Inequality and Aid

Simulating the correlation between economic

inequality and the effect of financial aid

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Introduction

The issue of economic inequality has been present in economic thought since the beginning. Adam Smith's groundbreaking book, Wealth of Nations focuses on the process through which a nation gathers it's wealth. This is the first description of the market forces (he used the term "Invisible hand"), and he argues, that it is both efficient and morally correct that there is inequality present in an economy, since it is the inherent method through which the good (the industrious) get their reward and the bad (the "lazy", the inefficient) get punished.

Over the past centuries the true efficiency of the free market has been questioned numerous times (although the work of Marx is the most obvious in this regard, it was neither the first nor the most detailed description of the market deficits). It has been proved time and again that there are factors disregarded by the "invisible hand", and these lead to serious social frictions. There have been attempts to remedy this problem, but there is no single, efficient solution. It can be argued, that the morality behind the last century's communist governments has been to eradicate the inequality of the system, and the frightening truth is, that where this was successful (mostly in East-Germany), the people felt oppressed and violated[1].

Since Keynes' time, the role of the central governments have been redefined. Keynes showed, that the government can, and should influence the economy, and since then it has become one of the most prominent role of a nation's government to ensure the steady growth of the nation. The emergence of the "social" states are another attempt in this new framework to lessen the inequality: through a strong redistribution these governments tax the rich and provide for the poor. For a long time this seemed the ideal compromise between the market-ruled societies focused on efficiency and the ideal communist societies focused on equality. Slowly, however, it became apparent, that the social societies have to face ever-increasing financial problems that resulted from the aging of the population (fueled by better medical services for the public and the decrease in the willingness to bear children).

Another great economic problem of the past century has been the ever-widening gap between the developed and third-world countries. This resulted in the same friction internationally that developed in the early nineteen hundreds within countries. The thought arose: try to solve these international issues the same way the national problems were dealt with: through wealth redistribution. This gave rise to the international aiding movement, where rich countries provided the low-income countries with additional wealth. The initial expectations have proved wrong, however, since aiding caused more problems than it solved.

This paper aims to show the inherent problem with financial aid, and the close ties between it's inefficiency and the inequality within the receiving nation. A modeling framework will also be shown, that lays down the path of my future work: to show the exact relationship between the aiding process and the inequality.

1It is true, that the whole communist system contained a large amount of oppression, but societies based on dictatorships often do. It was easy to see, however, that during the communist times the quality of life in the most market-based Hungary was a lot higher than in the most equalitarian East-Germany.

Financial Aid

The issue of financial aid is not a straightforward one. Why do the developed nations help the underdeveloped? Is it to win the goodwill of their people? To build up foreign markets for their own products? To prevent large-scale immigration? Whatever the motive, the theory is simple: giving money to low income countries will improve their quality of life.

It is obvious, that there are many moral and theoretical problems of such a statement, since it implicitly assumes that faster economic growth equals higher quality of living. In reality, many factors have to be taken into consideration (the utility function of the individuals in question[2], the aggregation of the utilities in the economy[3], etc.), but we usually disregard these, since they are not easy to describe numerically.

Even if we agree, that faster growth is better, one would have to know two things before resorting to aid: what determines growth, and how can this growth be affected.

Most models of financial aid use the neoclassical growth theory[4], that states, that stable economic growth depends on the population growth rate and corresponding capital growth rate. Based on this theory, an economy grows too slow if it does not have sufficient funds to provide the necessary capital investment to keep the country on the sable growth path.. From here the theory of aid is easy to deduct: investment has to be financed from an outside force, what would allow the nation to grow faster. A nearly similar result can be deducted from Martinás' new microsynthesis[5]: the growth of money and the possible growth of capital can result in faster economic growth.

There are some problems with these theories. The greatest of them is the fact that they do not work. In some nations the outside financial aid resulted in incredible growth of both output and welfare (most notably in the East-Asian region, in Taiwan, Korea etc.), but in a rather larger number of cases, the aid had different results. Even in the best cases financial aid proved to be ineffective, but in some nations it crowded out internal investment, increased consumption (thus reduced savings), developed aid-dependence, and in some case, Dutch disease. This gave rise to a large number of questions, most focused on why this happened, and what could be done against this.

