MEASURING EFFECTIVENESS IN HUMANITARIAN AND DEVELOPMENT AID

CONCEPTUAL FRAMEWORKS, PRINCIPLES AND PRACTICE

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Chapter 4

MODELLING THE IMPACTS AND EFFECTIVENESS OF AID

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ABSTRACT

The types of models used by economists to evaluate the impacts and effectiveness of aid have a substantial influence on aid and development policy and practice. In this chapter, two recent examples are discussed in which flaws in the modelling approaches resulted in poor policy recommendations: firstly the advocacy of 'trade not aid', and secondly the recommendation only to give aid to countries with 'good' policies. An overview of a recently-developed modelling framework is then presented, known as agent-based or multi-agent modelling, which is already being applied across a wide variety of fields, but which still seems relatively unknown in the aid and development literature. While not a magic bullet, agent-based modelling offers the potential to overcome many of the limitations of other modelling approaches, enabling the economic, social, political, legal, geospatial, epidemiological and environmental dimensions of development policy to be seamlessly integrated.

INTRODUCTION

Assessing modelling frameworks may seem far removed from the core concerns of those of us interested in the effectiveness of development aid. On the contrary, economic models in particular are enormously influential in policy debates over globalisation, trade and industry policy, foreign investment, aid effectiveness, health and education funding, infrastructure policy and workplace relations. Economic models are the main analytic frameworks used to answer politicians' questions about who wins and who loses from policy proposals – and who pays. They are so influential in fact, that they often 'trump' social, human rights and environmental perspectives in policy debates – not least because these other concerns have been so difficult to model. Reflecting on their interviews with a dozen prominent economists,

Colander *et al.* (2004, p. 10) concluded that the overwhelming view of the economics profession was that, "If it isn't modelled, it isn't economics, no matter how insightful."

Even when economic models are not used explicitly in debates on aid policies, the 'mental models' which thousands of politicians, business people, officials and commentators have picked up in a few undergraduate economics courses have a strong influence on decisions. John Maynard Keynes (1936, p. 383) perhaps put it best more than 70 years ago:

> [T]he ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be exempt from any intellectual influences, are usually the slaves of some defunct economist.

I begin by discussing two cases in which modelling frameworks have been highly influential: first, the assertion which gained popularity for a while, and which is still occasionally trotted out, that poor countries require 'trade not aid' to escape the poverty trap. Second, the argument that aid should go only to countries with 'good policies'. I argue that both of these cases reveal serious flaws in the ways in which these issues were modelled and therefore the policy conclusions which were drawn from them. In the second half of the chapter I discuss a new approach that in my view offers a more solid foundation on which to model aid policy.

MODELLING MISSTEPS

'Trade Not Aid'?

Over the last five years or so, it has been increasingly recognised that the once-common 'trade not aid' slogan is out of touch with what is required for economic development and the expansion of trade in poor countries (Stiglitz & Charlton, 2006). The slogan rested on a misleading dichotomy that arguably had more to do with fiscal and political expediency in OECD countries than sound development principles. It is increasingly well recognised that in order to benefit significantly from trade, developing countries need to build their capacities to trade, and that this capacity-building requires aid (OECD, 2001, 2006). Simplistic calls on poor countries to liberalise and trade their way to prosperity ignored the question of how such states could build the capacity for successful trade without substantially more aid than the rich world was willing to provide. Moreover, advising developing countries to liberalise their trade regimes no matter what their circumstances ignored the fact that comparative advantage is dynamic and can be intentionally acquired through policies to promote investment, learning and productivity growth in new fields. That is not to say that liberalisation is never appropriate – far from it. But whether liberalisation is the 'first best' policy option must be grounded in detailed modelling of individual countries' capacities and options. This is why the choice of the modelling framework is so important.

Computable general-equilibrium (CGE) models dominate many economic policy debates, particularly in international trade, but also in the domestic policy sphere.[4] Whenever we hear

4 See for example, Devarajan & Robinson, (2005) and Hertel and Winters (2005).

a prediction that a certain trade deal will bring '$300 billion' in benefits (World Bank, 2005; Anderson & Martin, 2005), we can be sure a CGE model somewhere has produced the figures. One of the main reasons, I believe, why the 'trade not aid' argument was able to gain such traction, is because the CGE models have to assume away many of the problems that aid is intended to address in order to remain mathematically tractable. These problems include market and information imperfections, heterogeneity among firms, households and people, spatial heterogeneity and segregation of markets, incomplete and unenforceable contracts, institutional corruption and incompetence, and variable infrastructure resulting in incomplete networks.[5]

