AGRICULTURAL RESILIENCE ACCORDING TO INDIGENOUS KNOWLEDGE-BASED CASE STUDIES AND ECONOMIC QUANTITATIVE INTERNATIONAL PRODUCTION STUDIES: DIVERGENT REALITIES OR DIVERGENT REPRESENTATION?

MSc. (AGRICULTURAL AND APPLIED ECONOMICS) THESIS

DUMISANI ZONDIWE MOYO

UNIVERSITY OF MALAWI

BUNDA COLLEGE OF AGRICULTURE

AUGUST, 2012

AGRICULTURAL RESILIENCE ACCORDING TO INDIGENOUS KNOWLEDGE-BASED CASE STUDIES AND ECONOMIC QUANTITATIVE INTERNATIONAL PRODUCTION STUDIES: DIVERGENT REALITIES OR DIVERGENT REPRESENTATION?

DUMISANI ZONDIWE MOYO

BSc (Agribusiness Management), Malawi

A THESIS SUBMITTED TO THE FACULTY OF DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF REQUIREMENTS FOR AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS

BUNDA COLLEGE OF AGRICULTURE

UNIVERSITY OF MALAWI

AUGUST, 2012

DECLARATION BY CANDIDATE

I, Dumisani Zondiwe Moyo, declare that this thesis is a result of my own original effort and work, and that to the best of my knowledge, the findings have never been previously presented to the University of Malawi or elsewhere for the award of any academic qualification. Where assistance was sought, it has been accordingly acknowledged.

Dumisani Zondiwe Moyo

Signature: _________________________________

Date: _____________________________________

CERTIFICATE OF APPROVAL

We, the undersigned, certify that this thesis is a result of the author's own work, and that to the best of our knowledge, it has not been submitted for any other academic qualification within the University of Malawi or elsewhere. The thesis is acceptable in form and content, and satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on 9th August, 2012.

Major Supervisor: Prof. Abdi-Khalil Edriss

Signature: ____

Date: ____

Supervisor: Dr. Lawrence Mapemba

Signature: ____

Date: ____

Supervisor: Dr. Boyson Moyo

Signature: ____

Date: ____

ACKNOWLEDGEMENTS

I gratefully acknowledge the financial and logistical support of the African Economic Research Consortium (AERC), the mother body to the Collaborative Masters in Agricultural and Applied Economics (CMAAE), which I studied for and towards which this thesis was developed. In the same breath, I am very thankful to Bunda College of Agriculture for their support in hosting this programme in Malawi, and according me the opportunity to pursue it. Similarly, I thank the University of Pretoria for wonderfully hosting the shared specialization semester of the programme. The total experience has been very valuable and has equipped me with additional knowledge and skills that will be of use during my whole life.

I am also deeply indebted to my supervisory team comprising Prof. A.K. Edriss (the major supervisor), Dr L.D. Mapemba and Dr B.H.Z. Moyo, who offered wonderful inspiration, motivation, encouragement and guidance on the journey to the completion of this thesis; a journey that sometimes seemed too much to me. In recognition of their direct contribution to this work, I gratefully acknowledge the fact that the little I have seen, I have seen because I stood on the shoulders of great men. I also thankfully acknowledge the contribution of Arthur Chibwana, one great friend, especially for drawing my attention to Zerfu (2002). It was a life-saver! Similarly, I am indebted to Dr Dietrich Vollrath and Prof. Steven Block for sharing with me their work on international agricultural productivity, as well as attendant ("cleaned") datasets and Stata do files in the case of Dr Vollrath.

Many other people also provided, in varied ways, immense help on this journey. To mention but a few, I would like to express my sincere gratitude for the intellectual, moral and/or material support rendered by my mother, Grace; my brothers, Machamo, Vitumbiko and Zikani; my friends, Patrick Mazick, Silekiwe Mwenelupembe, Michael Chipeta, Henry Kankwamba, Lisungu Banda, Paul Zauzau Chunga, Frank Mussa, Lovemore Mtsisti, Joshua Masangano, Rashid Mpinganjira, Innocent Sinjani, the entire Bunda College CMAAE classes of 2010/2012 and 2011/2013, and the entire CMAAE student body with whom I shared the specialization programme at the University of Pretoria; and all of my graduate school lecturers. You guys were great!

Above all, I thank my closest Friend, Father and Lord, the Almighty God – the force behind those somewhat mysterious, exhilarating moments when insights and cognitive breakthroughs would just pop-up, as it were, to ensure the successful completion of this project. I also thank you for the zeal and zest, and the immeasurable broader support.

ABSTRACT

This study essentially seeks to assess the reconcilability of two themes of sustainable agriculture as a means to attenuating the sustainable agriculture impasse. It responds to the following question: relative to apparently pro-modernization international production studies, which element of pro-indigenous-knowledge case studies is atypical: the micro-environments studied or the methodologies deployed?

In terms of methodology, the study applies the method of seemingly unrelated regression to a panel dataset of 124 countries mainly over the period 1981-2005 to estimate meta-production functions. The estimated coefficients are then used to evaluate series of values of the marginal physical/value productivity of agricultural land for each country. These values are used as indicators of agricultural resilience.

The results of the analysis, which prove to be robust to the measure of agricultural output among other things, suggest that the resilience of national agricultural systems falls with increasing use of external inputs. It is demonstrated that this finding implies that agricultural resilience is eroded when Western science and technology is introduced from the angle of trying to replace rather than foster indigenous knowledge based systems.

The contribution of this thesis has several implications for development and research policy. In general, economic analysis may need to (more fully) embrace the challenge of reworking its methods and approaches of research not least by opening up to alternative realities. In terms of development policy, the study unsettles the primacy of Western development, and reinforces evidence to the effect that sustainable agriculture might require enhancing, rather than nihilistically replacing, indigenous knowledges.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AERC	African Economic Research Consortium
B-P	Breusch-Pagan
C-W	Cook–Weisberg
C-D	Cobb-Douglas
CMAAE	Collaborative Masters in Agricultural and Applied Economics
DC	Developed Country(s)
FAO	Food and Agriculture Organization of the United Nations
FEM	Fixed Effects Model
FGLS	Feasible Generalized Least-Squares
FISP	Farm Inputs Subsidy Program
GDP	Gross Domestic Product
GIS	Geographical Information Systems
HI	High external input using country
I$	International Dollar
LDC	Least Developed Country
LI	Low external input using country
LEISA	Low External Input Sustainable Agriculture
LIA	Low Input Agriculture

LSDV	Least-Squares Dummy Variable
MPP	Marginal Physical Productivity
MVP	Marginal Value Productivity
N/A	Not applicable or not available
PPP	Purchasing Power Parity
REM	Random Effects Model
s.e.	Standard Error
SAP	Structural Adjustment Program
SUR	Seemingly Unrelated Regression
TFP	Total Factor Productivity
USA	United States of America
US$	United States Dollar
WCED	World Commission on Environment and Development

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background: the Global Challenge of Sustainable Agriculture

The problem of unsustainable agriculture has caused major setbacks to human development since historical times. Two quintessential cases from early history include the collapse of the ancient Mayan civilisation of Central America and the missing occupants of Easter Island (Tietenberg, 2006). The irony in all such cases is that humans have, wittingly or unwittingly, "generated the seeds of their own destruction", an identification that has come to be called "the self-extinction premise" (Tietenberg, 2006: 2).