If one examines the countries one-by-one, an other, even more relevant factor emerges. The example of Bosnia shows, that aid expenditure, while not achieving what it was meant to achieve, might result in a significant increase of welfare. The rebuilding of the war-demolished cities might show as an increase in consumption in aggregated macrovalues, but they sure did improve the quality of life. It is simply impossible to expect a nation to live in tents and spend aid on investment.

The motives of financial aid

First of all, the motive of providing financial aid is paramount in the discussion of inequality. There are three main reasons behind aid:

2My favorite example here is the hours worked. It is easy to see that if people worked more, they would produce more goods in the economy, what would make the price level lower and the products easier to export, an overall gain for the economy, resulting in faster growth. At the same time, the people would not enjoy themselves so much as before, meaning that their utility would actually decrease from this change.

3The two corner-solutions are the $\max(U_i)$ and $\min(U_i)$ functions; the first leading to dictatorship (only the dictator's utility matters), the last resulting in an extreme social economy, where everyone's utility would be equal.

4The original model developed by Samuelson and Solow, described in detail in [Meyer, Solt; 2002] and in [Begg, 2003]

5Published in the book [Martinás, Ayres; 2005]

- The **„PR"** reasons:

  „We need to help those less fortunate"

  The societies of the western economies need to be consoled. If they see, that their government does something to aid the low-income countries, they feel better about their leaders, their nation, and ultimately themselves. This serves the purpose of reinforcing their consumer habits which are the cornerstones of our modern societies.

- The **„social"** reasons

  „If we don't help, they come here"

  In our open, global world, the great differences between the quality of life might urge people in low income countries to move to the developed countries. This would obviously result in great inner tensions of the target nations[6]. This could (and is) constrained somewhat with laws against immigration, but the greater the economic differences, the less effect these laws have (while they also have the potential of further deepening the chasm among the nations). It is therefore beneficial to avoid these issues altogether by providing the low-income countries with a way of rising.

- The **„market"** reasons

  „Let's create market!"

  As many argue, the true reason behind financial aid might be the desire to create new markets for the goods of the western countries. If the growth rate of low income countries can be increased, this means that they become able to pay for the western products.

The effect of aid on inequality

For our, inequality-based purposes the last motive is the important one. If the aid is provided to create marketplaces, it is not irrelevant how it penetrates the society.

- If the aim is a short-term boost to the western economy, then it is sufficient that the receiving country spends the aid in the advanced countries. Although the theory behind the aiding process presumes that with the help of aid it will become possible to acquire more productive technology to work with, that would result in the desired faster growth and welfare, it is just as good if the money is spent in a non-productive fashion. This can be observed in some low-income countries, where the aid is spent on weapons[7] on consumer goods. The spending on consumer goods is usually done by a few members of the central government (or by king), thus *increasing* the inequality within the nation.

- If the aiding process aims to create a long-term market for western consumer goods, it is easy to see that the optimal behavior is a lot different. In this case, the standard of living of the *whole population* has to be increased, since that would result in the expansion of the international

6An easy example is Germany, where there has been bloody clashes among the German majority and the Turkish minority.

7Spending on weapons usually means a stronger military. This causes either aggressive expansionary politics (taking over neighboring countries), or strengthening the central government (the power of the local king/dictator).

market. This obviously means, that the **optimal aiding should reduce the inequality within the receiving nation**.[8]

The above two scenarios describe only the desired effect, however. This is not always how the aid turns out. As Tsikata showed it ([Tsikata, 1998]), financial aid usually increases neither investment nor savings, and the growth rate of the countries starts to lag even worse. The above mentioned aid-dependence means exactly this: the society switches it's consumption behavior to incorporate the financial aid as a source of wealth, and not as a source of investment.

The effect of inequality on growth

There are two main theories regarding the relationship of inequality and growth. The standard theory, founded by Smith in his aforementioned work and developed further by Keynes ([Keynes, 1920]), saving rates are an increasing function of wealth. This can be shown even in the most simplistic keynesian savings function ([Meyer, Solt; 2002]):

$$S(y) = -c_0 + \hat{s}\,y \;\Rightarrow\; s(y) = S\frac{(y)}{y} = \frac{-c_0}{y} + \hat{s} \;\Rightarrow\; s\overset{(+)}{(y)}$$

This means, that inequality channels wealth to the individuals whose marginal propensity to save is higher, thus increasing physical capital accumulation and the speed of development.