CGE trade models for example, such as the Global Trade Analysis Project (GTAP) model (Hertel 1997), generally implicitly assume that many of those capacities, which aid may be needed to build up, actually exist already: particularly, complete infrastructure and information networks, good human capabilities and mobility and sound institutions with no corruption and perfect, costless enforcement of contracts. It is perhaps not surprising then that while CGE models are routinely used to tout the benefits of trade liberalisation, they are almost never used to analyse the effectiveness of aid. I am aware of only a handful of CGE studies that attempt to tackle aid effectiveness (eg. Bach & Mathews, 1999; Lau *et al*., 2001). If this is an approximate reflection of the number of CGE studies on aid, rather than simply a reflection of my ignorance of the literature, it raises the question of why there are so few. Perhaps CGE modellers are uninterested in aid. But if the CGE framework was appropriate, surely more people seeking publications would have used it. Is it possible, rather that the paucity of CGE studies on aid is *prima facie* evidence that CGE modellers recognise the insurmountable challenge of trying to address such complexities with a standard general equilibrium framework? If so, then why is the CGE framework assumed to be ideal for analysing trade reforms in developing countries? Is it because the problems of trade capacity-building that aid seeks to address, are simply assumed away in CGE theory? If they are, then how much credence should be given to the results of CGE trade models? If their theoretical shortcomings make them unsuitable for analysing the pervasive 'market failures' that aid seeks to address, perhaps they are also not as suitable for analysing trade reforms in developing countries as they are often made out to be.

A major problem in modelling aid effectiveness in the economics literature has been that standard mathematical economic models, and, by extension, the large CGE trade models, are very restricted in what issues they can incorporate if they are to remain tractable. They are best suited to analysing an idealised, perfectly competitive market, which exists only in textbooks, and least suited of all to those contexts most in need of development assistance. Traditional analytic and CGE models are very poor at incorporating issues such as:

- differences between people in terms of age, education, health, ability/disability, opportunity, gender, income and ethnic group
- the birth, growth, education and development of children
- the effects of differences in ethics, honesty and corruption
- differences in bargaining power between buyers and sellers and between employers and employees

5 This is not the place for a detailed analysis of the theoretical problems with CGE models, which I have discussed elsewhere (Parris, 2006, Ch. 7). See also, Taylor & von Arnim, 2006.

- real spatial data such as land types, rainfall, crop cycles, community locations, etc
- the local legal framework and its enforcement, including human rights law
- ethnic tension and conflict
- genuine uncertainty about future events
- differences in infrastructure between different areas
- differences in quality of institutions, governance and corruption in different areas
- differences in the availability of credit in different locations
- the spread and effects of diseases such as HIV/AIDS, TB and malaria on the population
- environmental degradation such as groundwater pollution, soil erosion and deforestation

Assuming away these problems, in my view has meant that the gains from trade appear large compared to the gains from effective aid, because in effect, most of the gains from aid are assumed to have already been realised. Economic systems are modelled as if there is little need for aid, and then the results are used to argue that aid is of only marginal interest compared to the potential gains from trade. The net effect is that not only are the gains from aid likely to be understated, but also the gains from trade are likely to be overstated due to practical real-world constraints on countries' abilities to take advantage of the models' theoretical possibilities. Thankfully there is now a greater appreciation of the interconnections between trade and aid, and the need for more aid to build countries' capacities to trade. In the complex field of aid effectiveness, policy-makers are grateful for any clear-cut guidance. One recent study became enormously influential, by purporting to show that aid was effective in promoting growth, but only in the context of 'good' policies. I examine this study next as it is a good illustration of the complexities and pitfalls associated with trying to capture the impacts of aid using cross-country econometrics.

Aid Only for Countries with 'Good' Policies?

The debate in the economic literature on aid effectiveness was sharpened considerably by Burnside and Dollar's (2000) study *Aid, Policies and Growth*, arguing that aid was effective, but only in the context of 'good' policies (hereafter, BD). In its earlier incarnation as a 1997 World Bank Working Paper, this study heavily influenced the policy recommendations of the World Bank's 1998 report *Assessing Aid: What Works, What Doesn't and Why*. The policy implications were considerable, since the paper, the World Bank report, and studies deriving from it (eg. Collier & Dollar, 2001, 2002) urged donors to focus aid on countries with 'good' policies.

BD's results are surprisingly fragile however. Hansen and Tarp (2000, 2001), Dalgaard and Hansen (2001), Dalgaard, Hansen and Tarp (2004) and Parris (2006) have shown that BD's econometric evidence on the aid and growth relationship is not robust to variations in the sample data or estimation techniques, and there are substantial problems with their index of 'good policy' – which among other things, bore a striking resemblance to the then-prevailing 'Washington consensus' (Gore, 2000; Williamson, 2003). BD's 'policy' index is also highly sensitive to the regression specifications and choice of data. These conclusions are

supported by Roodman (2004) who conducted a battery of tests and concluded that the aid-policy linkage was extremely fragile. Easterly *et al.* (2004) reached similar conclusions, after adding a number of new countries and extending the dataset through to 1997.

In a turn that is unfortunately characteristic of the cross-country regression literature however, Easterly *et al.* (2004) go further in their conclusions than their results strictly allow. They claim that their study raises "new doubts about the effectiveness of aid and suggests that economists and policy-makers should be less sanguine about concluding that foreign aid will boost growth in countries with good policies." (p. 779-780). We may allow the second half of their conclusion without conceding the first half. Their results actually say very little about "the effectiveness of aid". Both BD and Easterly *et al.* (2004) implicitly assume that all aid from 1970 was given in order to promote economic growth. Their criterion for 'effective' aid moreover, is that it does promote growth. But aid has been given for all manner of purposes, not least of which was propping up friendly governments during the Cold War – and it was often very effective for that purpose.