Presently, the sustainability of global, regional and local agriculture is being portrayed as being at risk at different levels and for different reasons. For instance, Fischer *et al.* (2002) report that while present food production systems are already failing to feed the entire global population adequately, further increases in population is threatening natural resources as people strive to get the most out of land already in production or push into virgin territory for new agricultural land. Reports of arable lands lost to erosion, salinity, desertification, and urban spread; water shortages; disappearing forests; and threats to biodiversity are presented as mounting evidence (*ibid.*).

As if this is not enough, the 21st century appears to have come with yet another challenge, that of global warming and climate change, which is believed to be deleterious to production potential as well as irreversibly damaging to land and water ecosystems (*ibid.*). These warnings call for the development of plans to adapt to and mitigate the present, and possible future threats. This quest must necessarily begin with a thorough understanding of the dynamics that underpin the threat to global agricultural production. It entails explaining the evident failure, on the general picture, of the existing global agricultural production system and identifying potential avenues for its improvement.

The word, sustainable, is derived from the Latin, *sustinere*, meaning to keep in existence, implying permanence or long-term support (Rigby & Caceres, 1997). Sustainable development thus essentially concerns the process of generating welfare needs for the present generation while maintaining or even improving the capacity of the environment to generate the same for future generations (WCED, 1987). The operationalisation of this definition includes the requirement to maintain natural capital such as healthy soils (Tietenberg, 2006). Up to this point, the world seems to be in virtually unanimous agreement (*ibid.*). Beyond this, where more definitive themes and practices must be defined and implemented, a multiplicity of sometimes competing knowledge and practice systems have emerged (Rigby & Caceres, 1997). In effect, the world is presently faced with an impasse on sustainable agriculture as on development in general.

However, it should be noted that the near-unanimity is found in other significant dimensions as well. In this regard, it offers an important introductory base to indicate that the “Third World” has received noticeably particular negative attention in terms of the sustainability of its agricultural systems. For instance, its production systems have been widely branded as unresponsive to the growing challenges imposed by factors such as climate change and weather variability, and anthropogenic pressures (including rapidly growing populations) (Wiebe *et al.*, 2001; Fischer *et al.*, 2002; Briggs and Sharp, 2004, 2009; Eriksen, 2007; Moyo, 2009, 2010).

1.2 Problem Statement and Justification of the Study

1.2.1 Problem statement

Evidence abounds to the effect that the sustainable-agriculture impasse is cushioned and furthered by divergences within the information that nourishes it, as well as between the structure of such information and policy demands. In this regard, this study identified two broad research challenges.

Firstly, it was observed that there have developed two wings of evidence on the sustainability of modernist agriculture. On one hand, there have been a lot of case studies which effectively demonstrate the superiority of indigenous-knowledge-based farming/livelihood systems over their modernist counterparts[1] (for example, Briggs *et al.*, 1999; Beckford, 2002; Eriksen, 2007; Briggs and Sharp; 2009; Moyo, 2009, 2010). Paradoxically, on the other hand, economic quantitative international productivity studies effectively, generally suggest the opposite order of superiority, as demonstrated in Chapter 2. This dichotomy was seen as resonating with the unhealthy ambiguity in the information base referred to above so that it behoved one to critically explore it, as proposed by Rigby and Caceres (1997).

The second identification begins from the recognition that policy makers have for a long time used countries with different characteristics, such as ecological and socio-economic make-up, as counterfactuals of each other against the recommendations of science (Briggs *et al.*, 1999; Chirwa & Zakeyo, 2006; Briggs & Sharp, 2009; Moyo, 2008, 2010). Cases in point include the modernization drive in general (Escobar,

[1] Refer to Chapter 2 for an elaboration.

1995), the infamous Structural Adjustment Programs (SAPs) (Chirwa & Zakeyo, 2006), and arguably Malawi's on-going Farm Inputs Subsidy Program (FISP). Yet policy makers clearly continue to replicate the same "paracetamol for all headaches" model in current challenges. This study argues that the relevant challenge for the scientist then goes beyond examining the comparability of the cases considered by policy makers to examining the success of the considered models in their source countries.

1.2.2 Justification of the study

This study sought to patch up the missing information and research orientation that had led to the fore-going research challenges. The approach taken was inspired by the argument and demonstration by various authors, including Beckford (2002), Tembo (2003), Eriksen (2007), Briggs and Sharp (2004, 2009), and Moyo (2009, 2010), that the reality and representation of the world are multifaceted. In this study, divergence in reality represents a fundamental difference in truth, to the extent that truth is variable and negotiable (Blaikie, 2000). Representation refers to interface language, including the construction of narratives (Tembo, 2003). This language may stem from identities (who one perceive themselves as) and categorizations (who they perceive the other as, imposing a category) which define people's image predispositions (Tembo, 2003). Tembo (2003) further observes that these predispositions, carried to the interaction between different parties, are either challenged and reconstructed, or confirmed. Importantly, the foregoing definitions of reality and representation imply that differential representations are easier to reconcile than differential realities. This conceptualization offered an as yet underexploited challenge that might help with the current sustainable agriculture impasse.

Indeed, this conceptualization raised the question of whether the first research challenge outlined in the Problem Statement represented a divergence of evidence contained in the different types of datasets employed by the two sets of studies, or a divergence in representation. That is, was the macroeconomic data used by the international productivity studies providing contradicting evidence compared with the other case studies, or was it that it was only being differently analyzed and presented? Phrased differently, did the case studies only reflect the realities of unusual micro-environments whose resilience does not ripple on to the macroeconomic landscape? In terms of the second research challenge, notice that in answering this question, the study would inevitably determine whether the modernist model had, according to international production data, succeeded in the modernized world in the first place.

Naturally, the research project at hand embodied the possibility of challenging conventional wisdom in terms of the international perspective on agricultural modernization. The study thus sought to enhance the rigour of the analysis by submitting the results of the study to further robustness checks, going beyond what similar econometric studies traditionally involve. In this regard, one potential key concern was identified and addressed. As recorded by Block (1994) and Zepeda (2001), various quantitative international production studies have used different units of measurement of aggregate national output. The major approaches in this regard have been the use of the so-called wheat units and monetary units such as FAO's international dollar. Direct aggregation over mass or volume, say using tonnage, has usually been avoided (Zepeda, 2001). Chapter 3 presents a synthesis and critical analysis of the literature in terms of the strengths and weaknesses, and relevance of these three types of measures, especially for the present study. For now, it suffices to indicate that the existence of so many acceptable modes of aggregation conceivably introduces the possibility of obtaining contradictory results when different modes are applied for the relevant analysis.

Furthermore, the study addressed a research constraint that is similarly constructed. That is, data constraints have usually constricted the regression datasets used by the quantitative studies, both spatially and temporally. However, for one thing, sustainability is naturally a concept that warrants inspection over long timeframes (Rigby and Caceres, 1997). As such, any measure that might relax the existing data constraints while acceptably maintaining the rigour of the analysis would be helpful. In this regard, this study set out to explore the possibility of dropping some variables from the analysis.

This study thus re-examines international agricultural production data for corroborating evidence to the pro-indigenous-knowledge school of thought, while applying quantitative methods that include econometrics. The approach taken is to assess the impact of low, intermediate and high external input use on the productive capacity of land, while testing the robustness of the results to different methods of output aggregation and the exclusion of labour from the analysis. This answers to the need to transfer a healthy or healthier land base to future generations. At the same time, it reassesses the acclaimed success of the high-external-input model in the source countries. More importantly, it offers the opportunity to unify the two strands of evidence in question, as a useful step towards the synergistic conflation of their respective development approaches, methods, diagnoses and prescriptions.