The alternative modern approach introduced and proved by Galdor, Zeira and Moav[9] show, that inequality has different effects on the growth of an economy based on the return to human capital. In the early stages of a nation's development economic growth is primarily driven by capital accumulation. During this stage the neoclassical theory persists, and inequality actually fuels economic growth. In later stages, however, as the returns to human capital increases, it becomes the primary engine of growth. Due to it's unique nature, human capital accumulation is larger if it is shared by a larger segment of society, equality becomes a significant factor in economic growth. With the increase of the income, the differences in the savings rates decline and the positive effect of inequality becomes negligible. Again, this can be shown on the primitive savings function:

$$\lim_{y \to \infty} s(y) = \hat{s}$$

Their conclusion is, in case of the low-income countries a bias towards the higher-productivity skill-based industries could mean that equality is more of a drive of economic growth than inequality, if the capital inflow from outwards guarantees the high return to human capital.

8This can be considered a victory of the market. The self-interest of the aid-providing nations lies with the public interest of the aid receiving nation.

9See [Galdor, Zeira; 1993] and [Galdor, Moav; 2002]

The required modeling environment

The aim is to create an environment, where the effects of various kinds of aiding schemes can be shown with regard to growth and inequality. Taking the above factors into consideration, one can draw the outline of the required modeling environment to display all the relevant effects.

- There is a need to measure inequality. This means, that there has to be a state-variable that describes the "wealth" of the individuals in question, to be able to form a measure of inequality.
- There is also a need to measure the individual's level of education, to be able to describe an investment in human capital.
- There is an obvious need to be able to show the output of a nation, and from this have the ability to derive the nation's growth rate.
- There is also a need to induce various forms of financial aid to the nation.

The question remains: what kind of modeling environment could provide this level of flexibility?

Agent-based modeling

Agent-based modeling is a computerized modeling approach, that allows complex models to be constructed in a bottom-up approach. As opposed to standard modeling, the so-called individual- or agent-based models are simulations that describe the global consequences of local interactions of members of population. The individuals can represent many things; from cars in traffic through birds in a flock, to economic agents.

Agent-based modeling is a subset of multi-agent systems, where the complex whole is composed of several, communicating elements. Agent-based simulation differs from the general by being composed of autonomous agents.

Agent- vs. math-based models

In an agent-based model, autonomous individual agents act in a predefined environment, and their behavior as a whole defines the workings of the system. In the standard, math-based modeling, the behavior of the individuals is "averaged together", and this average is described in mathematical terms. The key differences are:

- Creation of the model: in an agent-based model, the creator has to model the behavior of the agents and the communication between them. In a mathematical model, one has to describe the whole system, and all interactions among the individuals has to be incorporated in the model to begin with. This means, that while in an agent-based scenario one can easily test the relevance of the agents (by comparing them to the real-life counterparts), it is hard to test the emergent macro-behavior. In mathematical models it is quite the contrary: the model describes the macro-behavior, that can be tested[10], whereas the underlying assumptions about the individuals remain hidden, and axiom-like.
- Macrobehavior: in math-based modeling it is easy to see, since the model describes it. In an agent-based environment, it has to be deducted from the agents' behavior (it has to be summed somehow)
- Changes of the outcome: Once again, it is easier to see the direct changes in a mathematical model, however these changes might not be the relevant changes. In an agent-based system we can gather information about the changes in the members of the population, and not only in their aggregated behavior.

All in all, agent-based models are more complex, but might be more relevant due to the fact that they are built up bottom-up, as opposed to the declarative construction of the mathematical models.

10See: aid. The model failed.

Adaptive agents

This is where the true power of the agent-based approach lies. Who is to say, that the agents in the system have to be described by static rules? An average agent is described by type characteristics, internalized behavioral norms,

internal modes of behavior and internally stored information about itself and other agents (state information). The internal modes of behavior usually describes the means of communication an agent has and it's decision making rules; and it is rather easy to implement a set of rules that allow the agents to actually learn. As opposed to math-based models, the individual-based models can learn in a distributed fashion, thus more accurately describe thinking entities. In this regard it is irrelevant how they "think", but it is possible to use advanced AI in them, namely neural networks and genetic algorithms, not only the standard if-then structures.

Economic applications

We need to examine the specifics of using the adaptive agent-based modeling technology in an economic context.

