

Economic Development from a Game Theoretic Perspective - from Micro Choices to Macro Dynamics

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Abstract: Economic development can be interpreted as essentially the study of how multiple outcomes may arise in economies, and how changing the incentives and rules of the game by which a society operates can dramatically affect the outcome and the resulting welfare of its players, creating a basis for either poverty or prosperity. This is an application of the concepts of game theory to development issues in an attempt to trace how interdependences, coordination failures and incentives at the micro level can explain macro phenomena of multiple equilibria, path dependence and development traps.

Keywords: economic development, game theory, interdependences, coordination

1 From the 'Invisible Hand' to Multiple Equilibria

Over 230 years since Adam Smith's (1776) classic *An Inquiry into the Nature and Causes of the Wealth of Nations* the question of why some countries are rich while others are poor remains a largely unsolved mystery. While 'traditional' economics typically assumed that markets arrive at a single, efficient outcome based on assumptions of no market failures, perfect information, appropriate institutions and enforceable contracts – in short preconditions for a first best world, real world economies are often shaped by constraints other than those of resource and technology, in particular informational restrictions, creating second-best scenarios. Although Adam Smith's conception of the 'invisible hand' postulated that a market consisting of self-interested individuals would yield an outcome that was best for society simply through the natural course of free exchange, even such conduct of economic activity via markets presupposes some method of enforcing contracts and property rights, as self-interest may yield very poor economic outcomes outside the discipline of well-functioning institutions. Development economics has thus increasingly devoted itself to understanding political, social and even psychological phenomena in poor countries as a way of trying to explain poverty (ranging from agricultural institutions, interlinkages and informal institutions through education choices to fertility), not only extending its scope, but also complementing its traditional tools.

As the study of economic development can be interpreted as essentially the study of how multiple outcomes in economies may arise (some better than others), where changing the incentives and rules of the game by which a society operates can dramatically affect the outcome and the resulting welfare of its players, creating a basis for either poverty or prosperity, recent work in game theory and information came to relax many of the above restrictive and unrealistic assumptions, focusing on multiple equilibria, incomplete markets and decisions under uncertainty and imperfect information [1]. Game theory can thus be used to model situations wherein the mutual interdependence of two or more players is recognized, potentially explaining a range of phenomena from multiple equilibria to the effects of increasing returns and externalities, analysing how an economy or region can be trapped in a low level equilibrium [2].

Central to this framework is a growing understanding of how social, political, and economic incentives at the micro level shape the pattern of economic development profoundly; focus in the following will thus be on how game theory can be applied to development issues to explain how interdependence and coordination affect incentives at the level of individual agents' choices and how this may manifest itself at the macro level, unfortunately often in the form of path dependence and poverty traps.

The structure of this paper follows this line of thought, leading from a discussion of strategic interdependence, incentives and coordination problems at the micro level in sections 2 and 3 to the analysis of the macro effects of decisions in this constrained frame in section 4. Section 5 offers an introduction to policy implications, while section 6 concludes. Although some examples are sketched to illustrate the main processes leading from the micro to the macro from a game theoretic perspective this is (understandably) without the aim of completeness, though parallels can be drawn for a number of related development issues.

2 Micro Dynamics: Strategic Interdependence, Incentives and the Potential for Change

Individuals everywhere are part of social, political and economic networks, which shape their decision environment and influence their best choices. Strategic interdependence or complementarity hence refers to a situation – ranging from interlinked markets in agriculture through segmentation in rural credit markets to fertility decisions – in which one agent's optimal decision depends at least in part on what other agents do and vice versa, making both people's actions and welfare interdependent. Such scenarios can be portrayed as games, whose solutions (though seemingly innocuous and everyday at the individual level), multiplied countless times over can largely determine what we observe as the economic outcome of a society [1]. Not only in stock markets do expectations materialise

themselves, trust and confidence in others' behaviour (or rather its lack) can result in self-fulfilling prophecies in the process of development as well, reinforcing themselves over time, leading to path dependence and hindering change, as a game largely depends on the institutional framework within which it is played and such systems – whether formal arrangements or informal patronage networks – are difficult to transform.