1.3 Objectives of the Study

1.3.1 General objective:

The main objective of this study was to assess patterns and measurement methods of agricultural land productivity in the face of ostensibly divergent evidence from largely qualitative small-scale case studies as compared to largely quantitative economic international agricultural production studies.

1.3.2 Specific objectives:

Three specific objectives guided the attainment of the overall objective:

(i) To identify the spatio-temporal patterns of changes in the productive capacity of agricultural land with increasing external input use.

(ii) To examine the land productivity patterns obtained from different methods of agricultural output aggregation and with different sets of explanatory variables.

(iii) To compare the results from specific objectives 1 and 2 with the literature on the binary tension associated with indigenous knowledge, and Western science and technology.

1.3.3 Research questions:

(i) Relative to the analysis in economic quantitative international production studies, which element of indigenous knowledge-based case studies is atypical: the micro-environments studied or the methodologies deployed?

(ii) How can indigenous knowledge, and Western science and technology be effectively studied and used in development theory and practice, and what are the challenges to this orientation?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter achieves two broad objectives. Firstly, it depicts the binary tension that has come to be associated with indigenous knowledge, on the one hand, and Western science and technology, on the other hand. This dyadic life-world is synthesized, critically analysed and presented in terms of its relation to the ongoing impasse on sustainable agriculture. In particular, the persistence of indigenous epistemologies that are rooted in systems that predate what has come to be widely viewed as a paternalistic transfer of Western epistemologies is used to unsettle some dominant ideas in environmentalist and developmentalist discourse and practice. It draws on a somewhat kaleidoscopic, yet insightful, array of indigenous knowledges and practices to set the underlying context of the present study, which rests on recognizing that the conceptual building blocks of Western science and technology need to be reassessed in the light of alternative knowledges that challenge the supremacy of the dominant concepts and practices of the West, and open up new development challenges that could offer better models of agricultural development (Briggs & Sharp, 2004).

Note that indigenous knowledge, here, is a somewhat relative – and location- and time-specific term – used to define knowledges generated by the locals of different areas (often from multiple sources of knowing) through their lived experiences (Briggs *et al*., 1999; Moyo, 2008; Briggs & Moyo, 2012). Contrast this with exogenously developed knowledges, in the sense of *in situ* or *ex situ* top-down development in which the local person is effectively devoiced.

Secondly, the chapter furthers its agenda by briefly critically synthesizing and analysing the methodological approaches and methods of economic quantitative international productivity studies. Ultimately, the entire review process identifies and analyses knowledge gaps that direct the rest of the thesis, which tries to address them.

2.2 Economic Quantitative International Productivity Studies in the Context of the Global Colonization Project of "Development"

A useful starting point is to realize that development is not only progress. In certain sections, particularly within the scientific community, development means other things too. Notably, Escobar (1995) details how development has, for many economists, metamorphosed overtime from the pursuit of progress to what is really a colonizing discourse or industry. While referring to Truman's infamous modernization "doctrine" as the departure point for the development industry, Escobar (1995: 40-42) observes:

> To understand development as a discourse, one must look not at the elements themselves but at the system of relations established among them. It is this system that allows the systematic creation of objects, concepts, and strategies; it determines what can be thought and said…. In sum, the system of relations establishes a discursive practice that sets the rules of the game: who can speak, from what points of view, with what authority, and according to what criteria of expertise; it sets the rules that must be followed for this or that problem, theory, or object to emerge and be named, analyzed, and eventually transformed into a policy or a plan… in short, it [has] brought into existence a space defined not so much by the ensemble of objects with which it deal[s] but by a set of relations

> and a discursive practice that systematically produce[s] interrelated objects, concepts, theories, strategies and the like. (square brackets added)

This conceptualization has been reinforced and supported with evidence not only by Escobar (1995) alone but also other authors including but not limited to Redclift (1995), Beckford (2002), Eriksen (2007), Riseth (2007), Krätli (2008), Briggs and Sharp (2004, 2009), Moyo (2009, 2010), and Howitt *et al.* (2012), and part of this evidence is discussed in the sequel. In Blaikie's (2000: 1037) words, "development is … an elaboration of an historically embedded global project to extend a universalising European and American knowledge-power regime to all parts of the world". The mechanisms for this colonization, as Howitt *et al.* (2012) call it, seem to have been strategically and surreptitiously woven into the discipline of economics. Escobar (1995: 100) relates this identification thus:

> From the classical political economists to today's neoliberals at the World Bank, economists have monopolized the power of speech. The effects of this hegemony and the damaging centrality of economics need to be exposed in novel ways. Making other models visible is a way of advancing this task.

Economic quantitative international productivity studies ostensibly represent an exemplar of the global project referred to by authors like Escobar (1995) and Blaikie (2000). Indeed, the results of these productivity and other similar studies largely, if not wholly, depict the "poorer" parts of the world as having agricultural systems that are less resilient and sustainable than those of "richer" countries. Fischer *et al.* (2002: 1), for example, assert that "[m]any of the most degraded lands are found in the world's poorest countries, in densely populated, rain-fed farming areas, where overgrazing, deforestation, and inappropriate use compound problems." This observation would seem to be supported by the findings of authors like Hayami and Ruttan (1971), Craig *et al.* (1994, 1997), Vollrath (2007) and Block (2010) who have shown, *inter alia*, that the productivity of land and labour have for the past few decades constantly been much lower among such poorer countries than among their richer counterparts. Indeed, in a synthesis of most, if not all, such studies prior to 2001, Wiebe *et al.* (2001) attempt to explain such findings, in part, with an indication that soil productivity loss is particularly problematic for most of sub-Saharan Africa where it explains food insecurity.

Moreover, findings from such studies to the effect that variables such as literacy ratio, school enrolment ratio, technical education (Hayami & Ruttan, 1971), percent irrigated land, agricultural research and development expenditure (Vollrath, 2007; Block, 2010) and average years schooling (Block, 2010), have a positive and statistically significant relationship with agricultural productivity support Escobar's (1995) "problematization of poverty" hypothesis alluded to above. Indeed, a closer inspection of these variables, especially when coupled with inspection of their methods of measurement, readily reveals that these variables are "predestined" to bear positive coefficients because they tend to be higher in the richer countries. By the same breath, the use of these control variables to proxy input quality differences among countries predestines the poorer countries to have, in the eyes of the expert, inputs of poorer quality. Moreover, input quality is actually a function of a multiplicity of variables whose influence can be location and time specific, and thus can hardly be meaningfully linearly modelled using individual coefficients. This is demonstrated in the next section. The burden of (presenting contrary) proof for this should really lie with those who introduced and those who continue to use such clearly simplistic and reductionist modelling. Importantly, it then becomes unsurprising that Kazungu (2009) refers to the production techniques of Tanzanian smallholder farmers as primitive and counter-developmental in terms of the campaign against "poverty".