The agent-based modeling is very much like a culture-dish experiment: to begin the work, a model economy must be constructed from a set of agents. These agents represent both the economic actors and the environment (social, cultural etc. issues). After the economy is thus initialized, it is left to evolve, and the macrobehavior emerges from the interactions of the agents. There can be no external interaction, only agent-agent interactions are allowed (for example, the price cannot be determined externally; it has to evolve from the decision(s) of one or more agents).

A great many issues arise when modeling an economy in this context. One of the greatest questions is: how do the agents "think", how do they behave? In some cases it is not needed that the agents behave like humans do, thus standard learning algorithms can be used. In other situations (when modeling social interactions), it is crucial that the agents behave as humans do, so new types of learning algorithms must be used.

It is also non-trivial to develop the protocols used among the agents. These protocols define the marketplaces (and off-the-market transactions) among the agents in the model, so it has great impact on the actual outcome of the simulation. A related issue is the formation of trade networks. What algorithms do the agents use to determine trade partners? Do they do it randomly? Do they incorporate past experience?[11]

The use of these experiments, however, promise to provide answers to questions which remain unanswerable in the standard terminology. These include:

- the development of cooperation among agents (does this appear in emergent behavior?)
- the "social utility" of a society is easily calculated, since every agent's utility is known; they can be aggregated using all methods available (this makes it possible to evaluate the outcome of an action using different "preferences", social utility functions.

11 This issue is not unrelated to the "thinking" of the agent. Agents using evolutionary algorithms might choose random partners and evaluate them according to a "fitness" function (more beneficial partners get higher scores, thus will be more likely candidates in the upcoming time). A neural network based agent, however, is less likely to act randomly, and will stick to satisfactory partners more than an evolutionary agent.
The true beauty of the agent-based approach lies in the fact, that it is perfectly easy to create a model economy composed of agents with different behaviors. What's more, the simulation can answer the question: which kind of 'thought" is the more successful?

- the resulting income distribution, the emergent inequality in the economy. (In some models, it is not easy to see the difference between social utility and inequality, but the more kind of agents we use, the more colorful the picture becomes.)
- the effect of interaction networks, channels of information on the emergent economy. (This is, in essence, the relationship between market structures and the emergent macroeconomic behavior.)
- the relationship between legislation and corporate capital structure (where do they get the necessary capital to invest)

The ASPEN model

Finally it is useful to look at one of the most complex agent-based economy model to date: the ASPEN model. It is, in essence, a model of the US economy as a whole.

The early ASPEN model was a rather primitive issue; it only contained market forces: the household (composed of 1000 agents), the "firm", producing food (4 agents), and a government (1 agent). This model was run at a daily decision cycle for 30 simulation years, and it could show a 7-year periodicity in the economy. This alone shows, that the microsimulation is a very powerful tool, and that the model worked according to expectations.

This alone was a great result, but it was far from the intended accuracy. ASPEN was developed to allow:

1. examining the results of legal, regulatory and policy-changes
2. examining the various sectors of the economy independently
3. simulation of the economic agents
4. observing the economy as a whole

and the initial mode was rather far from realizing this ambitious goal.

The next step was to create a more complex model, that could fulfill the promises of the developers. This model needed a more complex structure, that