Interlinkages in rural markets, in particular agriculture and credit, are thus examples of how systems that arose to share the risks inherent in these sectors led to the creation of a network of interdependences which has become deeply embedded in rural society causing overall inertia. Rural, especially agricultural markets are frequently characterised by interlinked deals, with landlords often providing credit, insurance or technology in addition to land. These interlockings, together with institutional arrangements such as the inefficiency of sharecropping¹ have a significant impact on agents' incentives and hence the success of changes, in particular that of land reform. It can be argued that 'the watershed between traditional and modern society is exactly the distinction between single-interest and multiplex relationships' [3] and as formal and informal arrangements reinforce such interdependences at the micro level it becomes more and more difficult to dislodge systems from a low level equilibrium.

Turning to credit, one of the characteristics of rural credit markets is the tendency towards segmentation with rural moneylenders generally serving a known, fixed clientele and being extremely reluctant to lend outside this circle. Though a result of problems of adverse selection and moral hazard, as well as often a response to the lack of complementary markets (e.g. insurance markets to mitigate the problems of income uncertainty, a central problem in agriculture increasing covariant risk) or the high costs of the use of formal bank arrangements for many individuals if the population cannot be assumed to be generally literate and numerate [4], such segmentation and thus monopolization can have several negative consequences in the long run. One of its costs is for instance that funds fail to flow across regions or groups of individuals even though there are potential gains from doing so (e.g. a flood may create a significant demand for loans to rebuild, however as credit institutions are localized, such flows may be limited [4]). A natural corollary of segmentation is also the variation in interest rates widely observed in rural credit markets with rates varying according to geographical location, the source of funds and the characteristics of the borrower [5]. As mentioned above, interlinkages also often take place along occupational lines with interlinked credit transactions as the complementarity of some production relationship (e.g. tenant and landlord or farmer and trader) facilitates the credit relationship. The interlocking of markets with the terms of transaction in

¹ discussed in detail in Zs. Koczan: Informational Imperfections, Uncertainty and Agricultural Development, in Proceedings of 6th International Symposium on Intelligent Systems and Informatics, Subotica, Serbia, September 26-27, 2008

one market depending on the terms and conditions in other markets is thus a common feature of (especially rural areas of) Less Developed Countries (LDCs), constraining incentives, being again far from the ideal benchmark version of perfectly competitive, efficient markets.

Interdependences of actions can also be observed in fertility choices as inter-household linkages and the milieu in which utility-maximization takes place also influence such decisions. A desire to imitate (whether due to an intrinsic desire to be like others or due to mutual positive externalities) can encourage norms of high fertility rates that no household would unilaterally desire to break. Although such practices could well have had a rationale in the past when mortality rates were high, rural population densities were low and mobility was restricted, they can survive even when their original purpose has disappeared. Imitative behaviour could thus offer a role for history through micro decisions by individuals/households, be a reason for the existence of multiple equilibria, with the possibility that society gets stuck at a self-sustaining mode of behaviour, characterized by high fertility and low educational attainment, even when there is another, potentially self-sustaining, mode of behaviour that is characterized by low fertility and high educational attainment. Two societies may thus be indistinguishable in terms of underlying preferences and conditions, however may nevertheless sustain different behaviour patterns as they operate in different social equilibria [6]. It has been argued that educated women can have a crucial role as tradition-breakers, being among the first to make the move toward smaller families. A concerted social effort could then help dislodge such a society from a spatially localized poverty trap to a mode of behaviour where fertility is low and educational attainment high, though as social norms break down and traditional support systems falter, those women who choose to change their behaviour become financially and socially more vulnerable, making a literacy and employment drive for women essential to smooth the transition [7].