Even the more recent poverty-focussed aid may not necessarily show up as clearly leading to economic growth, at least for a while. Aid that prevents illiteracy, illness and malnutrition in children may not show up in economic growth figures for 20 years as they grow up and begin to affect the quality of the workforce – and even then, other institutional reforms may have to have taken place if this effect is not to be swamped. Both BD and Easterly *et al.* (2004) also implicitly assume that if aid was 'effective' in reducing poverty, this would necessarily promote GDP growth. This is not an unreasonable assumption, but there can be quite different results for growth and poverty measures for the same set of regressors. Aid may be quite effective in reducing poverty, malnutrition and illness without necessarily significantly affecting the transactions that make up the official GDP statistics. This is especially so in countries where the shadow economy makes up more than 40% of total economic activity, as it does for most developing countries (Schneider 2005a & b; Schneider & Enste, 2000). Improvements in nutrition and agricultural productivity of non-marketed commodities among poor farming households, for example, may not show up at all in GDP figures.

Some recent studies have tried to distinguish aid in general from aid designed to improve growth. Clemens *et al.* (2004) summarised in Radelet *et al.* (2005) for example, examined aid flows to 67 countries between 1974 and 2001, and concluded that 'early impact aid' designed to support growth relatively quickly, such as roads, ports, electricity generation and irrigation systems on average tend to have strong and robust effects on growth – but with diminishing returns so that larger amounts have progressively smaller impacts (Radelet *et al.* 2005, p. 19). A possible reason for diminishing returns to large volumes of aid is the effect of aid flows on the exchange rate, a form of 'Dutch Disease' whereby increased foreign exchange inflows cause the local currency to appreciate, leading to a loss of export competitiveness (Rajan & Subramanian, 2005b). Berg *et al.* (2005), summarised in Aiyar *et al.* (2005), examined the effects of aid increases on five African countries with quite strong institutions, namely Ethiopia, Ghana, Mozambique, Tanzania and Uganda. They found that countries sometimes do not spend all the aid money allocated for fear of driving up the exchange rate, and instead may use it to reduce domestic debt. Aiyar *et al.* (2005, p. 28) emphasise that because of these sorts of effects, a sound analysis of aid effectiveness must include the interactions between fiscal effects, monetary effects and exchange rate effects, and the policies of the government in relation to these domains. Models based simply on 'real' effects (i.e. the majority of

analytic and CGE models), which ignore the interactions between aid and the financial sector, cannot hope to capture some of the most important dynamics of aid effectiveness.

To conclude this section, let me raise one final issue that is arguably of far greater concern than the econometric technicalities of BD's work: BD concluded, "Our results indicate that making aid more systematically conditional on the quality of policies would likely increase its impact on developing country growth" (p. 864). This conclusion was widely understood as a recommendation to donor governments to direct aid away from countries with 'bad' policies. But BD did not appear to consider the likely consequences of withdrawing support. BD was arguing that with limited aid funds, they need to be used most effectively, so channelling it towards governments with 'good' policies is sensible. This may make sense in terms of static allocative efficiency but even then, to argue that aid may be used more effectively in certain countries is by no means to demonstrate that it is wise to withdraw funds from countries in which it is being used less effectively. It may be that aid money is the only thing keeping the ship of state afloat and staving off anarchy. From a longer-term dynamic perspective static allocative efficiency considerations alone are certainly inadequate.

There are two fundamental problems with BD's recommendation to redirect aid away from countries with 'bad' policies. Firstly, it is a recipe for perpetuating malnourishment, illness and illiteracy among children and workers, making it less likely that the country will ever get a good government. If it does somehow get a decent government after many years of minimal outside support, it would then likely find itself saddled with a mass of poorly educated, alienated, unhealthy and largely unemployable people, poorly run companies and bureaucracies and decrepit infrastructure. 'Sound policies' at that late stage would be nowhere near as effective as they would have been if they could tap into a skilled and healthy workforce. This trajectory moreover, increases the likelihood of political unrest or even a failed state, which would most likely cost immeasurably more to put back together than was saved initially by a more 'efficient' allocation of aid.

Secondly, BD's recommendation neglects the potential global cost of the emergence and spread of multidrug-resistant strains of infectious diseases, by withdrawing aid and allowing health systems in certain countries to deteriorate. Multidrug-resistance thrives in poor drug control regimes and is already a major problem with tuberculosis (TB) and malaria. Approximately one-third of the world's population is infected with TB. In 2004 there were 9 million new cases, and around 2 million deaths from TB (WHO, 2006b, p. 1). As a result of poor drug control regimes in dilapidated health systems, the incidence of multidrug-resistant TB (MDR-TB) is surging.[6] Some 460,000 new cases of MDR-TB emerge each year (WHO, 2006b, p. 47), and around 80% of MDR-TB cases are also now so-called "super-strains", resistant to at least three of the five first line drugs used to treat TB. The cost differentials between treatments are staggering: A six month course of drugs to treat normal TB costs only about $10 in developing countries, whereas MDR-TB requires more costly drugs and takes up to two years, making treatment a hundred times more expensive (WHO, 2004).

