sjaastad looks at influence *of* migration. Particularly as an equilibrating mechanism in a changing economy. Sjaastad looks at gross and net flows of migration inside the US. While doing so, Sjaastad analyzes some of the important costs and returns to migration both, for the migrate as well as the society.

Sjaastad treats migration as a way to promote efficient resource allocation and since migration is an activity which requires resources he tries to estimate the returns to investment in migration. Quite a different approach to the rates of migration based on income differentials discussed so far.

4.1 Migration: too much or too little

Sjaastad clearly sees the merits of migration. The wage equalizing forces make the economy more efficient by distributing people to where they are needed the most.

In that sense *net* migration already goes in the right direction. I.e. from low income states to high income states. But *gross* migration shows a strong flow in the "wrong" direction as well. Almost marginalizing net migration in contrast. Why do people migration to low income states? Why do not much more people migration to high income states. Why do large income differentials persist?

Looking at data from the US[14] Sjaastad finds just small net migration from low to high income states. That is not due to a lack of mobility, it is more that to much people move in the wrong direction. But why? Clearly individual are not looking at average income distribution but on income related to their occupation.

The out-migrants may have left declining industries and may not have been qualified for employment in the expanding ones. Or, some or all of the in-migrants may have been disillusioned out-migrants of previous years (Sjaastad found reasonable intertemporal correlation in migration data). Their is also retirement. Perhaps retired persons are attracted to areas where wages are low or they may just move back to where they grew up. Whatever the

[14]United States Bureau of the Census, 1950 Population CEnsus Report

reason is for migration in the "wrong" direction, it is insufficient to look at net migration while testing the labor market's ability to remove income differentials.

A better alternative is to look at the problem strictly as resource allocation. To do so, Sjaastad treats migration as an *investment increasing the productivity of human resources*, and investment which has costs and which yields returns.

Treating migration as an investment provides a way to test the effectiveness of migration in reducing income differentials between sectors. That criterion is the rate of return on resources allocated to migration. The key to this approach is to identify and measure the costs as well as the returns to migration.

4.2 Costs of Migration

Sjaastad identifies two costs of migration. Direct costs of migration encapsulates the costs of the migration itself (transportation,...), while indirect costs include missed earnings during migration and, not to underestimate, "psychic" costs of leaving ones home.

4.2.1 Direct Costs of Migration

Sjaastad doesn't provide any data or reference on this matter but sees no doubt that those costs could be estimated easily. But forgoes doing so, since he assumes costs of migration to be marginal. Which maybe true for migration inside the US, but certainly costs are relevant in international migration

Lets look at some costs related to migration in an international setting[15].

Costs of Immigration: While it is perhaps cheap to migration inside a country (as stated by Sjaastad) international migration can be quite costly.

Humans smuggling may help estimate migration costs. Humans smuggling provides a market with market prices. An illegal market, not the less an market. We can use it's market prices to get a picture on costs of migration.

[15] While looking at costs of food lodging and transportation (for both migrants and their family) we can only include *increases* in those costs related to migration.

Clearly this data [Petr05] represents only illegal immigration, but it reflects on legal migration (one would hardly pay 26,00 USD to a smuggler for illegal immigration to the US, if legal immigration would cost less in money and time).

Routes	**Mean Costs in USD**
Asia-Americas	26,041
Europe-Asia	16,462
Asia-Australasia	14,011
Asia-Asia	12,240
Asia-Europe	9,374
Europe-Australasia	7,400
Africa-Europe	6,533
Europe-Americas	6,389
Americas-Europe	4,528
Americas-Americas	2,984
Europe-Europe	2,708
Africa-Americas	2,200
Africa-Australasia	1,951
Africa-Africa	203

Table 2: Global costs for human smuggling and trafficking

4.2.2 Indirect Costs of Migration

Two main costs are defined as indirect costs of migration by Sjaastad. First opportunity costs: the earnings foregone while migrating, search for or learning a new job, learning a new language. Second "psychic" costs: giving up friends, relatives an established social network.

Lost opportunity costs are reflected by reduced earnings, these costs are to be taken into account by choosing the appropriate expected earnings stream (after migration) for comparison with the expected stream had the migrant not moved.

Psychic costs difficult to quantify, they should be treated quite differently from the costs previously considered. The costs treated above represent real resource costs; however, the psychic costs are not. They are more like lost consumption by the migrant.

Although Sjaastad doesn't treat psychic costs as a component of the costs of migration he accepts that some part of existing income differentials represent tastes alone.

4.3 Returns to Migration

As stated earlier, psychic costs of migration will be omitted in this analysis. If one area is preferable over another, say due to a better climate, this should already be reflected in rents for land.

The direct returns of migration to the migrant is the *discounted lifetime income differential*. The increase (or decrease) in the discounted lifetime income compared to the previous sector.

With income $w_{t,A}$ in sector A (previous sector) and income $w_{t,B}$ in the sector B (new sector) and a discount factor β (between 0 and 1) we can define the discounted lifetime income differential ψ as

$$\psi = \sum_{n=0}^{\infty} \beta^n (w_{t+n,B} - w_{t+n,A}) \tag{14}$$

We can now subtract migration costs from discounted lifetime income differential and see if migration had a positive (private) return on investment.

4.4 Conclusion

1. Gross rather than net migration is relevant for studying migration.
2. Migration rates are not an appropriate measure for estimating the effect of migration.
3. Age is significant as a variable influencing migration and earning differentials.
4. The relation between private and social costs of, and returns to, migration depend on market structure, resource mobility and revenue policies.

Sjaastad analyzed migration inside the US. This allows him to argue on the merits of migration without facing political controversy. But clearly do his result hold true for international migration as well. Let's look at migration in Europe.

5 Migration in Europe

This section will give a brief look a current migration model for Europe and its resulting forcasts. In particular immigration from the CEEC 10[16] to the EU 15[17] as provided by Brücker, Alavarez-Plata and Siliverstovs [BrAS03].

Brücker applies a two-sector analysis. First for migration from CEEC 10 to Germany, and second for migration from CEEC 10 to the EU 15.

In chapter 2 we already saw a two-sector model developed by Harris and Todaro, to analyzed migration from rural to urban area in tropical Africa. In their model, migration was surprisingly strong, considering much higher unemployment in the city. But, and that was the driving force, wages in the city were much higher too. Due to strictly enforced minimum wage laws. Therefor people from rural area migrated to the city for as long as their *expected wage* in urban area w_u^e was higher than their expected wage in rural area.

The expected urban wages is the minimum wage w_M times the employment rate N_{empl}/N.

Today wages and employment rates still dominate the discussion on migration [BrAS03]:

> "Almost all models discussed in the empirical literature explain migration by income and employment opportunities in the respective countries and a set of institutional variables which should capture different migration restrictions. The main reason for the varying estimation results is that the different studies use different econometric estimators."

So. the same incentives, as in tropical Africa, are still relevant today. To predict potential migration we compare the income per person and the employment rates with the cost of migration.

As shown in Figure 10 and Figure 11 the employment rates are not much different in the EU 15 compared to the CEEC 10. But income per head in CEEC 10 is just 40 per cent of income per head in the EU 15.