The common theme of the above examples of agriculture, credit and fertility has been the interdependence of choices of individual agents, often leading to a self-sustaining process. Although the end result was a low level equilibrium, whether due to inefficiencies in the systems of land tenure, the costs of credit market segmentation or high fertility rates, originally each agent's behaviour was rational given his incentives, constituting a best response to the behaviour of others, resulting in a continuation of the mutually reinforcing behaviours. Before turning to the problem of the multiplicity of (Nash) equilibria at the macro level, a brief discussion of coordination failures follows as they also account for a significant channel through which agents' choices given their micro incentives affect the economy's future overall.

3 Coordination Failures and Sustained Low Level Equilibria

Many of the most pressing developmental challenges would require high levels of coordination between various actors; unfortunately this often runs into obstacles in the second-best, constrained settings that characterize most LDCs. Often agents are unable to coordinate their behaviour – whether due to lack of information, inadequate institutional rules, inefficiencies or differing expectations – resulting in a low level equilibrium [2]. More formally defined, ‘coordination failure’ in an economic context is a state of affairs in which agents’ inability to coordinate their behaviour/ choices leads to an outcome (equilibrium) that leaves all agents worse off than in an alternative situation that is also an equilibrium.

Turning to the causes of such coordination failures, [2] outlined factors that can lead to their rise and/ or persistence as ranging from asymmetric information, high transaction costs, absence of risk mitigation instruments and appropriate institutions through noncontractual social interactions to missing finance.

The presence of asymmetric information, in particular linked to the issues of adverse selection (hidden information) and moral hazard (hidden action) can significantly contribute to coordination failures as for instance the inability of one party to observe and monitor the other party could lead to noncooperation due to the risks associated with entering into a relationship with a number of stochastic variables. In a development framework this is often a problem in formal credit markets where constraints of imperfect information are particularly severe with banks having difficulties observing both the risk characteristics of individual borrowers and monitoring that the funds are spent as promised.

High transaction costs can also reduce incentives for collective action, increasing the costs of cooperation and making coordination failure more likely as in essence they constitute a barrier to the flow of information as well. Transaction costs can be exacerbated if actors are spatially dispersed, communication and transportation are difficult/ expensive or overly centralized and bureaucratic structures make the approval of work plans or projects cumbersome [2].

The lack of accessible, affordable and effective risk mitigation and transfer instruments (insurance, price hedging, credit guarantees...) combined with risk aversion can also dampen interest in participating in collective action. Already uncertainty in itself is a deterrent of cooperation, increasing the probability of coordination failure as regulatory uncertainty, inadequate legal frameworks, political instability and capricious changes in rules and contracts create obstacles to development. This is increasingly true as risk aversion rises; the low but certain outcome may easily overshadow the benefits of the high but uncertain outcome associated with collective action [2].

Problems with formal institutions also give rise to noncontractual social interactions as complete and enforceable contracts are often the exception, not the rule in LDCs. Many interactions between individuals, communities, firms, families, political groups and markets are noncontractual, informal arrangements, governed by social norms, power, trust and incentives to maintain mutually beneficial long-term relationships.

Further factors that encourage the persistence of coordination traps and low level equilibria over time are nonverifiable information, inability to change the rules of the game (the institutions circumscribing it) and insufficient common interest combined with a large number of agents making noncooperation their dominant strategy [2]. Coordination failures arising due to the attributes of such constrained frameworks can thus perpetuate themselves over time, meaning that the decisions of agents, while individually rational given their circumstances, can lead to a sustained lower equilibrium overall.

