Complexity Economics and Sustainable Development

The Sustainable Development Goals are global objectives set by the UN. They cover fundamental issues in development such as poverty, education, economic growth, and climate. Despite growing data across policy dimensions, popular statistical approaches offer limited solutions as these datasets are not big or detailed enough to meet their technical requirements. *Complexity Economics and Sustainable Development* provides a novel framework to handle these challenging features, suggesting that complexity science, agent-based modelling, and computational social science can overcome these limitations. Building on interdisciplinary socioeconomic theory, it provides a new framework to quantify the link between public expenditure and development while accounting for complex interdependencies and public governance. Accompanied by comprehensive data of worldwide development indicators and open-source code, it provides a detailed construction of the analytic toolkit, familiarising readers with a diverse set of empirical applications and drawing policy implications that are insightful to a diverse readership.

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Complexity Economics and Sustainable Development

A Computational Framework for Policy Priority Inference

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Omar's dedication: To Sanna, Rita, and Omar
Gonzalo's dedication: To Verónica, Almudena, and Valeria
For their unconditional and loving support and the loss of joyful family time they had to endure.

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Foreword

Recent global events have emphasised the uncertain and intricate nature of our world. Various unexpected shocks have disrupted our development pathways, and each of them requires attention and resources from policy makers. Determining where to allocate scarce resources is not straightforward. The traditional epistemological and methodological approaches, which rely on a linear and mechanistic understanding of causes and effects, are insufficient for comprehending social challenges and offering effective policy advice to achieve desirable societal outcomes. In light of these challenges, the authors of this book have stepped up to address this gap by providing a broad understanding of the multiplicity, interdependency, and ambiguity of forces involved in development practice.

Of particular note is their focus on the intertwining nature of development objectives. Policies aimed at addressing one objective can have an impact on other objectives, creating feedback effects, either complementarities or trade-offs. This interconnected reality, along with the fiscal constraints that most governments face, underscores the importance of policy prioritisation. How can governments identify those policy actions that will have the most impact across development goals, thereby accelerating systemic progress or lifting systemic bottlenecks? In this book, the authors provide a powerful framework, drawn from years of research at the Policy Priority Inference (PPI) programme, to help decision-makers navigate this effort.

Since the Fall of 2018, when I started my tenure as Regional Director at the United Nations Development Programme (UNDP), I aimed to bring new and diversified approaches to enhance the effectiveness of the development work we support, as the most important development agency of the United Nations, in the pursuit of the

achievement of the Sustainable Development Goals by 2030. Having had the chance to see the agent-based modelling and complexity work done by Omar A. Guerrero and Gonzalo Castañeda, I immediately thought of how much that approach could contribute to the UNDP's integrator role at the UN. We thus supported the launch of the Policy Priority Inference research programme, coordinated by Almudena Fernandez. The evolution of this research programme over time demonstrates the importance of efforts that intentionally seek to bridge the gap between academic work and policy engagement. By working together with local and national governments to apply the PPI to specific policy questions, the authors were able to strengthen the tool by ensuring that its cutting-edge methodologies were also grounded in real-world assumptions – from fiscal rigidities to limited information. It was not surprising that as soon as word began to spread about the framework and potential results presented by the authors in previous papers, colleagues and public officials began to take notice and seek out its insights. The demand for this kind of knowledge was immediate and organic, reflecting the hunger of policy makers for reliable and rigorous guidance on how to prioritise public spending to achieve better outcomes.

What sets this work apart is that its analytical framework is not only theoretically rich but empirically feasible and rigorous. This is achieved through an interdisciplinary approach, which draws upon insights mainly from economics, political science, computer science, and complexity science. Importantly, however, this book is more than just an academic exercise. It has the potential to influence policy by providing evidence and empirically driven knowledge of the interactions in the complex SDG space. This can be useful to inform the prioritisation of public spending to achieve better outcomes, given real-world budgetary challenges. Beyond offering guidance on how to reallocate expenditure to close development gaps in specific policy contexts, the computational tool described in the book also prompts a broader reimagining of how we can think about achieving the 2030 Agenda (with its 17 Sustainable Development Goals supported by 169

targets and over 200 indicators) from a more integrated and holistic perspective.

In short, this book is a must-read for anyone interested in understanding development as a complex process and the challenges of policy prioritisation in an uncertain world. It represents an excellent contribution to the field. I have no doubt that its insights will be of immense value to scholars, practitioners, and policy makers alike.

—Luis F. López Calva
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This book by Professors Guerrero and Castañeda is an important contribution to the social science of economic development, generally, and to sustainable development, specifically. Their goal, as described in the first chapter, is to provide a framework for formulating sustainable development policies in a multidimensional setting and from a complex systems perspective. The authors have backgrounds in economics and computational social science and interests in development economics, and each has experience working within the large ecosystem associated with international development activities, consisting of government agencies, NGOs, foundations, and international organizations like the World Bank and the United Nations. Their broad exposure to both academic and practical aspects of economic development is one reason this work is so exciting, for it takes on real-world challenges with new ideas and tools from the research frontier to first understand extant development strategies and then create new and better approaches.