As if this is not enough, the culture of referring to previous regression estimates, which were also based on the evidently inadequate theoretical model, as part of model adequacy checks neatly fits what Escobar (1995) identifies as a problematic characteristic of the development discourse, that Briggs and Sharp (2004:662) couch as "an arrogant confidence", and to which Howitt and Suchet (2004) attach Rose's (1999, cited in Howitt & Suchet, 2004) metaphor of a hall of mirrors. Escobar (1995: 42) demonstrates that "although the discourse has gone through a series of structural changes, the architecture of the discursive formation laid down in the period 1945-1955 has remained unchanged thereby allowing the discourse to adapt to new conditions." He uses the example of Hollis Chenery to put this into perspective. This then leading development economist at the World Bank is cited as having tried to reinforce a clearly inadequate theoretical framework, neo-classical economics (Moyo, 2008, 2009, 2010), by encouraging the conducting of more studies, with more sophisticated modelling but within the confines of the neo-classical theoretical formulation. In this regard, Chenery's said reference to models like computable general equilibrium models for this purpose serves to vindicate Escobar's (1995), Wilmott's (2000) and the present study's contention that mathematics and the various economic modelling tools based on it, including econometrics, can and have been easily misused and abused in development.

To be sure, the fore-going represents a really unpalatable excoriation of the discipline of economics and its sub-discipline of quantitative international productivity studies for an economist like the present author. However, more importantly, these remarks and the accompanying evidence (part of which is discussed in the sequel) challenge the economist to indeed consider a redefinition of his tenets and forms of analysis (Escobar, 1995). To this end, this chapter proceeds by outlining and critically analyzing a set of dominant concepts and practices, rooted in Western science and technology, against a set contesting concepts and practices which are based on "other models" that were central to the framing and answering of the study's research questions. It largely draws on situated glimpses which seem to exude some generalizability.

In doing this, the study essentially draws on Rigby and Caceres' (1997) encapsulating and informed treatment of the subject of sustainable agriculture. One important conclusion that they draw is that traditional themes, or "codified agricultural practices", like organic farming, are grossly inadequate in the pursuit of sustainable agriculture. Such themes, they explain, are not only self-contradictory and introduce vagueness of meaning, but also fail to answer some critical questions that these authors raise. For instance, "[i]f sustainable agriculture necessarily implies small-scale, more labour-intensive farming, then does this require a large scale return to land, and an end to much of today's industrial and manufacturing production as such large urban populations could not be maintained in the context of this form of agricultural production?" (Rigby & Caceres, 1997: 24). As a remedy, they assert that there is need for sustainable agriculture to be defined not only in terms of tools and techniques, but also in terms of philosophy.

They further observe that there is little to be gained from increasing the multiplicity of meaning of sustainable agriculture while much can be gained from generating a clearer sense of meaning. This has been notably corroborated by the British Prime Minister, David Cameron, and the German Chancellor, Angella Meckel, who have publicly declared, in evidently and perhaps deliberately general terms, that multiculturalism is dead (in Europe) (BBC, 5 February 2011). It then becomes of interest to set at least a fairly solid understanding of the meaning of sustainable agriculture as a foundation to the assessment that this study undertakes.

2.3 Key Themes in Sustainable Agriculture

2.3.1 A useful typology

It is interesting and quite informative to note that the key themes of sustainable agriculture can be understood as having their roots in the political economy. Unsurprisingly, the earliest of these roots may be traced to what Rodney (1972: 9) calls the "earliest times", when "man found it convenient and necessary to come together in groups to hunt and for the sake of survival." Rodney (1972: 10), who is corroborated by many authors including Escobar (1995) and Moyo (2008, 2009, 2010, 2011), goes on to elaborate thus:

> Development in the past has always meant the increase in the ability to guard the independence of the social group and indeed to infringe upon the freedom of others – something that often came about irrespective of the will of the persons within the societies involved.

Special and notable momentum and vividness was added to this impetus, as it were, in Truman's infamous 1945 speech which essentially called for the transfer of modern science and technology from the "growth poles", the West, to the hinterlands, mostly the global South (Escobar, 1995: 3). The reasoning included the position that this way, the "Third World" would, as a matter of necessity, be drawn away from traditional methods and set on a path to sustainable development (Escobar, 1995; Moyo, 2008, 2010). This pronouncement overtly introduced a useful typology, the traditional or pre-modernist versus the modern or modernist. This typology is also at least implied in dichotomies like Western science and technology versus indigenous knowledges (Moyo, 2008, 2009, 2010), received wisdoms versus indigenous knowledges (Briggs *et al.*, 1999), and industrial agriculture versus low-input 'traditional' agriculture, along with "conventional agriculture" versus the "alternative" agriculture movement (Rigby & Caceres, 1997).

This section uses this compartmentalization to trace and discuss the key themes in sustainable agriculture, particularly in terms of how they seek to ensure sustainability. However, it is underlined that this conceptualisation remains useful only as an analytical lens not least because practice has now largely evolved to straddle the two seemingly polar opposites (Hill, 1966; Rigby & Caceres, 1997; Briggs *et al.*, 1999; Moyo, 2008, 2009, 2010, 2011). Typical examples of the "hybridization" include *de facto* organic farming and low external input sustainable agriculture (LEISA) (Rigby & Caceres, 1997). What we really have is a continuum on which some farms lean towards one end more than others. Perhaps more crucially, if the two concepts come to be viewed as polar opposites in practice, there is the danger of conjuring up overdependence on either which potentially would jeopardise the delivery of improved living standards (Briggs *et al.*, 1999).

2.3.2 Points of departure

Another useful point in understanding the key themes at issue is to understand the points of departure of the two broad categories, pre-modernist versus modernist agriculture. In pre-modernist systems, the point of departure appears to be survival and reproduction which is largely couched in terms of food for humans (Briggs *et al.*, 1999; Moyo, 2008, 2010, 2011; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010). For pre-modernists, the overriding priority for agriculture is food. The rest, including cash for things like school fees, follow next. The centrality of food is demonstrated and underscored in the fact that they are even willing to limit resident population growth, taking the seemingly unpleasant consequences in the process, if necessary (Patel, 2002; Mertz *et al.*, 2010). For modernists, the point of departure seems to be rising living standards which is largely defined in terms of growth in financial returns (Escobar, 1995; Moyo, 2008, 2009, 2010, 2011). This entails more freedoms, not least in terms of birth control, and rising consumption (United Nations, 2010). Thus in both cases, in practice, sustainability arises as a necessary means and not an end in itself, and the ends sought after are diametrically opposite. Importantly, note that the connotation carried in the former view is the recognition that the earth is a finite resource whose use must be moderated through a modest overriding priority. In the latter, food effectively loses its vitality and becomes only one other consumer good, an effect similar to muddling trivialities with essentials. For them, the finiteness of the earth can be "conquered" through sustainable intensification (FAO, 2001; Howitt & Suchet, 2004; Moyo, 2008, 2009, 2010, 2011; BBC, 24 January, 2011). However, also note that if stretched too much, renewable resources become non-renewable (Tietenberg, 2006).

As alluded to above, the fundamental differences between the two strands of themes occur in terms of ontology and epistemology. In pre-modernist agriculture, sustainable agriculture must involve the intimate, assiduous, subtle, intensive and extensive use of internal, mostly organic, inputs while minimising or even eliminating use of external inputs for food security (Patel, 2002; Beckford, 2002; Sullivan and Kenwood, 2004; Eriksen, 2007; Moyo, 2008, 2009, 2010, 2011; Andriansen, 2008; Krätli, 2008; Briggs and Sharp, 2009; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010). In modernist agriculture, intensification of external inputs is emphasised for the express purpose of profit maximization through increased productivity and production (Moyo, 2008, 2010, 2011; BBC, 24 January, 2011). However, it is important to note that while this distinction is made in the subject matter, traditional systems too maximise profits save that the maximisation is defined in terms of food first and then financial profits (Moyo, 2008, 2010, 2011). Similarly, their production is still large-scale, looking at the numerous smallholders as a single entity, which in many respects, including their socialistic livelihood styles holds (Moyo, 2011 in personal communication). The real issue then seems to be that, in the modernist model, individuals seek to singly own large farms to maximise profits. More crucially, the attendant differences in materials and methods of production have direct as well as indirect effects on the physical and socio-economic environment as well as directly on humans.