4 Macro Effects: Multiple Equilibria, Development Traps and Path Dependence

A Nash equilibrium is a profile of (planned) strategies, each of which is a best response to the actual planned strategies of the other players (as specified in the profile), thus it assumes that beliefs are correct in a particular sense. Commonly quoted justifications for this concept include that it is a consequence of rational inference (though even the assumption of common knowledge of rationality does not imply that players will actually play Nash strategies) and that it is a necessary condition if there is a unique predicted outcome to the game (a single Nash equilibrium forms an intuitive outcome to a game that well-reasoning players are likely to anticipate, anticipations then create a focal point for play and become self-reinforcing; non-self-contradictory game theoretic recommendations must be Nash). A self-enforcing agreement should also be Nash, since if not, at least one player would have an incentive to break it if he believed that the others would stick to the agreement. It can also be justified as a stable 'prescription' for play, if e.g. a social convention, tradition or third party suggests a behaviour for players creating an expectation about play, neither player will want to deviate from these prescriptions. Finally, the limit of an evolutionary or learning process is also a Nash equilibrium, i.e. if players experiment with strategies over time on a trial-and-error basis (a dynamic, repeated game) the final settling point in the game should constitute a Nash equilibrium in which players develop a mutually reinforcing best response to one another's behaviour. However, while these reasons portray Nash equilibria as a powerful tool for understanding development problems (which in many cases it is), the above empirical examples have also pointed at its limitations, in particular the existence of multiple equilibria.

Multiple equilibria can explain how an economy can get stuck on the path of economic development as it becomes difficult to dislodge it from a low level equilibrium even though a higher level equilibrium often exists as well (as reflected in the above examples). Economic, political or social behaviours emerge that are negatively self-reinforcing causing society to be worse off than it could be and making change difficult, possibly imprisoning entire societies in long-term poverty [1].

A closely linked concept is hence that of path dependence, i.e. while initial conditions led to the establishment of a certain equilibrium, even though conditions may have changed, this equilibrium is reinforced over time, giving a role to history. An example of path dependence at the individual level can be quoted from nutrition linked to inequality, as findings in modern nutritional science suggest that poverty traps are a reality in those poor societies that harbour extreme inequalities in asset ownership. Inequalities in ownership, reinforced for instance by imperfections in credit markets can perpetuate themselves over time as nutritional history from the earliest stages of life can have a stranglehold over life chances. Indeed, even maternal nutritional status can leave a trace, for example through infants' birth weights. In the extreme, poverty traps can then be dynastic [8].

Path dependence and hence persisting differentials can also be observed in the field of human capital accumulation. Investment in human capital has both intrinsic and instrumental value: being educated and healthy are valuable achievements in themselves, while they also affect personal opportunities, the ability to work, to get a job, to expand one's incomes (in Sen's terms, to achieve a larger set of functionings [9]), have the social roles of increasing participation, power, redistributing and empowering, they also show externality-like effects as one person's ability to read in a community allows others to obtain valuable information (read pamphlets, government announcements...) and benefit growth more directly as well through raised social discipline and increased productivity. Combining these effects with their reverse causality can thus make the difference between virtuous and vicious circles, with human capital accumulation and active policy intervention encouraging growth on the one hand, while on the other hand low investment and inadequate public policy act as hindrances to development.

Examining the role of investment in human capital linked to wealth distributions it has been demonstrated that in the presence of credit market imperfections and indivisibilities of investment in human capital, the initial distribution of wealth affects aggregate output and investment both in the short and in the long run through differences in human capital accumulation [10]. Countries which have different historically determined wealth distributions hence follow different growth paths and may even converge to different steady states – suggesting an explanation for the differences in growth and development patterns between countries. This model is based on the idea that it is the inheritance of each

individual which determines whether he invests in human capital or not², thus the distribution of wealth determines the aggregate levels of investment, of skilled and unskilled labour and of output. The effect of wealth distribution continues as the different levels of investment in human capital in turn determine the distribution of income (investment feeds back), which gradually changes the distribution of wealth over time. There are thus rich dynasties, in which all generations invest in human capital, work as skilled and leave large bequests and there are poor dynasties, in which people inherit less, work as unskilled, and leave less to their children. The initial distribution of wealth determines how big these two groups of dynasties are, and therefore what the long-run equilibrium in the economy is [10].