---

[16] The Central Eastern European Countries including Czech Repuplic, Estonia, Hungary, Lativa, Lithuania, Poland, Slovak Republic, Slovenia and those soon to join the EU: Bulgaria and Romania

[17] EU-15 the members of the European Union before the expansion on 1 May 2004 consinting of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

	PPP-GDP[1)]		GDP[2)]	
	EURO	in % of EU-15	EURO	in % of EU-15
Bulgaria	6 500	28.0	1 875	7.8
Czech Republic	13 300	57.2	6 164	25.6
Estonia	9 800	42.2	4 535	18.9
Hungary	11 900	51.2	5 813	24.2
Latvia	7 700	33.1	3 613	15.0
Lithuania	8 700	37.4	3 638	15.1
Poland	9 200	39.6	5 092	21.2
Romania	5 900	25.4	1 982	8.2
Slovak Republic	11 100	47.8	4 229	17.6
Slovenia	16 000	68.9	10 499	43.7
Cyprus	21 118	90.9	15 171	63.1
Malta	..	..	10 553	43.9
Turkey	5 200	22.4	3 213	13.4
CEEC-8	10 675	45.9	5 407	22.5
CEEC-10	9 322	40.1	4 395	18.3
CC-13	7 764	33.4	4 001	16.6
CC-10	10 725	46.2	5 534	23.0
EU-15	23 236	100.0	24 050	100.0

Figure 10: PPP-GDP and GDP, 2001

5.1 Another Migration Model

Similar to Harris and Todaro, Brücker, Alavarez-Plata and Siliverstovs develop the migration function[18] as

[18]The dynamic migration model of [BrAS03] adds some lag variables to consider effects of the population already living abroad.

Finding the best econometric estimators very much depends on the data set used. The model developed in [BrAS03] is based on two data sets:

Germany 33 years of immigration to Germany from 19 source countries

EU 15 8 years of immigration to 15 destination countries from 20 source countries

For the German data sample a further lag of the endogenous variable is included in order to impose less restriction on the adjustment process. For the European sample, the model is restricted to one lag in order to avoid losing any further time-series observations.

The error term is a one-way error-component model $u_{fht} = u_{fh} + v_{fht}$ where u_{fh} is country-specific and v_{fht} is white noise. $mst_{fht} = \alpha + (1-\delta)mst_{fh,t-1} + \beta_1 ln(\frac{w_{ft}}{w_{ht}}) + \beta_2 ln(w_{ht}) + \beta_3 ln(e_{ft}) + \beta_4 ln(e_{ht})) + \beta_5 ln(P_{ft})) + Z_{fh}\delta + u_{fht}$

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	unemployment rate in % of labour force											
Slovak Republic	1.6	11.8	10.4	14.4	14.8	13.1	12.8	12.5	15.6	19.2	17.9	18.6
Poland	6.5	12.2	14.3	16.4	16	14.9	13.2	10.3	10.4	13.1	15.1	17.4
Bulgaria	1.8	11.1	15.3	16.4	12.8	11.1	12.5	13.7	12.2	16	17.9	17.3
Lithuania	na	na	3.5	3.4	4.5	7.3	6.2	6.7	6.9	10	12.6	12.9
Slovenia	na	10.1	13.3	15.5	14.2	14.5	14.4	14.8	14.6	13	12	11.8
Czech Republic	0.7	4.1	2.6	3.5	3.2	2.9	3.5	5.2	7.5	9.4	8.8	8.9
Romania	1.3	3	8.2	10.4	10.9	9.5	6.6	8.8	10.3	11.5	10.5	8.6
Hungary	1.7	7.4	12.3	12.1	10.9	10.4	10.5	10.4	9.1	9.6	8.9	8
Latvia	na	na	2.3	5.8	6.5	6.6	7.2	7	9.2	9.1	7.8	7.7
Estonia	na	na	1.6	5	5.1	5	5.6	4.6	5.1	6.7	7.3	7.2
CEEC-8	4.2	9.3	11.0	12.7	12.4	11.9	11.0	9.7	10.2	12.5	13.4	14.6
CEEC-10	3.4	8.1	10.7	12.5	12.1	11.3	10.2	9.8	10.4	12.5	13.1	13.5
memo items												
Cyprus	1.8	3.0	1.8	2.6	2.7	2.6	3.1	3.4	3.4	3.6	3.5	3.5
Malta	3.8	3.6	4.0	4.5	4.1	3.8	4.4	5.0	5.1	5.3	4.5	4.9
Turkey	8.2	7.9	7.9	7.6	8.1	6.9	6.1	6.4	6.8	7.6	6.6	7.9

Figure 11: Unemployment rates, 1990-2001

$$mst_{fht} = f(w_{ft}, w_{ht}, e_{ft}, e_{ht}, P_{ht}, Z_{ht}) \quad (15)$$

We can see the connection with Harris and Todaro's model[19] since mst_{fht}, the share of migrants from country h residing in country f in per cent of the home population P_{ht} depend on the

Wage in foreign and home country (w_{ft} and w_{ht}) and

Employment in foreign and home country (e_{ft} and e_{ht})

Z_{ht} is a vector of time-invariant variables capturing the causes of migration between two countries, i.e. the costs of migration, like travel restrictions and difference in culture and language.

5.2 Migration from CEEC 10

The results of Brücker, Alavarez-Plata and Siliverstovs research are shown in Figure 12, Figure 13 and Figure 14.

[19]Harris and Todaro assumed employment in rural area to be 1.

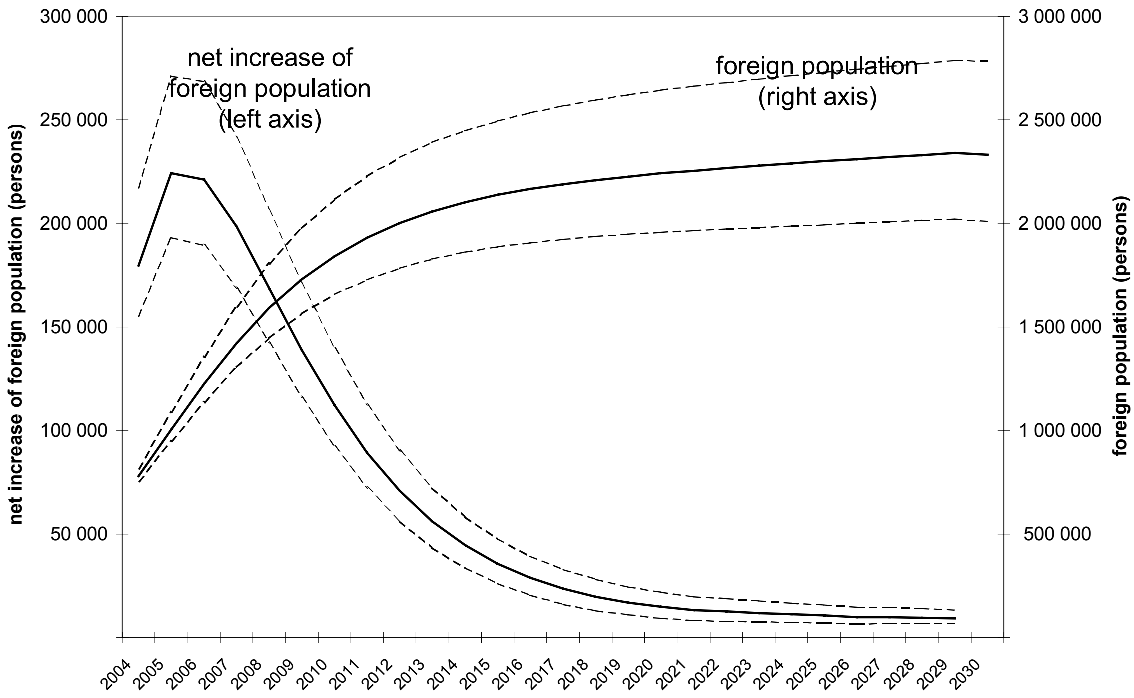

Figure 12: Migration scenarios for Germany

5.2.1 Migration from CEEC 10 to Germany

Figure 12 shows the simulations results for migration from CEEC 10 to Germany. The results are based on the German data set and the assumption that free movement is introduced for all ten CEECs in 2004. The results vary between 1.8 and 2.4 million residents from the CEEC 10 in Germany ten years after free movement has been introduced, and between 2.2 and 3.0 million residents 20 years after introducing free movement.