A striking example of the costs of withdrawing funds from health systems and allowing drug resistant strains to emerge occurred in New York. Following cuts to TB control

6 MDR-TB is defined as TB which is resistant to two of the five first-line drugs, isoniazid and rifampicin (also called rifampin).

measures in the late 1970s, a TB epidemic developed that resulted in 20,000 excess cases between 1979 and 1994 that would not have occurred if previous downward trends had continued. Around 20% of patients were infected with MDR-TB strains which pushed the total costs of the epidemic to well over $1 billion in excess health costs that would have been avoided if TB had been kept under control (Frieden *et al.* 1995). Stopping the epidemic was a public health triumph, but it took 20 years to get infection rates back below where they were in 1980 (Reichman & Tanne, 2002, p. 153). Recently there also emerged a so-called extremely-drug resistant, or XDR-TB strain which the WHO says is "virtually untreatable" and "a grave public health threat, especially in populations with high rates of HIV and where there are few health care resources." It is now found in all regions of the world, but is most common in Asia and the former Soviet Union. In a recent outbreak in South Africa it killed 52 out of 53 infected patients (WHO, 2006a).

The point of this epidemiological excursion is to explore how unhelpful policy recommendations can result from a type of economic or econometric modelling of aid effectiveness which is divorced from an understanding of the ways in which the system supposedly being modelled actually operates. The analysis commonly proceeds at a high level of macro-aggregates such as 'growth', 'aid' and 'openness' with little connection to the micro-level dynamics of the system such as the path dependency of children's development and epidemiological considerations. I doubt that any epidemiologist would agree that simply withdrawing health funds from a country with 'bad' economic policies in order to promote better 'growth' in another country was a terribly sensible approach to the use of aid funds.

Rather than recommending that aid be directed away from countries with 'bad' policies, without seriously considering the consequences, a far better response would have been to ask how we can deliver aid effectively to those who need it *even if* their government is incompetent. If a country has 'bad' policies, the current generation of children suffering under those bad policies should not be denied their only chance to grow up with adequate nutrition and a decent education just because their current government happens to be corrupt and incompetent. In such cases aid can often be carefully targeted at the basic needs of the poor, avoiding official channels where it may be siphoned off. This point was reinforced from what some would consider an unlikely quarter, by Stanley Fischer, First Deputy Managing Director of the IMF from 1994 to 2001. In the prestigious Richard T. Ely lecture to the American Economic Association in January 2003, Fischer (2003, p. 22) observed that:

> [W]hen aid to a country with bad government is cut off, most of those who suffer are private citizens, who are already suffering from poor government. Hence humanitarian aid generally does and should continue in such cases, like Zimbabwe, where the humanitarian crisis is caused by the actions of the government. Jeffrey Sachs and others … have made a powerful case that the very poorest countries should receive large amounts of aid, to enable them to improve health, education, and infrastructure, as part of an effort to jump-start development.

In summary, BD's strong policy conclusions, echoed in the World Bank's (1998) *Assessing Aid* report, appear to be not only surprisingly fragile, but also somewhat misguided. I am not suggesting of course that sound policies are unimportant for aid effectiveness. Rather it reflects the fact that aid influences both growth and poverty outcomes through a variety of channels and there are likely to be complex interactions with a number of macroeconomic and

social variables. Aid is also endogenous – meaning that to a significant extent, the countries in worse shape need the aid most, and so we might expect to see a correlation between high levels of aid and poor economic performances. Perhaps the aid will translate into GDP growth, but with what time lag? One year? Five years? Ten years? A generation?

The endogeneity of aid and the multiple complex channels by which aid affects poverty and growth makes econometric model specification and interpretation of aid regression results particularly difficult. In one of the most recent shots in this ongoing econometric struggle, Rajan and Subramanian (2005a) claimed to reveal definitively what the cross-country evidence *really* showed. Using Generalised Methods of Moments (GMM) estimators, which they argue account for endogeneity problems, and disaggregating aid by the purpose for which it was given, they found no robust effects of aid on growth either way. Whether Rajan and Subramanian's conclusions survive the next battery of tests with ever more sophisticated estimators and finer-grained, longer data series remains to be seen.

It seems likely though that we are witnessing diminishing returns to this cross-country approach to the relationships between aid, growth and poverty. Indeed, after the flurry of activity at the beginning of this decade that BD's paper precipitated, there seems to be declining interest in these kinds of cross-country regressions. Rodrik (2005) recently concluded for example that, "we learn nothing from regressing economic growth on policies."