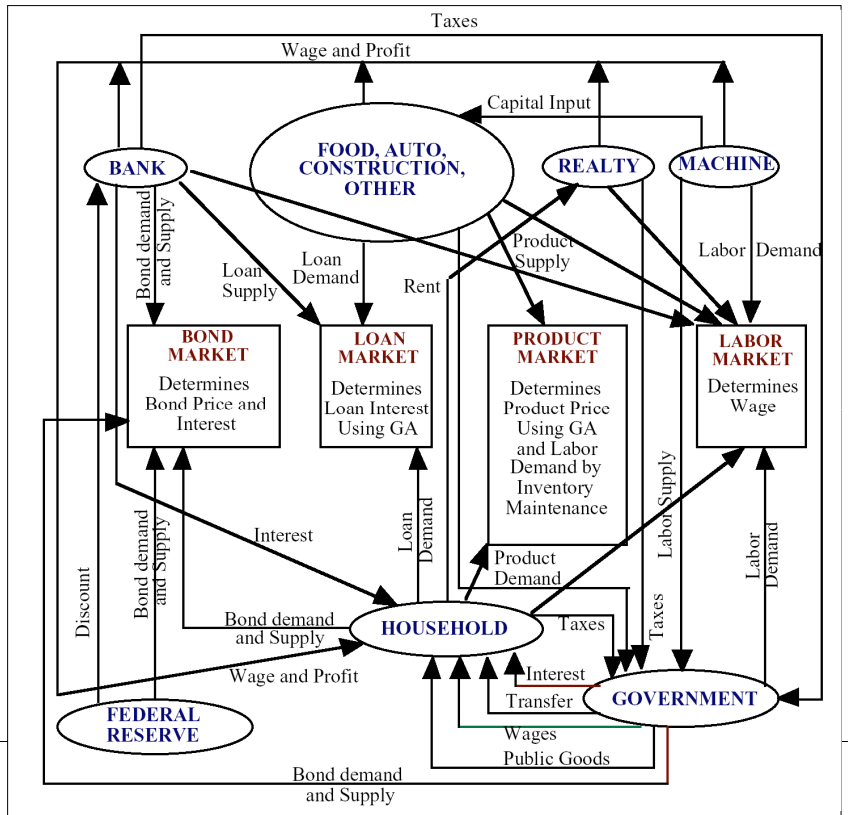


Illustration 1: Interaction among agents in the ASPEN

incorporated other sectors and the banking system, as well. Using this more complex model they have been able to predict the workings of the market with such a level of accuracy that was not possible before; thus proving the model and the concept sound.

During the past decade, computing and simulation has developed with exponential speed. The initial ASPEN model was run at the US Government's SCANIA laboratory, then housing the fastest computer in the world, the massively-paralel "TERAFLOP" computer. It had 9200 PII processors and 3.1 Teraflop peak performance. Just for comparisons' sake, the new Playstation III gaming console that is to be released coming January will possess 2 Teraflops of computing capacity. What's more, advances in GRID computing could theoretically provide unlimited processing power.[12] This allows the models to become immensely more complex, thus more lifelike.

Seeing that agent-based modeling theoretically provides the answer to many questions which remain unanswerable by other means, and also that there is a working model that has great explanatory power in a given economy, it seems clear, that such a simulation could provide the answers we need about financial aid. But how should such a simulation be constructed?

12In our case, GRID is not a solution. Whereas it is a marvelous platform to analyze the CERN data, it's bottleneck is the communication channel. An adaptive agent-based simulation needs fast communication among the computing nodes, so a large capacity multi-processor system seems a better solution than a computing GRID.

The ABMA model

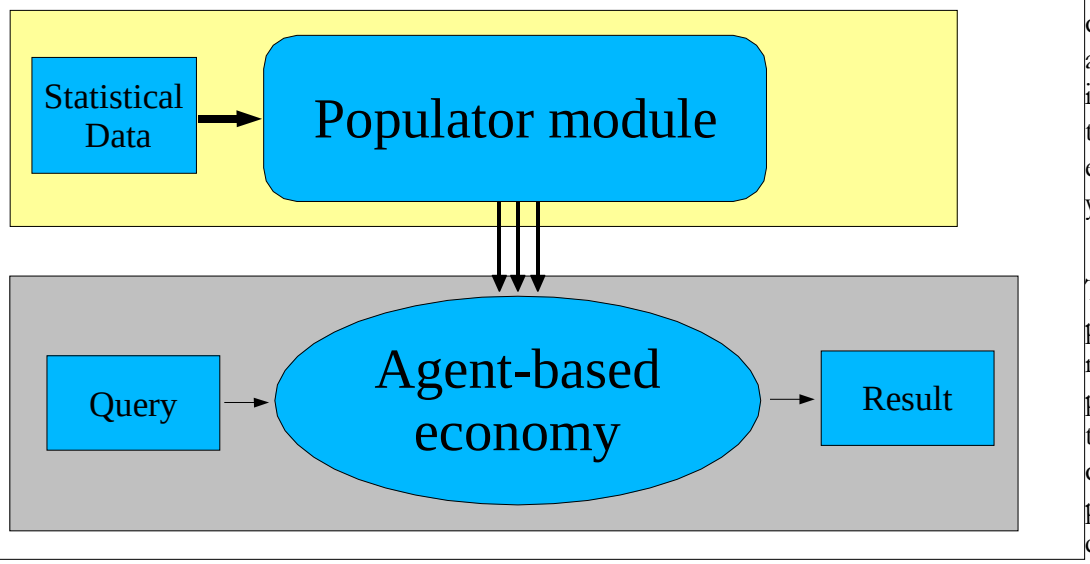
The researchers at Scandia labs successfully used the ASPEN model to predict the changes in price level, output, exchange rate, and even to simulate the possible outcome of an infrastructure loss of the economy. If such a large and complex economy could successfully be modeled, it must be relatively easy to construct a model of the low-income countries that could predict the effect of financial aid. In order to do so, however, we need a structure that allows the modeling of various countries, so that there would be no need to construct brand-new models for every possible country.