5.2.2 Migration from CEEC 10 to EU 15

Since the geographical distribution of the migrant population across European countries are quite stable over time we can extrapolate the results for Germany to the EU 15. We can expect this procedure to yield significantly more plausible results than simulations based on the European data set.

The migration from CEEC 10 to the EU 15 as shown in Figure 13 yields an initial net increase of the foreign population from the CEEC 10 of 294,000 persons. The net increase reaches its peak at around 370,000 persons. The

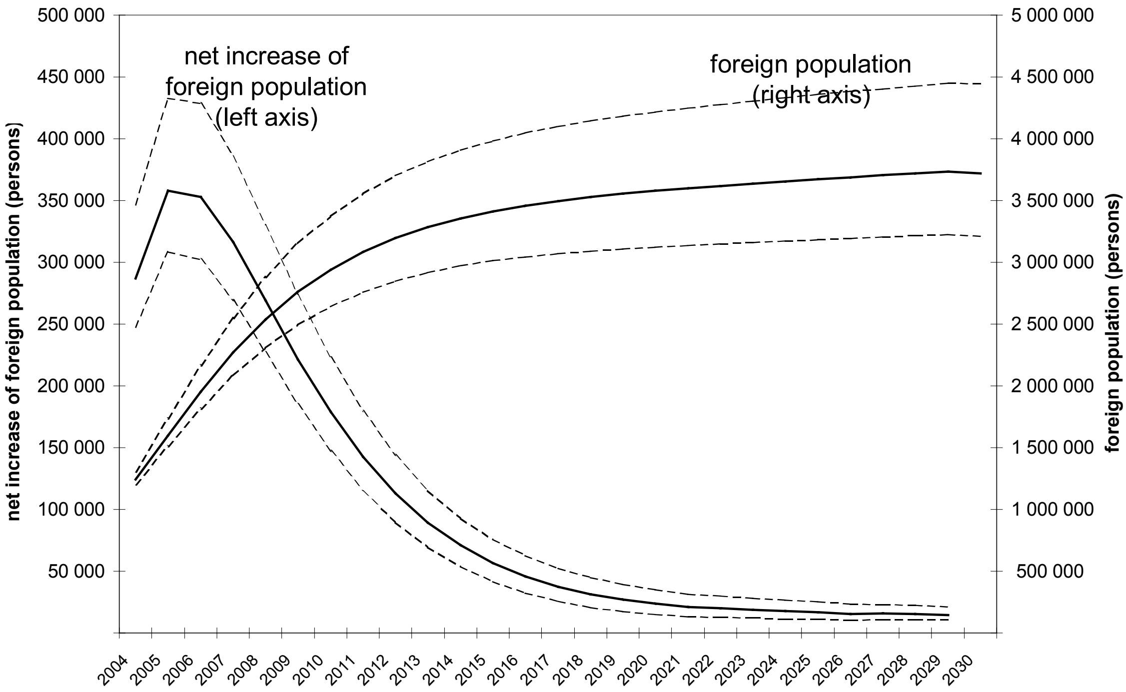

Figure 13: Migration scenarios for the EU15

long-run stock of migrants is estimated to number 3.8 million persons.

Note that less than 40 per cent of the foreign residents from the CEEC 10 are employees at present.

5.3 Simulation of Transitional Periods

The transitional period, meaning a delay of free movement for new members is another aspect analyzed by Brücker, Alavarez-Plata and Siliverstovs. Germany and Austria are examples countries taking full advantage of this transitional periods.

Figure 14 shows the impact of transitional periods in Germany of two years, five years and seven years for the CEEC 8. For Bulgaria and Romania the introduction of free movement in 2007, and transitional periods of another five and seven years are assumed.

Postponing free movement from 2004 to 2006, 2009 or even 2011 yields only a marginal reduction in the net increase of migrants after free movement has been introduced. The migrant stocks tend to converge relatively rapidly to their long-run levels in the different scenarios. Thus, postponing free movement neither reduces net migration flows in the initial years after liberalisation nor does it affect the long-run stocks of the foreign population.

Unfortunately Brücker, Alavarez-Plata and Siliverstovs do not assume any effects of those policies on economic growth and employment rates. If transitional periods are extended, or in the case of Bulgaria and Romania EU membership is postponed, economic growth in the CEEC 10 could decline. Leading to higher migration.

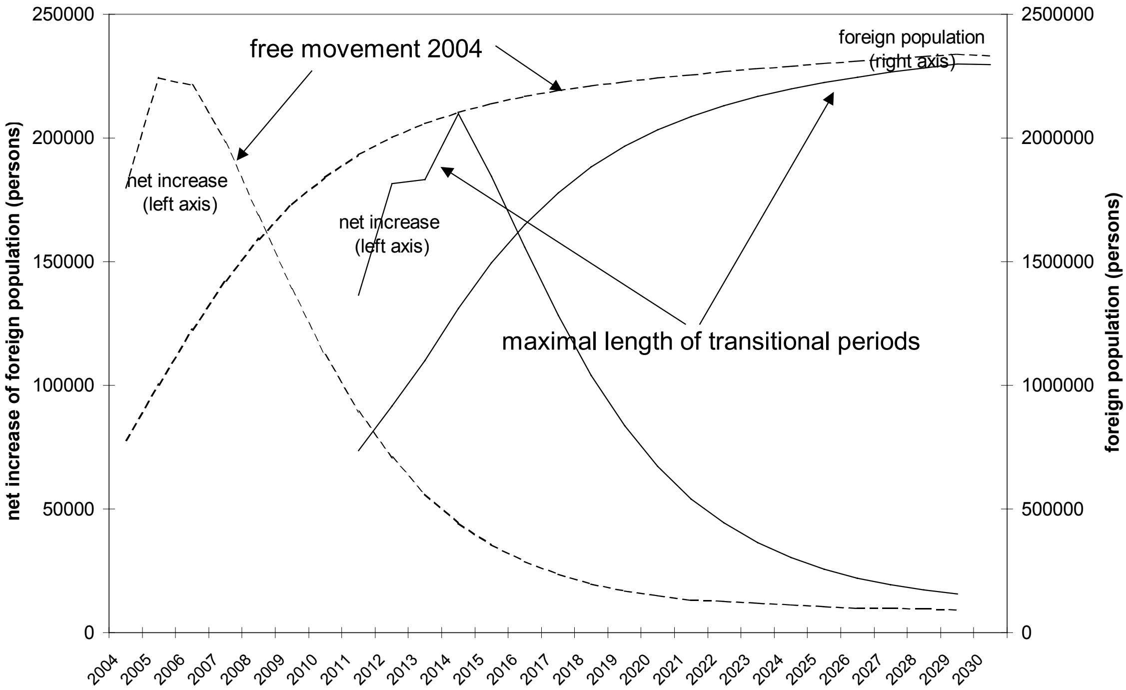

Figure 14: Migration scenarios for the EU15

5.4 Conclusion

Brücker, Alavarez-Plata and Siliverstovs use two data sets with very different time horizons. The German sample comprises 32 years of immigration to Germany from 19 source countries and the European sample with eight years of migration between 215 countries. The best estimator for the German sample is the SUR (Seemingly Unrelated Regressions) estimator, while the

GMM (Generalized Method of Moments) estimator shows better results for Europe.