The fragility of the cross-country 'average' results suggest moreover, that not only is the issue plagued by endogeneity problems and long and variable lags, but also that the results are highly country-specific. An 'average' result then, will not shed much light on the likely effectiveness of aid in a *particular* sector in a particular country. Averages can be useful when there is a small standard deviation around the mean. When the standard deviation is large however, we should remind ourselves of the joke about the statistician archer: His first shot is a metre to the left of the target; his second, a metre to the right. Triumphant, he pumps his fist in the air shouting, "Bull's-eye!" . The more important research question then, is not whether aid and growth are correlated 'on average' but why aid works so effectively in some countries and not in others. What makes the difference and what modelling framework best equips us to model the dynamics that need to be considered? To explore this question further, it is useful to delineate two of the most fundamental roles for aid: ensuring that children thrive and making markets work properly for poor people.

TWO FUNDAMENTAL ROLES FOR AID

We may distinguish two related but distinct roles for development aid (as opposed to disaster relief aid): First, ensuring that a country's children not only survive their childhood, but that they thrive – that is, they are given the nurture, nourishment, security and education to reach their potential. Second, making markets actually work properly for the poor – which includes attention to institutions and governance. These two categories do not exhaust the scope of useful aid programs of course, but they are useful to highlight in view of the scepticism in some circles about the value of aid, and as a means of emphasising the challenges involved in adequately modelling aid effectiveness using traditional mathematical analytic models, CGE models, or cross-country econometrics.

Ensuring Children Thrive

The fundamental goal here is to ensure that, as far as possible, no child grows up sick, illiterate, malnourished or traumatised. Children only get one shot at receiving a decent education and growing up mentally and physically healthy. Adequate nutrition in the early years is vital for ensuring that children's brains and bodies develop properly. While some five million children die annually from causes related to malnutrition, millions more suffer the debilitating effects of chronic under-nourishment (Gross & Webb, 2006). Around 38% of children under five years old in Sub-Saharan Africa suffer from moderate to severe stunting while 9% suffer moderate to severe wasting. In South Asia the figures are even worse: 44% suffer moderate to severe stunting and 14% suffer moderate to severe wasting (UNICEF, 2006, p. 105).

Every generation of children that grows up illiterate and malnourished is not only a tragedy of wasted human potential for the families and the individual children affected, but it also delays the day when their country has a skilled, healthy and educated workforce. No amount of economic tinkering later on can make up for those lost years. This is a critical aspect of economic path dependency that is often forgotten by economic modellers. Preventing such an avoidable waste through substantial increases in aid to poor countries should be an urgent priority. In a very real sense it does not matter if this sort of work is not 'sustainable'. Each child immunised, given adequate nourishment and educated is worthwhile, even if the program is financially 'unsustainable' in the long term. If necessary it should be thought of as a legitimate, long-term subsidy until the country is either able to fund the program from its own resources, or until well-being has increased to the point where it is no longer needed. As discussed above, such programs are particularly necessary in countries riven by corrupt, incompetent or despotic regimes which neglect children's well-being.

Making Markets Work for the Poor

A number of development agencies, such as the UK Government's Department for International Development (DfID), and NGOs use the 'Sustainable Livelihoods' framework for analysing poverty and designing appropriate aid responses.[7] The Sustainable Livelihoods framework distinguishes five types of 'capital': Human, Natural, Financial, Physical and Social.[8] Analyses of the process of wealth creation and branches of economics such as both the Old and New Institutional Economics however, suggest that an important dimension is missing from this schema, namely institutions. To these five, I would therefore add 'Institutional Capital'. The Social and Human Capital categories of the Sustainable Livelihoods framework do not adequately capture institutional realities like the state of the property, business and human rights laws, the independence of the judiciary, the access to information, markets, insurance and credit, the soundness of the political and banking systems, the competence of the government's economic and development policies, the costs of enforcing contracts, the institutional incentives for corruption and so on. In recognition of

7 See: http://www.livelihoods.org/

8 The definition of 'capital' here may be being stretched to the point of uselessness. One wonders whether a word like 'inputs' would serve just as well.

this, DfID is now working with a framework called *Making Markets Work for the Poor* (MMW4P, often shortened to M4P for ease of pronunciation) in which institutions are given a higher priority (DfID, 2005):

> **Making Market Systems Work Better for the Poor** (M4P) is an approach that aims to accelerate pro-poor growth by improving outcomes that matter to the poor in their roles as entrepreneurs, employees or consumers of markets. M4P focuses on changing the structure and characteristics of markets to increase participation by the poor on terms that are of benefit to them. It addresses the behaviour of the private sector and therefore reinforces the strengths of market systems, rather than undermining these systems. In this way, M4P is based on recent thinking about how to use market systems to meet the needs of the poor and how to support the private sector through market mechanisms that bring about sustainable change.

Essentially the M4P approach combines the analysis of poverty using the Sustainable Livelihoods framework with an empirical examination of the ways in which markets actually function – or don't function – in particular contexts, and how to make them work more effectively for the poor. It takes seriously the realities of actually-existing markets, including 'market failures', imperfect competition, imperfect information and transaction costs. The M4P approach recognises that the states of actually-existing markets in the poorest countries are leagues away from the idealised markets of neat mathematical models and CGE simulations.