2.3.3 To conquer or to live within the limits of nature?

Internal inputs, particularly as used in traditional agriculture, usually inflict minimal, if any, known direct or indirect damage on the physical environment and humans. This is illustrated through a few examples from a multitude of relevant cases. In traditional agriculture, degraded soil from years of cultivation is restored through organic means like shifting cultivation and cultivation with cassava (Moyo, 2008, 2009, 2010). On the contrary, modernist agriculture emphasizes the intensive use of chemical fertilisers (Moyo, 2008, 2009, 2010, 2011), while “lip service” is paid to sustainable intensification (FAO, 2001). Chemical fertilisers destroy natural soil fertility (Moyo, 2008, 2010, 2011). Similarly, “best practice” in pesticide use only minimises, as opposed to eliminating, environmental damage (Lewis & Tzilivakis, 1998).

Through mono-cropping, modernist agriculture seeks to maximise efficiency and thus financial profits while it erodes biodiversity in affected ecologies, for which need arises, among others, for even higher fertiliser per fixed output and higher pesticide application to control pests for which abundant food has been made available in the face of declining natural adversaries (Moyo, 2011). Similarly, Lewis and Tzilivakis (1998) note that adaptive selection with pesticide application generates pesticide-resistant weeds which then require higher pesticide application rates or new pesticides altogether, an argument that is biologically readily extendable to cover pests. Moreover, higher yields naturally mean the soil grows barren as it is continually “mined” (Moyo, 2011). All these are mitigated or eliminated through means like multiple cropping (and harvesting i.e. harvesting more than one crop part) and shifting cultivation in traditional agriculture (Moyo, 2008, 2009, 2010, 2011; Mertz *et al.*, 2010).

Intensive fossil fuel consumption burns non-renewable petrochemicals and produces gases that cause pollution and are linked to climate change (Moyo, 2011). Heavy tractors cause soil compaction and thus disturb soil aeration, percolation, drainage and microbial activity, among other effects (Moyo, 2011), a thing that is well avoided in traditional agriculture through reliance on hand-held implements, among other things (Rigby & Caceres, 1997; Moyo, 2008, 2010; Mertz *et al.*, 2010). The point here is that pre-modernist agriculture is more organic, in terms of tools and techniques, than modernist agriculture. Phrased differently, pre-modernist agriculture resonates more with strong sustainability whereas modernist agriculture resonates more with weak sustainability (Tietenberg, 2006).

Another important difference, alluded to above, is that while modernist agriculture cleaves towards reducing the inherent variability of nature, traditional agriculture leans towards minimal resistance against the variability but instead seeks to use that variability to advantage (Briggs *et al.*, 1999; Patel, 2002; Eriksen, 2007; Krätli, 2008; Moyo, 2008, 2010; Briggs and Sharp, 2009; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010). For instance, multiple cropping and garden types are used in the latter to, *inter alia*, weather rainfall variability, substitute off-field storage, mitigate pest effects, ensure continual or continuous production, and as a source of continuous, life-long experimentation and knowledge generation (Briggs *et al.*, 1999; Moyo, 2008, 2009, 2010; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010). On the other hand, in the quest for maximal profits, the specialisation embodied in mono-cropping, with relatively negligible diversification, dictates the concentration of resources and managerial capacity on a single, or few, enterprises so as to maximise technical and/or economic efficiency in modernist agriculture. The role of storage can also be taken over from nature (for example, cassava left in the field for years without harvesting – Moyo, 2008, 2010), and artificial crop processing and storage technology applied to avert storage losses. Pests can be controlled using pesticides which, as explained above, incrementally perpetuate dependence on the pesticides which can be non-environmentally-friendly. Experimentation and observation can be conducted in short outbursts of effort in so-called scientific tours, experiments and trials which typically span a few years at the most. This is echoed in Chamber's (2008) branding of such tours as "development tourism" and Briggs *et al.*'s (1999) argument that formal scientific research is "short-termist".

2.3.4 Time

The question of time is of particular importance. As Rigby and Caceres (1997), echoed by Briggs *et al.* (1999), Nissanke (2001), Moyo (2008, 2010) and Howitt *et al.* (2012), suggest, the best assessment of the sustainability of an agricultural system occurs in retrospect and considers long periods of time, even millennia. To the extent that pre-modernist agriculture has sustained humanity for thousands or even millions of years while modernist agriculture has only been around for about 300 years or so, the former has outperformed the other in what is arguably the greatest assessment of all possible assessments.

Modernization, or more appropriately, industrialisation, is a relatively newer concept versus indigenous knowledge, having definitive roots in the industrial revolution of Britain during the 18^{th} and 19^{th} centuries (Rodney, 1972; Rigby & Caceres, 1997; Nation newspaper, 21 February 2011). The apogee of the revolution so far has arguably been witnessed since World War II (Wilmott, 2000). However, as Briggs *et al.* (1999), Wilmott (2000), Nissanke (2001), Sullivan and Homewood (2004), Moyo (2008, 2010), and Howitt *et al.* (2012) would caution, the nascence of modernization challenges its robustness as it has witnessed far less environmental history and rarities, some of legendary proportions such as Africa's rinderpest epidemic of the 1890s (Sullivan and Homewood, 2004), as opposed to traditional knowledge which benefits a lot from hind-sight. Thus, for instance, modernist forecasting is usually based on a short length of time series data and is thus prone to missing occasional shocks or long-term patterns (Wilmott, 2000; Angeles, 2007). This is compounded by the fact that modernists consider traditional knowledge as having little to offer in the quest for human development, as indicated above (Escobar, 1995; Briggs *et al.*, 1999; Blaikie, 2000; Beckford, 2002; Robinson, 2003; Eriksen, 2007; Moyo, 2008, 2010; Briggs and Sharp, 2009). Interestingly, Eriksen (2007) and Moyo (2008, 2010) demonstrate that pre-modernists are good readers of patterns that occur over long timeframes despite their illiteracy. The locals of Zambia, in Eriksen (2007), and those of Malawi, in Moyo (2008), have shown that they too can read long-term changes in their natural resource endowments like soil fertility and forest/bush harvests, and seek ways of adjusting accordingly.

Yet still, the short-termism of the modernist model is exacerbated by the short-termist experimentation and observation mentioned above. Not surprisingly, in areas where there has been minimal modernist influence, the environment has suffered minimal, in some cases no known degradation, in as far as agriculture is concerned, and sustainability of food security little lost at worst (Briggs, 2004; Moyo, 2008, 2010; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010). Further still, it is interesting to note that many formal science recommendations are now reverting to (respect for) traditional epistemologies as a trend as evidenced by the promotion of organic fertilisers against previous agricultural rhetoric (Rigby & Caceres, 1997; FAO, 2001; Fischer *et al.*, 2002; Briggs & Sharp, 2004; Moyo, 2008, 2010).