The results show an net increase in the number of foreign residents from the CEEC-10 in Germany -which roughly equals the net migration flow- is estimated at 180,000 persons immediately after the introduction of the free movement and ca be expected to reach its peak at around 225,000 persons one year later. The long-run migration potential is estimated at 2.3 million persons, which will be reached 25 years after free movement has been introduced.

These simulations are based on the assumption that per capita GDP levels converge at an annual rate of 2% and that the employment rates in Germany and the CEECs will remain constant at their average levels from the second half of the 1990s.

The estimates based on the European sample are much less precise than those based on the German sample and Brücker, Alavarez-Plata and Siliverstovs abstain from basing simulations on that data.

Extrapolation of the German sample to the EU-15 yields better results. An initial net increase of residents from the CEEC-10 of 294,000 persons, which reaches its peak at almost 370,000 persons one year later. The long-run stock is estimated at 3.8 million persons. This results relay on the assumption that present distribution of migrants from the CEECs across the individual EU Member States remains constant.

Interestingly, the transition period applied by Austria and Germany fails to avoid possible pressure from migration on the labor market. Since the migration stocks converge rapidly to their long-run levels. And, more generally Brücker, Alavarez-Plata and Siliverstovs show that migration responds rather quickly to changes in GDP and employment growth.

6 An n-Sector Migration Simulation

6.1 Introduction

This simulation is based on interacting *agents*, representing *workers* and *firms*. Agents are placed in various sectors and can than migrate to sectors where they expect higher income.

Each agent forms his decision independently from other agents. There is no communication between agents. Agents form their decisions based on wage expectations defined by various strategies.

As will be formalize later, wage in country L is given by $w_L = F_L/N_L$, yielding a negative relation to the number of people N_L in L and a positive relation to the number of firms F_L in L. More workers means more competition for jobs and therefor lower wages. The reverse is true for firms. More firms, competing for a constant number of workers, lifts wages.

6.2 The Model

6.2.1 Workers following higher Wages

A worker will migrate from A to B if his expected lifetime income in sector B minus his migration costs $c_{A\to B}$ is greater than his expected lifetime income.

$$A \xrightarrow{c_{A\to B}} B$$

$$E(\Phi(B)) - c_{A\to B} > E(\Phi(A)) \tag{16}$$

Migration costs $c_{A\to B}$ capture all parts of the migration from sector A to sector B. Another sector may be another village, state, country or continent. This costs include direct costs like transportation, immigration and working visa as well as indirect cost like leaving family and friends behind or the life with a new culture and language (see chapter 4.2 for more details and estimates on migration costs).

Obviously costs differ a lot. Migrating from Salzburg to Vienna or from Pyongyang to Washington D.C. certainly makes a difference. For workers *and* firms. In case of migration from A to B via Z costs of migration just add up.

In this simulation migration cost must be payed by the agents savings S. Workers and firms accumulate savings from their income over time. Saving

$$A \xrightarrow{c_{A\to Z}} Z \xrightarrow{c_{Z\to B}} B = A \xrightarrow{c_{A\to Z} + c_{Z\to B}} B$$

equals the sum of past income minus past expenses in form of migration costs.

Therefor migration is only possible if equation (17) and (16) are satisfied.

$$c_{A\to B} < S \tag{17}$$

Abstracting from any consumption may seem harsh but consumption is not key for this simulation and instead of arbitrarily assuming some consumption, fixed or as percentage of income, we can as well just leave it out[20].

Lifetime income Φ is the sum of all discounted future wages. Expected[21] lifetime income for workers in sector L is

$$E(\Phi(L)) = \sum_{n=0}^{\infty} \beta^n E(w_{t+n,L}) \tag{18}$$

6.2.2 Firms following lower Wages

Firms, like workers, try to maximize expected lifetime income. Therefor firms will just as well migrate from A to B if equation (16) and (17) hold.

Migration cost $c_{A\to B}$ for firms are different than migration cost for workers but never the less follow the same logic. Capturing distance and differences in (work) culture, language, government regulations, accounting rules, taxes and so on. Again collected in $c_{A\to B}$.

The number of workers n_L is equal for all firms in sector L

$$n_L = \frac{N_L}{F_L} \tag{19}$$

Profit π_L for firms in sector L is given by a simple production function with decreasing return of scale for labor n_L (the number of worker as the only input) minus the cost of labor $n_L w_L$.

$$\pi_L = Log(n_L) - n_L w_L \tag{20}$$

[20]To account for different costs of living, it makes more sense for this setting to see income as money left after consumption.

[21]Expectation: $E_{t+1}(a_t) = E_t(a_t) = E(a_t)$ but $E(a_t) \neq E(a_{t+1})$

Therefor the expected lifetime income for firms in sector L is:

$$E_L(\Phi) = \sum_{s=0}^{\infty} \beta^s (Log(n_{L,t+s}) - n_{L,t+s} w_{L,t+s}) \tag{21}$$

Maximizing profit π_L for the number of employees n_L in (20) yields $w_L = 1/n_L$. With $n_L = N_L/F_L$ we can now derive the wage paid by firms in sector L to be

$$w_L(N_L, F_L) = \frac{F_L}{N_L} \tag{22}$$

All firms share the same production function (20) and employee the same number of workers. Therefor wages payed in sector L are equal for all agents in L.

6.2.3 Wage Expectations

The behavior of workers and firms in this setting can be modeled as inductive behavior. Analog to the *El Farol Problem* [Arth94] where Arthur stated:

> First, if there were an obvious model that all agents could use to forecast (wages) and base their decisions on, then a deductive solution would be possible. But this is not the case here. Given (wages) in the recent past, a large number of expectational models might be reasonable and defensible. Thus, not knowing which model other agents might choose, a reference agent cannot choose his in a well-defined way. There is no deductively rational solution - no correct expectational model. From the agents viewpoint, the problem is ill-defined and they are propelled into a world of induction. Second, and diabolically, any commonalty of expectations gets broken up: If all workers believe *few* will go to B (therefor yielding higher wages in B), all will go to B driving wages *down*. But this would invalidate that belief. Similarly, if all believe *most* will go, *nobody* will go, invalidating that belief. Expectations will be forced to differ.

Agents form their wage expectations based on past wages as collected in the knowledge matrix W. Going from period 0 till period t and sector 1 till sector M.

$$W = \begin{pmatrix} w_{1,t} & w_{2,t} & \dots & w_{M,t} \\ w_{1,t-1} & w_{2,t-1} & \dots & w_{M,t-1} \\ \vdots & \vdots & \ddots & \vdots \\ w_{1,0} & w_{2,0} & \dots & w_{M,0} \end{pmatrix}$$

Agents have access to certain parts of the knowledge matrix W depending on their inherited strategy. Strategies are randomly assigned to each agent. In the following list $E(w_{L,t})$ is the expected wage for sector L.