Basic structure

The idea behind the ABMA model is simple: let's create the formal workings of a low-income country, and the specifics should appear as differences in the distribution of agents. This would allow a singular framework to be used in all experiments, yet would make possible to incorporate country-specific information in the prediction process.

As shown on Illustration 2, the soul of the ABMA model is a populator module. This takes as it's input the statistical data that describes the country to be modeled, and produces the set of agents that can model the given economy. Through this method it becomes possible to use a unified model for the agents, and yet allow different countries to be modeled. The populator module would be ran only once, at the initializing stage, and after it created the necessary number and type of agents, all the changes are internal to the economy.

Illustration 2: The ABMA model

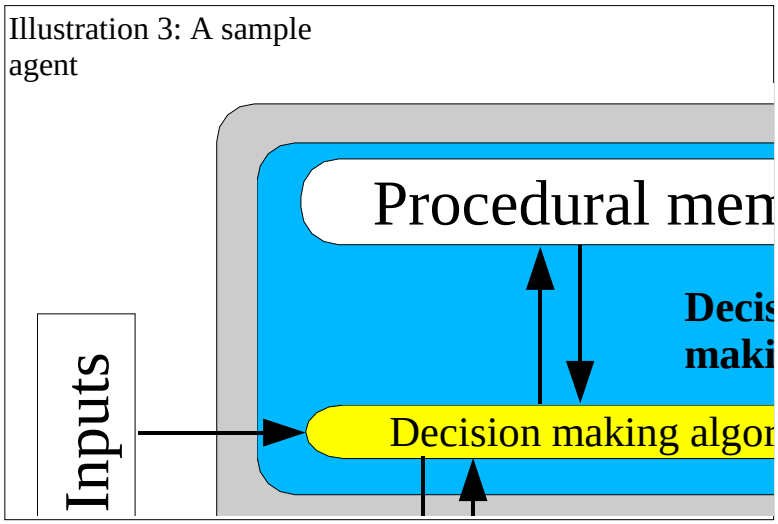


This process makes it possible to create petri-dish economies that can be played with. To test any hypothesis, one only has to induce an external change to the economy, for example command the "central bank" agent to reduce the reserve ratio. After the external change had been made, the agents slowly adapt to the new situation (the "bank" type agents will increase their lending, the "corporation" type agents will increase their investment, etc...), and the emergent behavior will be the aggregated macro-effect.

Agent attributes

In order to be able to model the triangle of aid, economic growth and inequality, the agents has to have a rather detailed structure. Their basic structure is that of any adaptive agent, shown on Illustration 3, but there are specifics need to be addressed.

Illustration 3: A sample agent



The agent acts by reading its inputs: a vector of it's surroundings that includes the actions of other agents, communications (bids, offers, etc). The decision making algorithm evaluates these according to the internal state (described by the state variables), the goal of the agent (some sort of utility agent maximum), and in case of a "thinking" algorithm, it's own procedural memory (for example it's neural network).

To be able to fulfill the promise of the model, the agents have to have a rather large set of state variables. In addition to the standard variables it needs to have a wealth vector (that shows the amount of items it possesses for each good in the economy), it's belongingness to a certain "family" (father, mother, spouse and children form a bidirectionally navigable pointer-chain), the age of the agent (to have the ability to detach itself from it's family network and form a family of it's own; and to have the ability to die), etc.

In order to better describe economic inequality, it is also possible to log the agent's past consumption of all the goods of the economy. Using this data, the measure of inequality could not only be decided by the "stocks" of the agents, but also by their lifetime consumption.