2.3.5 Autonomy

Also, as pre-modernist agriculture is based on local knowledges and locally available materials, it seeks to attain some minimum level of autonomy (Mwale *et al.*, 2005;

Moyo, 2008, 2009, 2010, 2011). Experience has unambiguously taught pre-modernists that the market is unstable and unreliable in the delivery of agricultural inputs and outputs (Rigby & Caceres, 1997; Chirwa & Zakeyo, 2006). External knowledge, such as that from extension workers, is also received with cynicism given such cases as the need to pay for veterinary drugs, besides their knowledge that most of it is irrelevant (Tijani & Omodiagbe, 2006; Moyo, 2008, 2009, 2010; Briggs & Sharp, 2009; Jerven, 2009). Modernist agriculture is the opposite in all such aspects as it emphasises reliance on external inputs and formal scientific knowledge transfer, which may be perpetual as some knowledge is so perilously complex and/or esoteric that even only a few scientists/specialists master it (Wilmott, 2000; Chambers, 2008).

Typical examples of market failure in terms of sustainability also include organic farming, where some farmers are genuinely organic while others are solely motivated by organic premiums (Rigby & Caceres, 1997). For the latter group, all sustainability embodied in this farming method would be slowed down or even reversed if the premiums were to fall (Rigby & Caceres, 1997). This is clearly related to the point of departure, and illustrates the weakness of profit-induced supply, as opposed to one based on the vitality of life, survival and reproduction. Incidentally, indigenous knowledge, the basis of traditional agriculture, ensures that all members of society, across educational attainments, age and gender have a relatively complete set of agricultural knowledge even though there are, say, age and gender differences in culturally-based tasks and roles (Moyo, 2008, 2010; Young & Banda, 2008). Relationships and expectations among social actors are mutual and non-exclusive (*ibid.*). In essence, a discernible dimension of sustainability is defined and addressed by traditional agriculture as it hedges against the externalisation of control over production and thus evades spill-over shocks from foreign territories in terms of input supply and the absence of specialists (versus agricultural knowledge and skills).

This conceptualisation becomes more potent if Rodney's (1972: 10) observation above is invoked at this point. Indeed, there is abundant evidence that the transfer of goods and services between societal boundaries, both tangible and intangible, has been and continues to be infused with the externalization of risk to the "others". This is evident in Moyo's (2008, 2010) account that hybrid maize varieties, which are particularly prone to storage losses, and tomatoes treated with pesticides, which are potentially deleterious to human health, are usually used in production meant for the market and not for domestic consumption. Briggs *et al.* (1999) report greater rights and access to resources for the "owners of the land" in Egypt's Wadi Allaqi, the Ababda, than the "visitors", the Bishari, despite the latter having lived in the area for over 30 years now. They also report what strongly seems to be hoarding of historical knowledge of the values of vegetation species along the same ethnic lines with the effect that the Ababda are aware of a larger range of use possibilities than the Bishari in an environment where diversified knowledge and practice is vital for survival. Moyo (2008, 2010) as well as Chirwa and Zakeyo (2006) also record the ambiguities and subsequent failure of the infamous Structural Adjustment Programmes, which is arguably but one phenomenon in a litany of proclivities to experiment with and exploit human lives among the "others" (also see Mkandawire, 1998: 58). This way, the sustainability of (food) agriculture through externalised control becomes untenable not only through adventitious or natural shocks (in foreign territories), but also from deliberate, human tendencies. This supports the various calls for nearly closed systems and thus precludes unlimited population growth and rural-urban migration or urbanisation (Rigby & Caceres, 1997). Note that this "internal" nature of local knowledge does not at all contradict the claims that it is inclusive to various knowledge systems (Hill, 1966; Escobar, 1995; Briggs *et al.*, 1999; Moyo, 2008, 2009, 2010), as hinted at above. Rather, the generation of local knowledge is typically based on deconstructing, mastering and assimilating various knowledge systems and forms, regardless of source, based on perceived utility (Briggs *et al.*, 1999; Beckford, 2002; Moyo, 2008, 2009, 2010).

2.3.6 The role of social capital

Furthermore, pre-modernist agriculture particularly involves building and preserving social norms, values, ties and togetherness (Briggs *et al.*, 1999; Patel, 2002; Moyo, 2008, 2010; Mertz *et al.*, 2010). This is reflected in activities like reciprocal labour for crop production, keenness among parents or adults to transfer agricultural knowledge and dexterity amongst themselves and especially to children or the youth, social efforts to contain population growth, the definition of food security as a phenomenon at community versus family level, and so on (Briggs *et al.*, 1999; Patel, 2002; Moyo, 2008, 2010; Mertz *et al.*, 2010). Essentially, such processes ensure food security at community level in the present as well as the future. More subtly, it is worth noting that such organisation answers to the principle of bounded rationality (De Bondt *et al.*, 2008) more forcefully as it seeks to contain individualism, inexperience, myopia and greed (one of the major causes of the credit crunch of 2008) through social pressure. For instance, Moyo (2008, 2010) reports of food security at community level being a socially and culturally determined objective that is imposed on every farmer. Briggs *et al.* (1999) report of sustainable harvesting and proprietary rights to natural resources as socially determined and enforced. Patel (2002) reports of socially influenced human fertility control. Interestingly, social pressures thus become a form of law that has stood the test of time (Young & Banda, 2008). On the contrary, modernists start from assuming the existence of "beautiful" or rational individuals and markets, in which process society is relegated to a relatively inferior status (De Bondt *et al.*, 2008). In addition to the development crises in many parts of the global South (Escobar, 1995; Chambers, 2008), this reasoning seemingly hit the hardest in the 2008 financial crisis, from which the understanding that the individual's economic intuition is particularly fragile and that societal rationality transcends individual rationality seems to be taking its rightful place (De Bondt *et al.*, 2008; Rizzi, 2008). Besides, even where formal law has been used to try to enforce sustainability, as in organic farming, it has been failed by at least its narrowness (i.e. not every requirement can be transcribed into formal law) and the multiplicity of legal jurisdictions (Rigby & Caceres, 1997). This denotes the irony or tyranny of formal law, again a plus for pre-modernist against modernist agriculture. That is, the initial, underlying spirit can eventually be subdued or killed altogether. For the purpose of the present discussion, the upshot here is that modernization through its denigration and destruction of social fabric is self-defeating and thus unsustainable.

2.3.7 Failed by alienness

Last but not least, modernist agriculture has failed to take hold in the first place, in many parts of the global South, simply because it does not match with local contexts, knowledges and lifestyles (Sharma & Zeller, 2000; Howitt & Suchet, 2004; Eriksen, 2007; Chambers, 2008; Moyo, 2008, 2010; Briggs and Sharp, 2009). One important argument in this regard is simply that not everyone has the Midas touch, and thus the market is not a panacea for everyone (BBC, 16 December 2010). Some simply have to produce for their own needs and wants. Similarly, Rigby and Caceres (1997) observe that while organic farming reduces yields and conventional agriculture does the opposite in developed countries, the situation is a perfect converse in developing countries. Also, Briggs and Sharp (2009) report of scientific land demarcation methods being resisted because they failed to account for the local, physical environment context and culture among the Bedouin of Egypt. In South Africa, as in many colonies, during the early years of mineral mining by Whites, the Black had to be coerced to work for the White as for him (the Black), the concept of working for pay, especially as a permanent occupation, was alien and unnecessary (Lanning and Mueller, 1979; Angeles, 2007). To the extent that modernization fails to have an adequate proportion of its constructs accepted so as to meet the minimal requirements for sustainability as per its own theory, it runs the risk of being unsustainable as a result of partial acceptance/adoption as the Structural Adjustment Programmes are thought to have demonstrated (Chirwa & Zakeyo, 2006).