Strategies

- the same as last period: $E(w_{L,t}) = w_{L,t-1}$
- the average of the last three periods: $E(w_{L,t}) = [w_{L,t-1} + w_{L,t-2} + w_{L,t-3}]/3$
- the same as two periods ago: $E(w_{L,t}) = w_{L,t-2}$
- the average of all last period wages: $E(w_{L,t}) = \sum_{i=0}^{M} w_{i,t-1}/M$ where M is the number of different sectors
- the inverse of last period: $E(w_{L,t}) = -w_{L,t-1}$
- random walk[22]: $E(w_{L,t}) = random(w_{t-1})$
- ...

An analog set of strategies will be applied for $E(\pi_{L,t})$.

Each worker will choose the sector with the highest (expected) wage

$$L^* = Max(E(w_{1,t+1}), E(w_{2,t+1}), \dots, E(w_{M,t+1}) \quad (23)$$

Each firm will choose the sector with the highest (expected) profit

$$L^* = Max(E(\pi_{1,t+1}), E(\pi_{2,t+1}), \dots, E(\pi_{M,t+1}) \quad (24)$$

Agents compare their expected lifetime income in L^* with the expected lifetime income in their current sector L_c and will migrate from L^c to L^* if they can improve their income as stated in equation (16) and afford to migrate as stated in equation (17).

[22]Random walk, i.e. an agent randomly picking sectors, will be an important control group. Successful predictors should out-preform random walk.

6.3 Results of the Simulation

Using the *Repast Agent Simulation Toolkit* I wrote a simple simulation capturing the above model. The implementation follows the outline stated in 3.4.

First migration is simulated with fully informed and rational agents. Subsequently those assumption will be relaxed as agents information will be limited and their rationality bound.

6.3.1 Wage Convergence

Lets start with a setting of three sectors. In population and wage structure somehow aligned to the EU-15, the CEEC and Turkey (actual data is given in chapter 5).

Sector	Workers	Firms	Initial Wages	Initial Profits
EU-15	39000	10000	0.25	0.36
CEEC	7500	1000	0.13	1.01
Turkey	7000	700	0.10	1.30

Table 3: Configuration of computational model

Initially wages in figure 15 are highest in the EU-15, lower in the CEEC and still lower in Turkey. Profits, due to lower wages are initially highest in Turkey, than the CEEC and lowest in the EU-15. Since migration is costly and needs to be paid by agents savings, it takes till till $t = 8$ before agents can afford to migrate.

Migration starts with workers leaving the CEEC for the EU-15. This emigration causes wages to rise and profits to fall in the CEEC, and vice versa in the EU-15.

At $t = 11$, attracted by higher profits, firms start migrating to Turkey, causing Turkish wages to rise and profits to fall.

At $t = 18$ wages and profits are balanced between the CEEC and Turkey, causing them subsequently to move synchronized.

By $t = 22$ a new equilibrium is reached. Wages are still highest in the EU-15, but have fallen as wages in the CEEC and Turkey have risen. At this point, income differentials equal the costs of migration. Interesting to note: in this

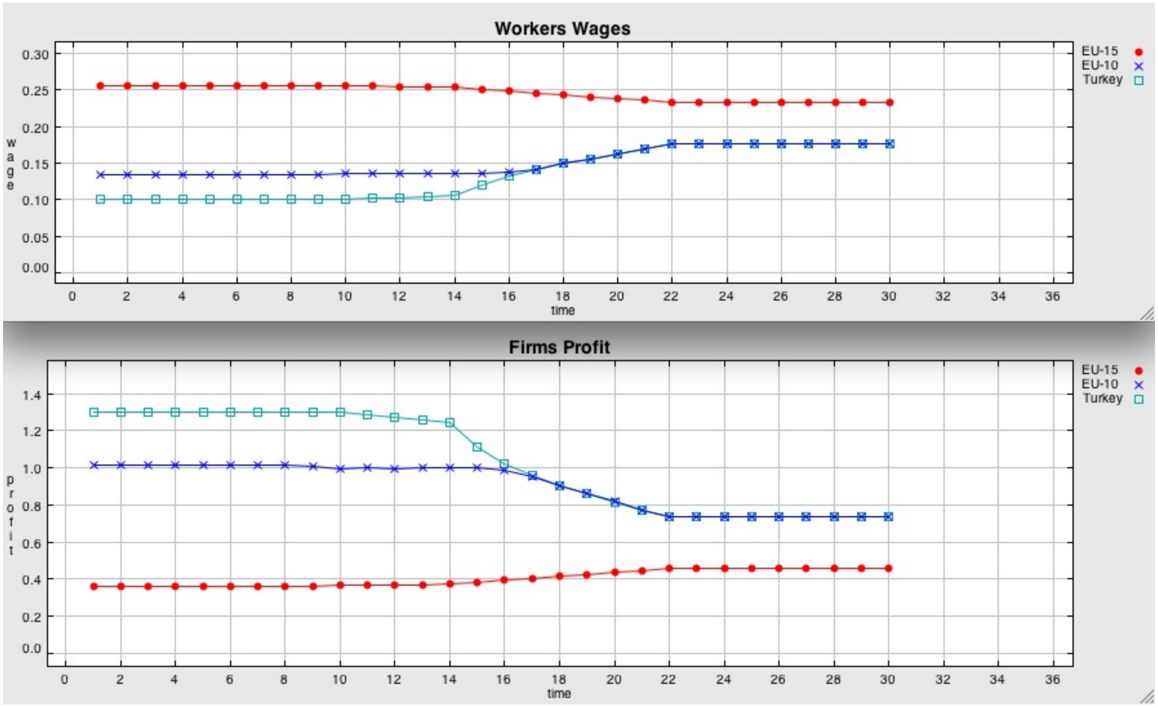

Figure 15: Wage Convergency with Migration Costs

setting wages of workers in EU-15 have fallen by equal proportions as profits of firms have increased.

A rerun of the simulation without costs of migration is shown in figure 16. This setting brings faster wage convergency and ends up in a equilibrium with equal wages (and equal profits) for all sectors.

Clearly migration improves homogenization of wages.

6.3.2 Social Networks and Information Constraints

The next step in this simulation is to limit the scope of information available to each agent. As we saw in Axtells agent based simulation in chapter 3, we can constrain information by including a social network. A list of friends.

In the simulation above, all agents had full information about all sectors. They could therefor quickly identify the sector with the highest income and migrate there as soon as possible.