The set of tools they build on are grounded in the emerging science of *complexity economics*. A well-known economist once quipped of the field of environmental economics that its relation to the overall profession of economics was like the relation of military music to music in general: its repertoire limited, its instruments a subset of all instruments. In certain ways, development economics

is similar: the methodologies used by development economists may be years or even decades behind current practice at the forefront of the profession, such as heavy reliance on regression models in the desire to be empirically relevant. But we are living through the great flowering of data in the social sciences, from small-scale laboratory experiments with human subjects to larger-scale field studies and internet-enabled experimentation, to administrative data that constitute complete universes – every relevant person represented – in a wide variety of fields within economics and beyond, for example, finance. There exists today a far-ranging and rapidly growing set of tools and techniques for working with and analysing such data, from machine learning (ML) to artificial intelligence (AI) approaches. The focus of Guerrero and Castañeda on 'agent computing' is one of these, with so-called multi-agent systems usually considered a branch of AI. It is from these rich and hopeful advances that the field of *complexity economics* has arisen, focusing on social networks, direct agent–agent interactions, out-of-equilibrium dynamics, and realistic behavioural rules, among other things. While today this new approach has been used to model markets, firms, trade, and many other sub-fields within economics, its application to development questions is really in its infancy, which brings us to the focus of this book – Policy Priority Inference (PPI).

While the roots of this idea lie in the abstract ideas of complexity economics, its goal is to deal with real-world development challenges, to take capabilities from the 'know-how' stage to actual knowledge about specific countries and their development trajectories. As described in this book, particularly Chapters 2–4, PPI is a way to use all the data that are available for purposes of first understanding what is going on in a country, from the development perspective, assessing the performance of existing policies and programmes, and only then moving on towards the creation of more effective policies.

I am not an expert on economic development. However, I have spent much of my career trying to apply the new tools and techniques from complexity economics to real-world problems, from

firms to fisheries, housing to Hayek, the formation of economic classes and retirement economics. It seems to me that Guerrero and Castañeda have leveraged the particular strengths of the new approach in order to advance development thinking, and for that they are to be commended. Specifically, economics graduate students today are immersed in a highly idealised theoretical world in which assumptions about the attainment of equilibrium, the rationality of economic actors, the utility of representative agents, and myriad others are taken as given, despite the fact that most of these specifications are vitiated by the facts, especially in developing countries where markets are often more volatile than in the developed world, people face higher transaction costs, production may be less efficient, and so on. Therefore, to the extent that the relaxation of such heroic assumptions is the main goal of complexity economics, to build more realistic models, and if this can be accomplished with agent-based modelling, for example, it must be even more true that problems of sustainable development can benefit from such an approach relatively more. If complexity economics can help us understand economies from the bottom up, as largely self-organised, spontaneous ecologies of people and groups, partially guided and regulated from the top down, surely it can aid in our understanding of why some parts of the world are stymied from comparable achievements.

Crucially, Guerrero and Castañeda also have specific, deep domain knowledge of the Mexican development situation. This helps them frame PPI in a realistic way, focusing on the kinds of policies that have some chance of success, for they have seen good intentions lost to bad policies in their home country. But any developing country is vulnerable to ineffective development attempts, stemming from partially or largely incorrect diagnoses of the problems in the first place. The novelty of PPI is that it does not separate its diagnosis of extant problems from its recommendations about what should be done. It is an integrated perspective and a welcome breath of fresh air over the crude statistical and econometric analyses that dominate conventional development discussions and policy recommendations.

This book serves as the best, most comprehensive introduction to PPI. I think it is fair to surmise that the authors do not think of it as the 'last word' on the subject, but perhaps something closer to the 'first word'. As such, it represents a new approach to sustainable development, one with great promise, a modern approach for the computational age in which we live. This is not a book that could have been written 10 or 15 years ago. Back then we simply did not either have sufficient data or computing for this approach to be feasible.

But now we are entering a whole new world, in which increasing amounts of both intra- and inter-country data are becoming available and reshaping our empirical understanding of our world. What is in short supply now is new thinking about how economic development works, how it changes lives, and how crafting country-specific policies can lead to sustainable development. This book offers us hope that such new ideas, fueled by new data, can be brought to bear on development economic questions, under the rubric of complexity economics.

This book offers us a kind of 'chemical' mixture of new data and new computational tools – the data having little use without the models, the computing vacuous without the data – out of which, in true complexity style, the whole is more than the sum of the parts. And for this we can be very grateful to the authors.

—Robert Axtell
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Abbreviations

ABM agent-based model
AI artificial intelligence
Banxico Banco de México (Mexico's Central Bank)
CGE computable general equilibrium
CIDE Centro de Investigación y Docencia Económicas (Center for Research and Teaching in Economics)
CONEVAL Consejo Nacional de Evaluación de la Política de Desarrollo Social (National Council for the Evaluation of Social Development Policy)
CSS computational social science
DiD difference-in-differences
ENIGH Encuesta Nacional de Ingresos y Gastos de los Hogares (National Survey on Household Income and Expenditure)
EPSRC Engineering and Physical Sciences Research Council
ESRC Economic and Social Research Council
GDP gross domestic product
HDI Human Development Index
INEGI Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography)
LAC Latin America and the Caribbean
LPI line of poverty due to insufficient income
MENA Middle East and North Africa
ODA Official Development Assistance
OECD Organisation for Economic Co-operation and Development
PPI Policy Priority Inference
RCT randomised controlled trial
RoL rule of law
SCG subnational central government
SDG Sustainable Development Goal

SDR Sustainable Development Report
SHCP Secretaría de Hacienda y Crédito Público (Secretariat of Finance and Public Credit)
UK United Kingdom
UN United Nations
UNDP United Nations Development Programme
UNSDG United Nations Sustainable Development Goals (data platform)
US United States
USD United States dollar
VAT value added tax