2.4 Mapping the Geographical Distribution of the Key Themes

Closely related to the identification of these key themes is the identification of their physical locations to facilitate this study's assessment. A relatively definitive narrative is contained in Rigby and Caceres (1997) who indicate that "high-input, modern or industrial agriculture" is prevalent in Western Europe and the United States of America, and is also associated with cash-cropping in many "developing" countries. On the contrary, many "poorer", non-industrialised nations, are impliedly predominated by low-input, "traditional" agriculture (*ibid.*). And the rest of the countries should be in between or among the two opposites. This identification is corroborated by authors like Blaikie (2000), Moyo (2008, 2010) and Briggs *et al.* (1999) particularly in their association of the words “Western” or “Europe and North America” with modernist tendencies and “indigenous knowledges” with the global South, or “developing” parts of the world.

Rigby and Caceres (1997) effectively propose another useful indicator, rural-urban population proportions. Specifically, highly populated rural areas should be associated with pre-modernist agriculture while sparsely populated rural areas are associated with modernist agriculture. However, while this may hold for several countries, cases like Korea and Japan, where smallholders remain key players in agriculture, albeit one reshaped by the green revolution, render the indicator readily challengeable. Indeed, the challenge is reinforced by the case of pastoralists who may be sparsely populated but pre-modernist.

2.5 Some Reflective Remarks

Finally, a few caveats pertaining to the interpretation and critiquing of the fore-going discussion may be in order. To begin with, it is challenging and self-defeating to imagine pre-modernist agriculture successfully ensuring food security in a modernist society. To be sure, traditional agriculture requires the conducive milieu of a pre-modernist society. This may seem radical and unseemly, but if Meckel’s and Cameron’s declarations mentioned above are to be taken seriously, such compromises may sooner or later have to be made. Observe that while their comments were directed towards extremist groups, their message was general, and more importantly, it gives an indication of the political options that remain open when diversity and tolerance become intolerable. Indeed, the two cannot be taken lightly outright given the influence of similar declarations by Truman versus modernization, and Thatcher and Reagan versus neo-classical economics (Moyo, 2008, 2010). The true test of liberalism comes in moments of crisis, as Europe, like many others, has found at its cost. Therefore, it becomes prudent to bring to bear the philosophy of pre-modernist societies, including fertility control and minimal travel and contact, to dispel ostensibly genuine concerns like those to do with scale, productivity and local organization (Rigby & Caceres, 1997).

Another pitfall area is to rush into under-valorising pre-modernist agriculture due to occasional failures, like Palestine's massive fertility loss over the last 3000 years (Rigby & Caceres, 1997) and the misuse of penicillin in Zombwe EPA (Moyo, 2008, 2010). Three caveats may be advanced in this regard. First, it has already been explained that pre-modernist agriculture involves lengthy periods of experimentation and observation. Therefore, there is the risk of labelling unmastered knowledge as "settledly" pre-modernist, thereby violating the meaning of what may be termed core pre-modernist knowledge. This is particularly seen in Moyo's (2008, 2010) penicillin example where there is clear information asymmetry between scientists and the locals on the dangers of the practice in question. Secondly, it is hypocritical to ignore the fact that accidents occur even in formal scientific experimentation and observation, even in the short term. Besides experimentation, occasional setbacks to development are basically common to both systems as the global financial crisis demonstrates. Thirdly and most importantly, the interest here is more in the underlying philosophies, the ontological and epistemological stances. That is, it is the basic intentions and reasoning, as opposed to the *de facto* practices, that have been discussed. Failures relating to specific practical cases do not necessarily reflect flaws in the ontology and epistemology (Young & Banda, 2008).

There are even more examples of counter-pre-modernist arguments which, though colourful, lack sufficient grounding in empirical evidence as yet. For instance, while Rigby and Caceres (1997: 24) effectively ask whether pre-modernist sustainable agriculture would "require a large scale return to land, and an end to much of today's industrial and manufacturing production as such large urban populations could not be maintained in the context of this form of agricultural production?" as indicated above, they neglect or miss (recognizing and) mentioning that in some countries, like Malawi, production of both food and cash crops is largely by small-scale farmers and not large-scale farmers. Indeed, the fears raised, therefore, run the risk of spawning unwarranted problematization of pre-modernist agriculture and fuelling the adaptive nature of modernist discourse as explained by Escobar (1995).

Also note that the present review has eclipsed the role of other cultural priorities like religion with food in pre-modernist agriculture (Rigby & Caceres, 1997). This has been influenced by records of food superseding religion overtime, as in Tikopia where yam use for rituals has been abandoned overtime and where the role of food security pressures in this change is more implied than precluded (Mertz *et al.*, 2010). Again, this is seen to be another example of the natural ordering of priorities within priorities that survival pressures and, more importantly, time dictate.

On the other hand, this review cannot claim to represent a totally comprehensive understanding of pre-modernist and modernist agriculture. Rather, it has attempted to show, arguably in microcosm, that sustainable agriculture is subsumed in (and not necessarily identical to) pre-modernist agriculture and the unsustainable counterpart in modernist agriculture. No intention is held to romanticise and over-valorise pre-modernist agriculture.

Last but not least, the author outlines the factors that determine the choice of themes to follow, by farmers and other stakeholders, and thus foster or impede the sustainability of agriculture. These include but are not limited to gender, special skills and knowledge, exposure and travel, employment opportunities, community demands, monetisation and commercialisation, formal education, protectionism and liberalism, monetary as well as non-monetary income levels, weather/climate/nature, time and location, current husbandry practices, religion, the political and regulatory environment, personalities, and, more broadly, histories, geographies and socio-cultural constructs. The relationships between these variables are so intricate and complex that attempting to discuss these forces would be tantamount to an unwarranted, labyrinthine foray for which there is not enough space. The interested reader may consult Moyo (2008, 2010), Briggs *et al.* (1999) and Rigby and Caceres (1997) for a relatively encapsulating treatment. However, all other references used in this Chapter apply. The relevant variables and relationships for this study are discussed in Chapter 3. However, be forewarned that due to the particular scarcity of data for such sustainability studies (Lee & Zepeda, 2001; Wiebe *et al.*, 2001; Zepeda, 2001; Mhango & Dick, 2011), the study is forced to deal with the variables for which data is sufficiently available. Of course, this constraint is ameliorated by the principle of parsimony (Gujarati, 2004) which obviates some of the variables.

2.6 Evolution into the Mainstream and the Periphery

As alluded to above, governments, and to a lesser but notable extent non-governmental organizations, give preference and control to scientists, technicians, national decision makers and donors whose agenda is remarkably still largely modernist while the rural, traditional farmer is devoiced (Escobar, 1995; Briggs *et al.*, 1999; Moyo, 2008, 2009, 2010). Participatory development still remains largely somewhat empty rhetoric (Chambers, 2008). While politics is central to this position, it is particularly influenced by agricultural lessons at school which virtually idolise modernist agriculture along with market orientation (Moyo, 2008, 2010). This is reinforced by the fact that the evidently ineffective communication of the more novel qualitative study approaches deprives formal scholars, researchers and planners of alternative realities and thus of a critical eye as demonstrated above.