Human capital investment can thus be seen as a channel accounting for path dependence and persistent differences between economies, with variation not being due to technology (though the way an economy adjusts to a technological improvement also depends on the initial distribution of income as the benefits from innovation are dependent on investment in human capital), but to differences in investment in human capital due to credit market imperfections. An economy which was initially rich with its wealth distributed among many, will thus end up rich, while an economy with a large initial amount of wealth which is unequally distributed ends up poor in the long run due to different resulting human capital investment rates as there are multiple long run equilibria and the specific one the economy converges to depends on the initial distribution of wealth (more specifically on the percentage of individuals who inherit a large enough wealth to enable them to invest in human capital).

Examined from a slightly different angle, the complementarities phenomenon also affects educational decisions, explaining path dependence as the success or failure of coordination that can make the difference between virtuous circles of growth and vicious circles and development traps respectively. One of the most striking features of statistical comparisons between LDCs and MDCs (More Developed Countries) are differences in education and literacy. Moreover, these statistics undoubtedly underestimate the true correlation between poverty and educational underachievement since there are also tremendous variations within countries. Poor regions within individual countries are nearly always associated with education levels that are below the average of even a poor country [1]. Choices of low education levels can however be explained in terms of rational decision-making, while the presence of complementarities and strategic interdependence means that multiple Nash equilibria are possible and coordination and confidence matter. Education is an investment in which current resources are sacrificed in

² Based on generational altruism where individuals live for two periods: in the first they may either invest in human capital and acquire education or work as unskilled, while in the second they work as skilled or unskilled according to their education level, consume and leave bequests (individuals are assumed to be identical with regard to their potential skills and preferences and differ only with respect to their inherited wealth)

exchange for future benefits, and even though numerous personal and social spillover benefits are associated with higher education levels, the monetary rewards to education depend heavily on factors such as technological improvement, the education levels of other actors, the level of specialization in the economy, institutional changes and efficient markets and is also frequently reliant on active policy intervention (as emphasized e.g. in [11] accentuating the advantages of internalizing the external benefits of education through public intervention).

The complementarity and mutual reinforcement of education and technology has also been documented empirically, e.g. related to the Green Revolution in India. Reference [12] showed that returns to primary schooling increased during the period of rapid technological change, with returns increasing much more rapidly where change was faster, highlighting the fact that educated individuals can better manage new technology or are quicker to adopt. Technical change also had a higher effect on profits where education was higher, thus inducing private investment in schooling (net of changes in wealth, wages and the availability of schools) due to expectations about the benefits of future technical change, while school expansion importantly increased levels of schooling [12].

5 Game Theory, Policy Implications and Payoffs

Policy implications following from a game theoretic analysis of development problems can to a large extent be understood in terms of changing the institutional rules or payoffs of the game to obtain the desired outcome, e.g. transforming prisoner's dilemma games, making high level equilibria dominant or promoting cooperative dimensions in non-cooperative games. Such interventions could be of the 'one-shot' variety, e.g. changing property rules or could be permanent/repeated, e.g. having the government compensate parties for potential crop losses. They could range from 'enlarging the shadow of the future' [13], to making penalties for the violators of rules sufficiently large (e.g. many banks impose severe punishments in the form of cutting off credit lines or demanding an unusually high interest rate for delayed loan repayments; imposing credible penalties for the violation of tax and other laws, as an ineffective tax system can offer real benefits to late payments [14]). However, such interventions often have large informational requirements concerning the game itself, its limiting factors (rules and institutions underlying the interaction) and its payoffs (estimates of the costs and benefits for each strategic interaction, at least in relative terms) and have to be feasible given the technology, social norms and institutional enforcement capacity [2].

Institutions thus become particularly important as using a game theory analogy they can be defined as the formal and informal rules (social norms) of the game

for individual and organizational interactions [15, 16]. While formal rules include a legal system and policy measures, informal rules include norms of behaviour and self-imposed codes of conduct. Changing the rules that govern an interaction can then shape outcomes. Functioning properly, institutions make the good outcomes more likely and the bad outcomes less likely as efficient rules, by providing proper incentives and establishing a stable structure of human interactions, encourage individuals to engage in productive activities, thus promoting economic growth [14].