Conclusions on Modelling Aid Effectiveness

Two of the most fundamental roles for aid, ensuring children thrive and making markets work for the poor are both concerned with areas that are generally not well modelled with traditional econometric techniques or traditional analytic economic models, including CGE models. Econometric problems include the endogeneity of aid, multiple causal paths, variable time lags between causes and effects and inadequate data. Economic modelling problems include the need to deal with the detailed realities of actually existing markets (and lack of markets), including the need for a truly dynamic, multi-generational framework, and the need to account for the spatial fragmentation of markets, incomplete infrastructure and information networks, institutions of variable quality, corruption, risks due to volatile prices and weather, the informal sector and extreme heterogeneity in human capabilities and opportunities.

Capturing these complex interactions requires an interdisciplinary, bottom-up approach. Model design would begin with detailed literature searches, discussions with domain experts, surveys, spatial mappings, participatory appraisals and other research methods with communities to try to establish why they are poor, where the market failures are and what bottlenecks are locking people into poverty and preventing wealth creation. Bottlenecks could include lack of access to credit, inadequate roads, endemic disease and malnutrition, irregular electricity supplies, lack of skills in business, logistics and organisation, poor sanitation, lack of title to land and houses preventing access to loans, gender discrimination, endemic corruption among local officials, inability to meet quality standards for the local supermarket chain, cumbersome and expensive business registration processes, inability to access critical

information such as commodity prices in a timely way, and so on. Statistical, analytic and econometric techniques would be used to analyse the data to build up a conceptual map of the complex situation facing the community or district.

Only once the complexities and interconnections of the poverty trap in a particular context are understood, will we then know enough, not only to select the critical variables, but perhaps just as importantly, to select them at the right levels of aggregation. For example, can we get away with modelling just households or even villages as our lowest level of aggregation, or do we need to actually model individuals to capture critical processes? Once we have made these choices, we can choose the most suitable modelling framework to enable us to develop (hopefully) successful aid interventions and evaluations of aid effectiveness. If major bottlenecks can be addressed, then wealth-creating businesses may have a chance of flourishing, and poverty should continue to decline long after aid flows have ceased. Modelling aid effectiveness adequately I believe requires a framework that permits us to analyse these dynamic interactions of highly heterogeneous agents in a spatial setting. Agent-based modelling is one such approach.

AN INTRODUCTION TO AGENT-BASED MODELS

Over the last two decades, a new approach to analysing complex systems has emerged known as agent-based (or multi-agent) modelling, which has the potential to simultaneously address many of the criticisms of standard analytic modelling. Agent-based models (ABMs) are dynamic, evolutionary computer simulations of discrete 'agents' interacting with each other and their environment in real time according to carefully specified rules.[9] ABMs emerged from the revolution in computer power and object-oriented programming and are developed in object-oriented computer languages such as Smalltalk, Java, C++ and C#. The agents in an ABM are 'objects', which *encapsulate* both attributes (parameters) and behaviours (methods). This notion of encapsulation is perhaps the most fundamental concept of object-oriented programming. It enables agents to be created whose attributes and behaviours can be closely modelled on their real-world equivalents. In procedural programming conversely, attributes (data) and behaviours (functions) are normally kept separate.

As Axelrod (2006) observes, ABMs are ideally suited to acting as a bridge between disciplines. They have opened up a new interdisciplinary research frontier spanning ecology (Breckling *et al.*, 2006; Janssen & Ostrom, 2006; Green & Sadedin, 2005), geography (Parker *et al.,* 2002; Batty, 2005; Dibble, 2006), epidemiology (Eubank *et al*., 2004; Huang *et al.,* 2004; Dunham, 2006), political science (Cederman, 2001, 2002, 2003; Kollman and Page, 2006), anthropology (Axtell *et al.* 2002; Diamond, 2002; Kohler *et al.* 2005; Bousquet *et al.*, 2001), economics (Holland & Miller, 1991; Lane, 1993a & b; Tesfatsion, 1997, 2001, 2002, 2003, 2006; Batten, 2000; Chen, 2003, 2005; Deguchi, 2004; McFadzaen *et al.,* 2001; Leombruni & Richiardi, 2004), finance (Palmer *et al.*, 2004; Arthur *et al.*, 1997; LeBaron, 2002, 2006), innovation and organisation theory (Cartier, 2004; Gilbert *et al*., 2001; Ahrweiler *et al.,* 2004; Albino *et al*., 2006; Dawid, 2006), combat (Ilachinski, 2004; Kohler *et*

9 For an excellent overview see Leigh Tesfatsion's website at: www.econ.iastate.edu/tesfatsi/ace.htm

al. 2006; Chaturvedi *et al*., 2005), terrorism (Elliott & Kiel, 2004; Carley *et al.* 2006), peacekeeping (Schwarz & Lampe, 2005), transport (Gambardella *et al.* 2002), operations research (Paolucci & Sacile, 2004), and more general works (Axelrod, 1997, Epstein & Axtell, 1996).

In their comprehensive overview of the applications of ABMs to political science for example, Kollman and Page (2006, p. 1434) remarked:

> In our view, complex systems and computational techniques will have a large and growing impact on research on politics in the near future. This optimism follows from the observation that the concepts used in computational methodology in general and agent-based models in particular resonate deeply within political science because of the domains of study in the discipline and because early findings from agent-based models align with widely known empirical regularities in the political world.