Now agents only know about sectors where they have friends. I.e. inside

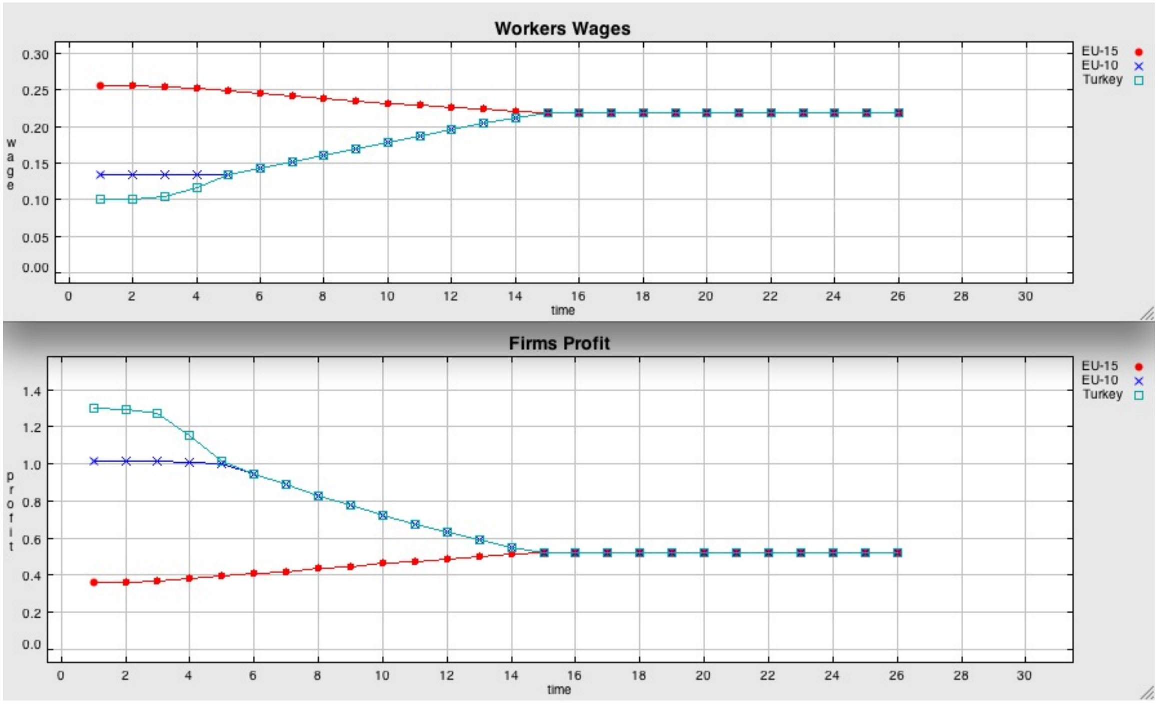

Figure 16: Wage Convergency without Migration Costs

their social network. The constraint of information extends to migration. If an agent doesn't know about another sector, he can not migrate. Clearly the more friends an agent has, i.e. the bigger his social network is, the quicker he can find the sector providing the highest income.

Figure 17 shows the relation between the size of the social network (the number of friends each agent has) on the horizontal and the resulting time laps till a wage equilibrium is reached on the vertical axis.

Without a social network (number of friends per agent = 0) no migration is possible and therefor wages cannot converge. But even in the smallest possible social network (number of friends per agents = 1), wages converge as in the previous setting and ultimately reach an equilibrium. In the case of one friend per agent, the equilibrium is reached after 46 periods. For two friends it takes 31 periods. For three only 25. As the size of social networks increases, wage equilibrium is reached faster. The relation between social network size x and periods till an wage equilibrium is reached follows an e^{-x} shaped distribution as shown in figure 17.

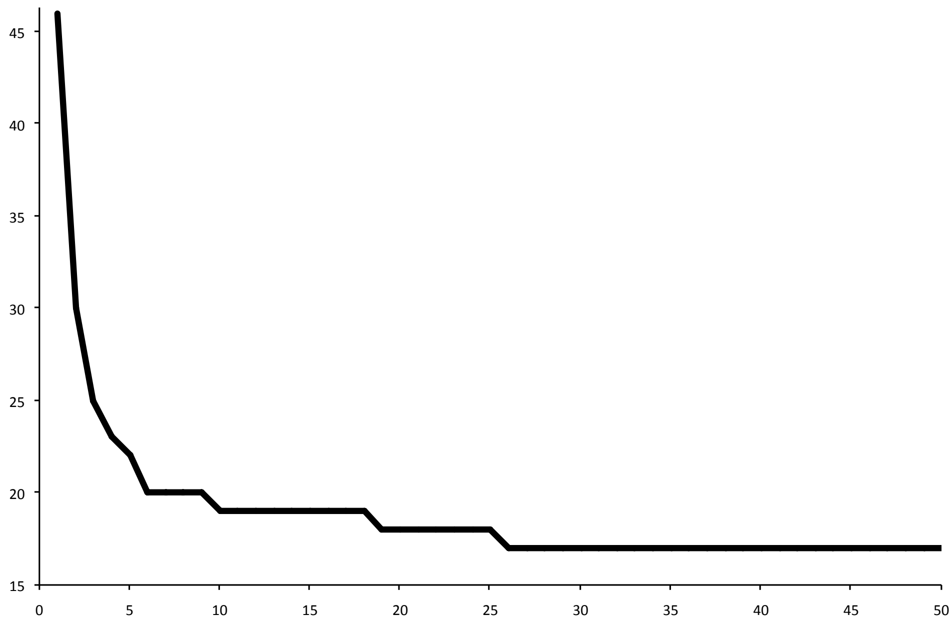

Figure 17: The number of periods until reach wage equilibrium is reached (vertical axis) decreases with an increasing number of friends per agent (horizontal axis).

6.3.3 Bounded Rationality: Strategies on Wage Expectation

The simulations above assumed perfect rationality on side of the agents. In this section (as discussed in section 6.2.3) we will relax that assumption and compare various strategies on making migration decisions. With some strategies less rational than others.

Highest Income Strategy This is the strategy applied during the previous simulations. Agents migrate to sectors with the highest lifetime income[23], assuming current wages stay constant.

Random Walk Strategy Agent randomly change sector if they are able to do so. Their migration is only constraint by their savings and social network.

Lowest Income Strategy Comparing incomes from all sectors, agents will migrate to sectors with the lowest income known in their social network. Again provided their savings can cover the costs of migration.

[23]Lifetime income $\Phi(L) = \sum_{n=0}^{m} \beta^n w_{t+n,L}$ is calculated with a discount factor $\beta = 1$ over $m = 10$ periods instead of ∞ as stated in 6.2.

Do Nothing Strategy With this strategy, agents do not migrate. They keep working in their current sector and accumulate their savings.

The *Highest Income Strategy* was already analyzed as the default strategy above. Next lets look at a *Random Walk*:

Every period agents collect their income and accumulate savings. As soon as an Agent stocks up enough money to migrate he will randomly choose a new sector among those known to his social network.