As illustrated by the example of agricultural institutions and interlinkages limiting the potential for land reform, institutions acquire a central role in the development process as (by their static nature) they often ossify suboptimal outcomes. Reference should here be made to the seminal article by Acemoglu, Johnson and Robinson [17] highlighting the path dependence of economies as determined by their institutional structure. Examining data on the mortality rates of European settlers in colonies, they argued that the presence of tropical diseases encouraged more extractive policies, while institutions were set up in regions with lower settler mortality rates laying the foundations for long run economic growth, contending that differences in institutional quality and hence growth rates between former colonies can be traced back through this historical sequence of events to the earliest period of colonization.

6 On ‘Missing the Boat’ and Probabilities

With the advent of game theory and information economics, attention has increasingly turned towards the analysis of second-best scenarios, relaxing many of the unrealistic textbook assumptions concerning the functioning of markets in LDCs. The above discussion is an introduction to the consequences of individual decisions in a constrained micro framework for the macro potential for development. It attempts to highlight that in the context of most LDCs, the presence of multiple equilibria and path dependence reinforced by institutions mean that formal and informal arrangements and interdependences of incentives do matter and significantly shape the trail an economy will follow.

Poverty traps have thus been a recurring theme, outlining the obstacles LDCs face when trying to dislodge their economies from low level equilibria. It should however be noted that in fact these traps are probabilistic; unlike black holes, it is not impossible to escape from them, just difficult [18]. However, efforts to help those who so far ‘missed the boat’ have to acknowledge that circumstances are second-best, that additional constraints of information and uncertainty give a role to history and that path dependence and multiple equilibria complicate policy design in the face of game theoretic issues related to incentives, interdependences and coordination failures.

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An Approach from Micro to Macro Perspective. *Theoretical Economics Letters*, 11, 1-20. doi: 10.4236/tel.2021.111001. 1. Backdrop. Several factors influence the decision-making process of an individual. The present study provides a comprehensive view of how narrative influences individuals' choices to economic policies and provides a crucial linchpin in wealth concentration. To the best of the authors' knowledge, the existing literature has not touched upon this nexus and remains new research. The study is segregated into two parts, first, micro perspectives that deal with how narratives can influence an individual's decisions and, subsequently, community decision. *Economic Development from a Game Theoretic Perspective - from Micro Choices to Macro Dynamics* Zsuzsanna King's College, Cambridge, UK. *Intelligent AVR Control Using Hybrid Optimization Based On Bacterial Foraging and Clonal Selection* Dong Hwa Kim*, Jae Hoon Cho** * Hanbat National Univ., Korea, ** Chungbuk National University. *Economic Development from a Game Theoretic Perspective - from Micro Choices to Macro Dynamics*. As the study of economic development can be interpreted as essentially the study of how multiple outcomes in economies may arise (some better than others), where changing the incentives and rules of the game by which a society operates can dramatically affect the outcome and the resulting welfare of its players, creating a basis for either poverty or prosperity, recent work in game theory and information came to relax many of the above restrictive and unrealistic assumptions, focusing on mult... Microeconomic theory typically begins with the study of a single rational and utility maximizing individual. To economists, rationality means an individual possesses stable preferences that are both complete and transitive. The technical assumption that preference relations are continuous is needed to ensure the existence of a utility function. Just as on the demand side, the position of the supply can shift, say from a change in the price of a productive input or a technical improvement. The "Law of Supply" states that, in general, a rise in price leads to an expansion in supply and a fall in price leads to a contraction in supply. Combining system dynamics and agent based modeling, we formalize a simulation approach of the Human Development (HD) perspective to explore the interactive effects of economics, culture, society and politics across multiple human scales. Rooted in comparative political economy, the HD perspective is a qualitative, trans-disciplinary approach to understanding modernization and development through the lens of interdependent economic, cultural, social and political forces at multiple scales, from individuals to institutions and society as a whole. These decisions are constrained or incentivized by the changing macro economic, cultural, social and political environment via HD theory, conditioned on individual attributes at any particular time.