The field is young and there is currently a lively debate over the extent to which ABMs can be made useful for economic policy-makers. Recognition of the potential of ABMs however, is reflected in the fact that the second volume of North-Holland's prestigious *Handbook of Computational Economics* is devoted entirely to agent-based modelling (Tesfatsion & Judd, 2006). The 23 chapters of the *Handbook* give an outstanding overview of the range of applications ABMs have had so far in economics and related disciplines.

The agents in an ABM may be highly heterogeneous, numbering in the tens of thousands or even millions. They may represent individuals, households, firms, governments, pathogens, features such as the landscape or weather, transport and power networks or even higher level abstractions such as 'overseas markets', the stock market or a meta-agent which collects and analyses data and feeds information back to particular agents. Agents interact through carefully-specified rules, which may themselves evolve. Agents may face realistic limitations such as limitations on their cognitive capacities, spatial and movement restrictions, inability to access needed information, and impaired functioning due to illness or malnutrition. ABMs can also explicitly model the spatial dimensions of economic and social changes with agents moving on a spatial network, grid or 'real' landscape based on Geographical Information Systems (GIS) data (Brown *et al*., 2006; Dibble, 2006; Dibble & Feldman 2004; Gimblett, 2002; Lim *et al*., 2002; Westervelt, 2002; An *et al.,* 2005; Castle & Crooks, 2006).

In my view, ABMs offer the most promising means to *simultaneously* integrate the various dimensions of development, including dimensions that are not well served by CGE and analytic models. These include: imperfect information, heterogeneous interacting agents, learning and innovation, money and credit, genuine uncertainty, imperfectly rational agents, incomplete markets and contracts, power asymmetries and bargaining dynamics, realistic spatial, land use and infrastructure data, realistic political and legal frameworks, realistic labour and stock markets, epidemiological effects and so on; all characteristics of real economies. Analytic approaches can incorporate some of these dimensions individually, and journals are filled with articles relaxing one or two core assumptions of the standard models. But to try to incorporate all of them simultaneously would make an analytic or CGE model completely intractable.

Dynamic simulations of nonlinear mathematical models using Runge-Kutter algorithms and so on in packages such as Matlab, VisSim and Mathematica do better than simple

analytic models, since they are able to simulate equations which have no analytic solutions. But even these approaches struggle to represent the market fragmentation, information asymmetries, spatial heterogeneity and bargaining dynamics between multiple heterogeneous agents that characterise real-world economies. The great advantage of ABMs on the other hand, is that they *are* able to simultaneously integrate these different dimensions. This is achieved through the primary innovation of ABMs, which is to shift the necessary analytic mathematics to discrete modules *within* an overall algorithmic computational framework, rather than having the requirements for a closed-form analytic solution constrain the model like a straightjacket.

ABMs therefore still include mathematical components, but their overall structure is evolutionary and computational and this structure enables modellers to go beyond what is possible in a purely analytic mathematical framework. As such, agent-based modelling may be thought of as a more general framework than computable general equilibrium modelling. There is no presumption of equilibrium, or any requirement for it in an ABM, which allows us to study out-of-equilibrium evolutionary behaviour quite naturally. As Arthur (2006, p. 1552) emphasises, this is not a trivial innovation:

> This out-of-equilibrium approach is not a minor adjunct to standard economic theory; it is economics done in a more general way. When examined out of equilibrium, economic patterns sometimes simplify into a simple, homogeneous equilibrium of standard economics; but just as often they show perpetually novel and complex behavior.

Howitt (2006, p. 1606) has also pointed out that ABMs are ideally suited to modelling the co-ordination of economic decisions, which plays a crucial role in economic growth and development:

> Economic growth depends not only on how people make decisions but also upon how their decisions are coordinated. Because of this, aggregate outcomes can diverge from individual intentions. … Agent-based computational methods are ideally suited for studying the aspects of growth most affected by coordination issues.

In a recent comparative study, ABMs compared very favourably with other modelling approaches. Boulanger and Bréchet (2005) evaluated six different approaches to modelling sustainable development policy: macro-econometric, general equilibrium, optimisation, Bayesian networks, system dynamics and multi-agent (agent-based) models. They based their evaluations on five criteria: the capacity to incorporate an interdisciplinary approach; the ability to model uncertainty; the capacity to integrate the long-term dynamics of different temporal processes; the ability to seamlessly link macro and micro perspectives; and the capacity to foster stakeholder participation and the incorporation of stakeholder knowledge into the model's specifications. They then assessed the suitability of the six model types for three different applications: a 'generic' policy application, a land-use and transport application and an energy application. They found that ABMs ranked first in all three applications, and concluded (p. 349):

> Unambiguously, the most promising modelling approach seems to be the multi-agent simulation model. … It is our opinion that public scientific and R and D policy-makers

and advisers should foster their development and use in universities, schools and research institutions.

ABMs are not a magic bullet and they are not going to be appropriate for every question or modelling task we might have. But their radically different structure from analytic mathematical frameworks offers the potential to simultaneously address many of the problems that plague conventional economic models and in doing so, to cut the Gordian knot surrounding some of the complex dilemmas of development policy.