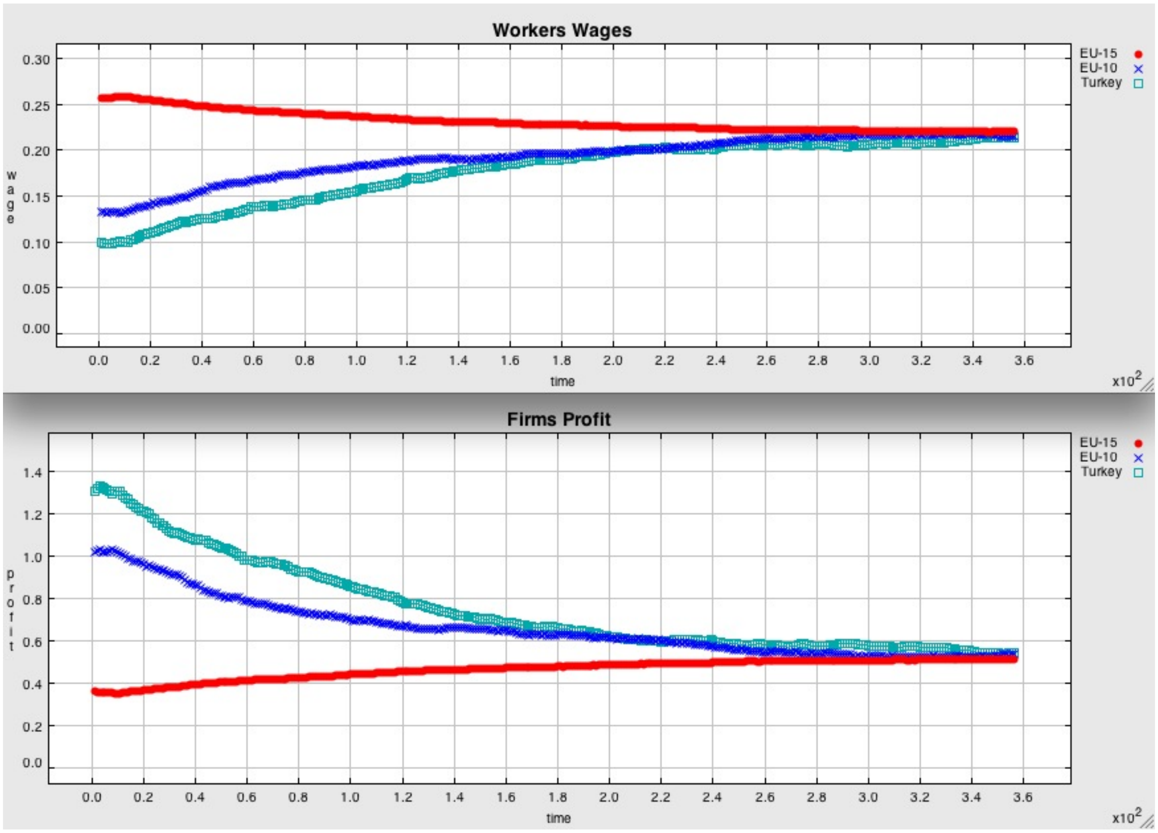

Figure 18: Random Walk

Although migration appears random, we can see in figure 18 that wages and profits tend towards an equilibrium. Clearly this due to the nature of dividing two function effected by random values. The number of firms and the number of workers in each sector.

Agents following the *Lowest Income Strategy* keep migrating to sectors with the lowest income. The results, terms of wages and profits can be seen in figure 19.

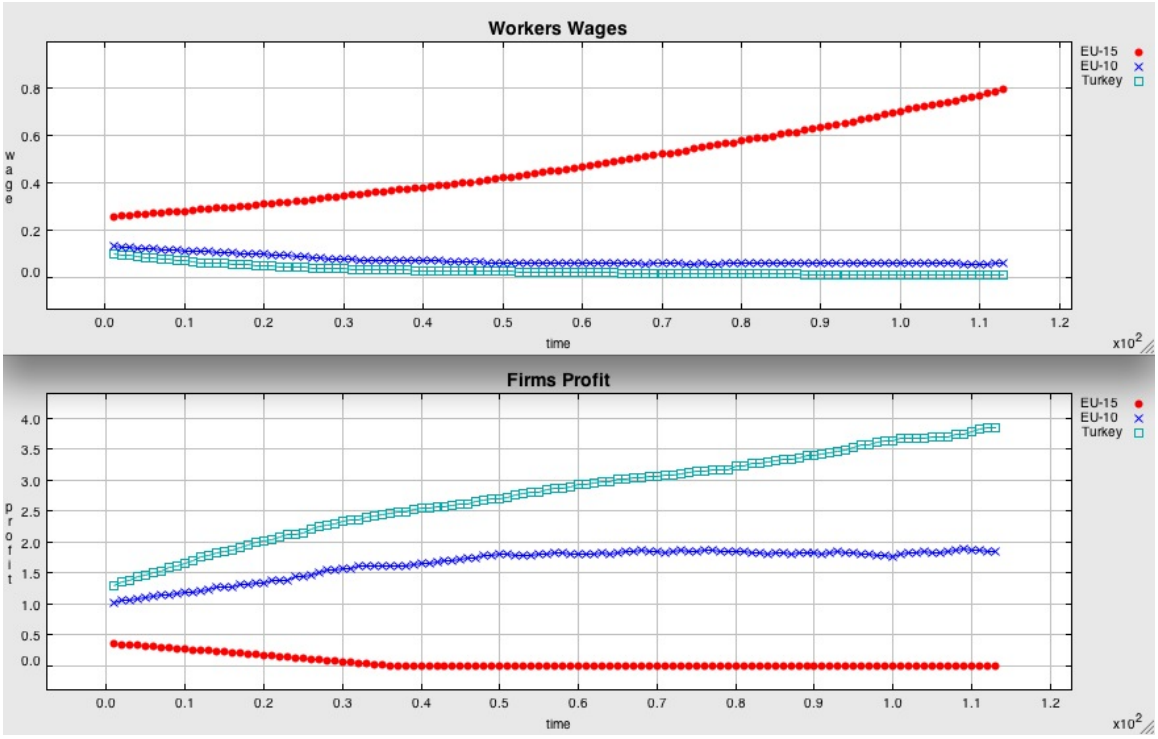

Figure 19: Lowest Income Strategy

Since agents take the reverse decisions of the Highest Income Strategy wages and profits develop in reverse as well. Instead of convergence we find divergence, with wages and profits growing apart until one sector captures all the wages and another captures all profits.

Combining all four strategies in one simulation yields convergency as we saw for the Highest Income Strategy, although shakily (that's the Random Walk part) and slower with the convergence (since the Lowest Income Strategy pushes for divergence).

What is more interesting is the comparison of the affect the four strategies have on the savings of the agents applying the strategies. Which strategy yields the best returns? Figure 20 shows the accumulated savings of agents, grouped by their inherited strategy. To highlight differences, the plot shows the deviation from average agent saving.

Initially doing nothing seems to be the best strategy. However starting at $t = 45$ Highest Income becomes the most profitable strategies for those agents applying it. Random Walk yields slightly below average savings, and the irrational Lowest Income Strategy turned out -as expected- with the lowest

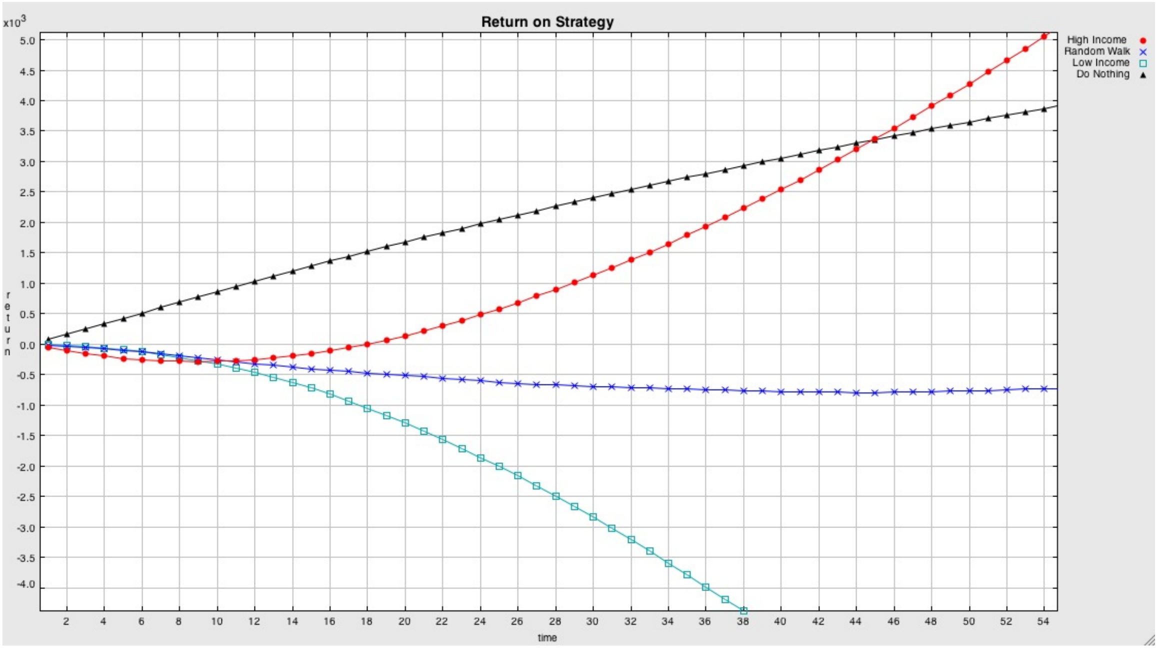

Figure 20: Saving by Strategy, as deviation from average agent savings

savings.