If we denote by p_i the price of the product i, and q_i the quantity available to the agent from product i, then we have the three measures of wealth in the form of:

- pure wealth measure: $W = \Sigma_{i=1}^{N} p_i \cdot q_i$
- past consumption measure: $W = \int_{T_0}^{T} c_{(i,t)} \cdot p_{(i,t)} dt + \Sigma_{i=1}^{N} p_i \cdot q_i$
- past consumption measure in current prices: $W = \Sigma_{i=1}^{N} p_i \cdot \left(q_i + \int_{T_0}^{T} c_{(i,t)} dt \right)$

The "goal" of the agent is also rather complex, since it has to take into consideration the utility of the other members of it's family (maybe with different weights).

Both the initial state variables and the goal of the agents are filled in by the populator module at creation time.

Institutional surroundings

These define the framework that the agents navigate:

- the basic form of communication among the agents

- the structure of the economy (the number and distribution of the "factory" agents, the capital allocation and productivity, the connection of the other agents and the "bank" agents in the economy, etc),
- the social attributes (average family size, expected length of life, etc)

These information are also filled in by the populator module.

Key problems

Creating a framework that would allow the description of low-income countries is a hard task in itself. It needs to possess great descriptive power, yet not contain crucial information about the countries. The country-specific information has to be coded in the composition of the agents, what might be a tougher task than it looks (since it demands, that the key differences among the countries have to be identified and simulated on agent-level).

Creating the framework might not be as hard as the description of the social systems. In an agent-based environment, the social structure is best displayed by having multiple types of "person" agents, that have different characteristics (utility functions, etc, to describe "homo economicus", "homo custodius", etc), and the mixing of these agents in the proper ratio would result in the desired social framework. Here the question of "base" person-types arrise: how should one divide up the "human" agents? Along their utility function? The education they received (implying their productivity)? Along multiple dimensions?

Another troublesome issue is the thought processes of the agents. It is pretty moot to make them think differently (so the method of "thinking" should be the same), but it is not trivial whether it can be beneficial to allow some agents to "remember" better than the others.

The creation of the "populator module" contains a large number of implicit assumptions about the modeling technology. These regard:

- INPUT DATA TYPES: the assumption is, that the key differences among countries can be deducted from statistical data. The term "statistical data" is rather vague: what kind of data do we need to be able to describe the aforementioned social system, for example? What has to be known to be able to tell apart the social framework of Zimbabwe and Timbuktu?
- DATA AVAILABILITY: is this data available? If not, can they be replaced by other data? If neither, what is to be done?
- POPULATION PROCESS: It is assumed, that by having the necessary "statistical data", it is straightforward to create the proper number and type of agents. Is it a deterministic process? Or does the populator module use a stochastic function to create the population of the petri-dish economy?

It is easy to see, that these problems do not appear with equal weight during the creation of all kinds of agents. The agents representing the bank sector can be easily described from data by IMF. The government itself is a relatively easily describable entity. The households, however, are a lot trickier (for example they need to be described in a hierarchical fashion; their earnings and consumptions are partially individual, and partially family-based). How to create the "families of agents" is a rather complicated problem.

Last but certainly not least, it is crucial to be able to depict foreign trade. This is usually done by introducing another agent, the "rest of the world" agent. Whereas it is not a pretty solution modeling-wise, it is not really far-flung, since most low-income countries are "small" countries, meaning that they have precious little effect on the world market as a whole.

Conclusion

It was shown, that agent-based modeling is a radically different approach to economic modeling than the standard framework. Agent-based simulation allows the modeler to delve into the micro-workings of the economy, and gather information not only about the economy as a whole, but about the changes in the state of the individuals as well. These state-changes can provide macro-information not available in the standard modeling framework, for example the level of inequality within the economy. This might allow a better evaluation of the changes (since we can directly see the changes in the utility and inequality, whereas normally these values would remain hidden in a macromodel), and could also mean better predictive ability regarding the future of our economy.

Using the populator module it is straightforward to incorporate the level of inequality present in a society, and the emergent behavior defines the inequality arising through the aiding process.

There are no computational differences in the implementation of this model. Current advances in the IT infrastructure make it easy to collect sufficient amount of CPU power to run such a model fast enough to gather the needed data in time.

Theoretical problems persist, however. A transparent agent-based model needs to be developed, that would allow the modeling of all low-income countries. A populator module is also needed, that would be responsible for the creation of the required number and type of agents in the economy. Finally a suitable method for indicating the various ways of providing financial aid is needed, so that the most beneficent way of providing financial aid can be found.

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