Critics of the standard neoclassical analysis of economic development often argue that it is *precisely* in the analysis of trade and industrial policy for example, that the short-comings of standard microeconomics are most apparent. These areas require a nuanced theory of production that includes complex long-term interactions between firms and governments, technological innovation, learning and adaptation, realistic representations of money and credit and a realistic model of expectations formation that takes into account imperfect information and genuine uncertainty.

As another example, to adequately model the interlocking causes of poverty and the complex dynamics of aid effectiveness and poverty eradication also requires a richer modelling framework than current purely analytic approaches permit. Poverty is often caused by a combination of factors such as weak bargaining power, gender discrimination, lack of access to markets and credit, poor soils and drought, endemic malnutrition and disease, dysfunctional and corrupt institutions, poor infrastructure and poor macroeconomic management. Parris (2006, Ch 9) develops the demographic and social foundations for an ABM of development processes in Tanzania using data from a household survey, the national census and a social accounting matrix (SAM). Some 10,000 individuals are grouped into around 2000 households and are differentiated by location, gender, age, education, health, income, marital status, and household access to transport, electricity, sanitation and communications. The statistical properties of the individuals and households generated by the model closely match those of the census and household survey. This framework enables a high degree of individual and household heterogeneity to be represented, which in turn permits the bargaining power of individual households and its effects on poverty to be modelled.

The micro, macro, spatial, institutional, epidemiological, climatic, political and environmental dimensions are all relevant to these two examples, and an agent-based modelling framework seems to be the only one capable of integrating all these perspectives simultaneously in a dynamic evolutionary setting. The extensible, object-oriented architecture of ABMs makes it possible to integrate more realistic economic models with political, social and environmental models to produce an overall model of the development process that is integrated to an extent that has never been possible previously.

The extensible, modular, object-oriented design of ABMs can also contribute to their transparency because in an open-source community, the properties and behaviour of specific modules can become well documented and quite well known. In this way it is possible to build up a standard model from a library of interchangeable modules that may be swapped for different purposes. It allows domain experts to examine existing modules, such as the treatment of disease transmission, or the structure of the maize market, to build better versions and to make these available to the modelling community. Bruun (2002) has raised

this possibility for economic systems using the *Swarm* platform, and more recently Atanasova *et al.* (2006) have explored a similar idea in the realm of modelling aquatic ecosystems.

To ensure the continued enrichment of agent-based modelling, Chen (2005) has urged closer interactions between agent-based modellers and those studying experimental and behavioural economics. He and others have also emphasised the importance of field studies to inform model building (see Udry, 2003 and Izumi *et al.* 2005 for good examples).[10] Marietto *et al.* (2003, p. 197) suggest the use of participatory-based simulation in which "a set of stakeholders, such as domain experts or the system end-users, contribute to discuss and negotiate the validity of the specification and the simulation results." Participatory development of ABMs is an expanding field (Becu *et al.* 2003; Ramanath and Gilbert, 2004; Siebenhüner and Barth, 2005). Examples of participatory 'companion modelling' exercises that have recently been undertaken include an irrigation project in Senegal (Barreteau, 2003a & b, Barreteau and Bousquet, 2000; Barreteau *et al.* 2001; D'Aquino *et al.* 2003) and water management in Kiribati (Dray *et al.* 2006).

The core idea in using ABMs for aid and development modelling is that the ABM can be used as a tool to integrate information gleaned from sources as diverse as the national accounts, GIS mapping and local participatory research exercises. The resulting information is too complex for any person to hold in their head. But once it is integrated into an ABM, the model can be used to explore a variety of scenarios and policy options. Such a model would not simply be run once to produce an 'answer'. It would be run hundreds, or even thousands of times, sampling different parameter values across the possible parameter space, to produce a probabilistic 'landscape' of possible outcomes. In other words, rather than a model which tells us: "If we reduce textile tariffs by 10%, the wages will go up by 2%", the results of an ABM would be couched in terms of probabilities for different scenarios: "Given all that we know of the complexity of the system, if we reduce textile tariffs by 10%, there is around an 80% probability of average wages rising by 2%, a 15% probability of nothing much happening to wages, and a 5% chance of average wages actually falling if the reality is that we have a particularly unfortunate conjunction of parameter values out there in the real world." The verification and validation of ABMs is of course an active and important area of research, but one which takes us beyond the scope of this chapter.

CONCLUSIONS

The choice of modelling framework and the assumptions built into the models used to evaluate the impact and effectiveness of aid exert a substantial influence on policy debates and on aid program designs. In my view, while it is not appropriate for all problems, agent-based modelling could be a tremendously powerful tool with which to overcome many of the limitations of other approaches. Agent-based modelling is still in its infancy in the aid and development field, but it holds out the promise of finally enabling us to seamlessly integrate the economic, social, political, legal, geospatial, epidemiological and environmental dimensions of aid and development policy in a way that has never previously been possible.

10 Useful materials on field research for development economists can be found at: http://sticerd.lse.ac.uk/FIELDWORK/

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