For details on running a simulating based on your own parameters, consult section 7.1 on how to run a simulation.

6.4 Conclusion

This work started with a *Two-Sector Migration Model* inspired by Harris and Todaro's [HaTo70] and applied Agent Based Simulation aligned to Axtell's *Emergence of Firms* to extend it to an n-Sector Migration Simulation.

Challenges with the simulation:

- *Complexity*: The amount of data coming out of simulations is enormous. Consider the following setting. Their are v variables to monitor (number of workers and firms in each sector, wages of workers, profits of firms, gross product of sectors, return of strategies,...) in l sectors, with a agents, s strategies, during t time slots and r runs of the simulation. Therefor each simulation gives $v * l * a * s * t * r$ data sets to monitor[24].

Repast has good visualization tools which provided me with the graphs of in this chapter. But one still has to work thru data sets to comprehend results of simulations.

Ergo, complexity quickly becomes the key challenge. Even for small simulations like this.

- *Parameters*: This simulation is based on external parameters. Costs of migration, distribution of agents, number of firms,...

  One is tempted to "design" the parameters in order to produce the results one is looking for. If the results are unrealistic, it might be easier to fiddle with the parameters than reanalyze and possibly rewrite the model.

  It's like choosing the assumption afterwards to produce the expected result.

Possible extensions:

- As noted at the end of chapter 3 the integration of a full market between firms (and sectors) determining prices and wages is omitted in this simulation. However inclusion of an *output market* would allow to simulate growth, a key part of current migration discussions.
- A further step would be to deal with with complexity. Better visualization might help. The movement of workers could we visualized on a map.
- *Evolutionary approach:* If agents prosper and die, strategies can mutate and evolve to yield better (fitter) strategies of forming wage expectations. Better strategies will survive and propagate.

[24]Even a minimal setup, as in this case has $v = 6, l = 4, a = 210, s = 4, t = 2000, r = 30$ and yields more than a billion data sets.

7 Appendix

7.1 Running the Simulation

The reader is encouraged to run her own simulation. Doing so is simple:

1. download the required files[25]
2. unpack the downloaded zip archive
3. execute the shell script *compile_run*

After a fresh compile the application will start with a control screen analog to figure 21.

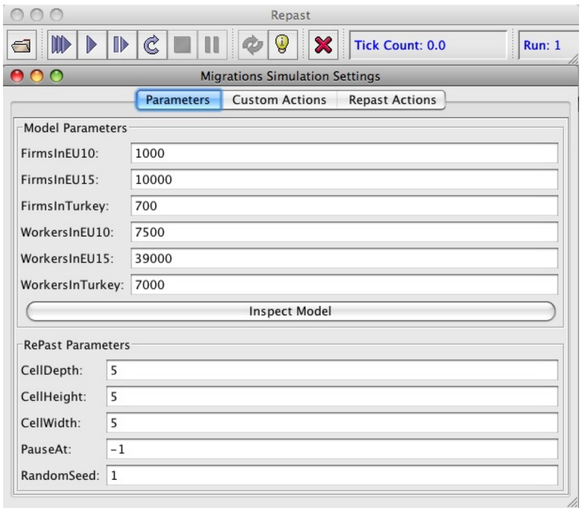

Figure 21: Screenshot - Simulation Control

The top control row includes the following items:

Load Model: Clicking on the folder button will display a dialog for loading a simulation model into Repast.

Start Multi-Run: The start multi-run button starts a batch run of a simulation.

[25]http://www.derbaum.com/tu/migration-simulation.zip

Start: The start button starts the simulation when it is paused or has not yet been started, iterating through the scheduled behavior.

Step: The step button starts the simulation when it is paused or has not yet been started, iterating through a single iteration the scheduled behavior.

Initialize: The initialize button starts the simulation but pauses before iterating any scheduled behavior.

Stop: The stop button stops the simulation.

Pause: The pause button pauses the simulation.

Setup: The setup button "sets up" the simulation by executing the user defined setup code.

View Settings: The view settings button will display the various model settings panel if it is hidden or destroyed.

Exit: The exit button will shutdown the simulation and exit.

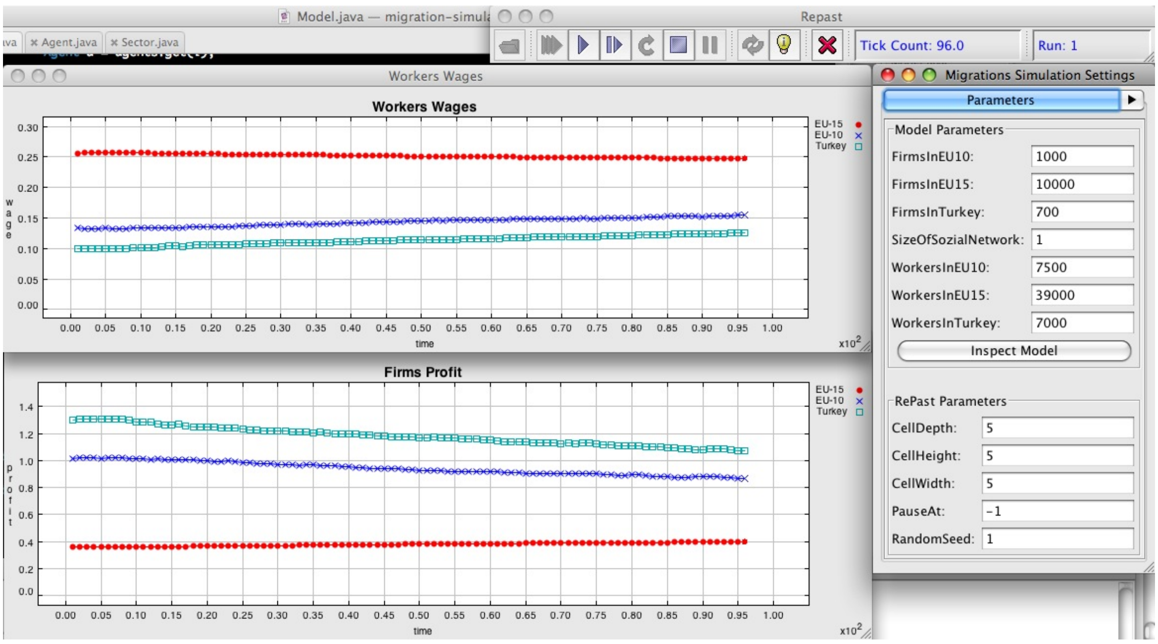

Figure 22: Screenshot - n-Sector Migration Simulation

To run a simulation click either the start, step or initialize button. If you clicked the initialize button, you can than click step or start. When you want to stop the simulation and then run it again, you click stop and then the setup button.

You can provide your own parameters to simulate your own migration setting.

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