Current, mainstream policy then is guided based on a narrow interpretation of the present and historical context, and thus does not benefit from the richness of conceptualisation, rationality and strategy that would be conferred by multiple sources of knowing. No wonder, "conventional agriculture" has failed and spawned the mushrooming of the "alternative" agriculture movement (Rigby & Caceres, 1997). More importantly, conventional policy is then less useful than it could be as it is resisted by rural farmers (Moyo, 2008, 2009, 2010) or generates development crises at worst (Chambers, 2008).

2.7 Rethinking the Building Blocks: Ontology, Epistemology and Agenda for Research

One fact that emerges from the discussion of key themes above is that pre-modernist agriculture carefully balances the ecological, economic, social, humaneness and adaptability requirements for sustainable food agriculture. The modernist, on the other hand, has a bias for economic growth and effectively stages a fatal attack on the ecology, social systems and human life itself. One key reason for this is that the modernist responds directly to wants, which are usually espoused in the phrase "socially acceptable". The pre-modernist is pragmatic and is thus preoccupied with a substantive need, food. The superiority of this position over the former has been vindicated by time. Indeed, economic poverty then ceases to be meaningful when defined in economic terms, for example using semiotics like GDP per capita. Environmentally-friendly technologies, safety from foreign shocks and so on, even with minimal economic output per capita, can and should define richer lives. The pre-modernist perspective should, therefore, set the definition and meaning of sustainable agriculture.

This leaves the issue of hybrid perspectives unanswered. To be sure, this chapter's deconstruction of sustainable agriculture leaves no room for relaxing the assumptions involved. The historical review has provided no evidence of sustainability being enhanced by the introduction of modernization, especially in its pure form, as it were. In fact, such conceptualising contradicts the principle of retrospection emphasised above. In so far as modernization is a nascent concept, its adoption is really an experiment with human life that can potentially spawn extinction of the global human society. This hypothesis seems to manifest itself in evidence such as the particular toxicity, persistence and withdrawal from use of DDT, as well as the link from massive production levels and intensive chemical fertiliser use to the accentuation of the loss of gaseous ammonia and nitrous oxide which contribute to acid rain and global warming (climate change) (Lewis & Tzilivakis, 1998). Moreover, this third, intermediate conceptualisation is fraught with the danger that it represents an adaptation of modernist discourse that is geared not so much towards true development, in this case sustainability, as it is towards maintaining a destructive agenda (Escobar, 1995).

The polarised nature of sustainable agriculture in theory implies at least three patterns of sustainability. Western Europe and North America should represent the path of a typical modernist while least-developed countries (LDCs), the quintessence of economic poverty and non-industrialism, should at least reflect more closely, especially in the earlier years of analysis, the path of pre-modernists. The rest presumably reflect the path embodied in efforts to modernise, which may either be the path to modernisation, or the careful and necessary adaptation of indigenous knowledges. This categorisation, as a basis for assessing sustainability, bears the advantage that it directly informs policy in terms of what seems to be a universally accepted *sine qua non* for development, industrialisation, and, to a lesser but significant extent, the broader modernization.

However, the review so far demonstrates that the subject of sustainable agriculture is very intricate and broad. The unrestrained quest for realism is bound to be soon immersed in a non-manageable quagmire. This dictates the need to zero in on specific concepts and build understanding sequentially (Ethridge, 2004). The challenge posed then is how to do this without compromising the chosen meaning of sustainability, which is essentially based on the various themes working in unison. This dilemma is helped by the recognition that each theme represents a necessary condition for sustainability. Remove it and there will be no sustainability. Therefore, a useful step in the assessment is the evaluation of the individual constituent components. To a lesser extent, to be helpful and useful, an initial step towards introducing the ontological and epistemological position of this study in an environment of so much diversity in the understanding of sustainability is to pick on a criterion or criteria that are widely, if not universally, agreed upon (Escobar, 1995). One such criterion that emerged from the literature review is the productivity of land. No objection was identified towards the notion that declining productivity erodes sustainability. In this regard, an assessment of the relationship between this productivity and increasing external input use may provide a useful entry point for further and more sophisticated analysis.

To this end, one glaring gap in the debate is the emphasis on theorising at the expense of empirical studies as alluded to in Chapter 1. This position is rekindled by Moyo (2008, 2010) who calls for more research towards understanding indigenous knowledge, the basis of pre-modernist agriculture. Within the few empirical pro-indigenous-knowledge studies available, this review observed that the quantification of sustainability beyond quantifying perceptions is particularly missing. While the largely qualitative lens answers to the need for "revolutions in development enquiry" as articulated by Chambers (2008), the traditional, rather top-down approach would provide some kind of a check on the more common bottom-up assessments (Guan *et al.*, 2009). To be specific, no study was found to have assessed the *de facto* changes in international, marginal land productivity at low and high chemical fertiliser use overtime and over space, for example. Indeed, it is important to note that much of the theory and evidence used to discuss the key themes is based on case study research (for example, Moyo, 2008, 2009, 2010; Birch-Thomsen, *et al.*, 2010; Mertz *et al.*, 2010).

Case studies are important and instructive in the generation of narratives and theory of limited application (Tellis, 1997). They usually fall short of generating scientifically acceptable generalizations, especially for blanket policies at national and international levels (*ibid.*). Therefore, the information generating process can be significantly enhanced through an international-level study that adopts the top-down quantitative approach. In fact, the use of so much qualitative analysis may indeed explain the alienation of indigenous knowledges by scientists for whom rigorous and acceptable science continues to be identified with the quantitative, top-down approach. Quantitative analysis thus adds value to the qualitative approach merely as a means for effective and efficient communication with a group that holds considerable influence over the sustainability of agricultural production. It contributes significantly to responding to Briggs *et al.*'s (1999) and Rigby and Caceres' (1997) call for balancing theory generation with empirical evidence which remains, to a significant extent, unheeded. To sum it all, the selected research approach or position engages with spatiotemporal dynamism and the vagueness of meaning in the assessment of agricultural sustainability, which constitute key issues identified by Rigby and Caceres's (1997) representative and insightful review of the literature.

2.8 Further Synthesis of the Modelling Deployed by Quantitative Productivity Studies

To this end, it should be noted that with the broadness of the topic of sustainable agriculture has emerged a multiplicity of measures of agricultural sustainability in the literature (FAO, 2001). If we zero in on the capacity of land, as a resource, to produce food, the scope of directly relevant measures narrows as well. In a broader sense, these include pollution studies (for example, Lewis & Tzilivakis, 1998; FAO, 2001; Birch-Thomsen *et al.*, 2010), for example. However, the world of the economist, particularly in quantitative international productivity studies, appears to be mainly confined to two key measures: the total factor productivity index (TFP) and measures of the productivity of individual resources (Hayami and Ruttan, 1971; Craig *et al.*, 1994; FAO, 2001; Wiebe *et al.*, 2001; Vollrath, 2007; Block, 2010). In as much as the TFP lumps all inputs together, it is of little relevance to this study's research agenda.

On the other hand, many inter-country productivity studies have so far focussed on evaluating and explaining *de facto* productivity, average physical or value productivity to be specific (Craig *et al.*, 1994; Wiebe *et al.*, 2001; Vollrath, 2007). The major flaw in this approach is that it does not incorporate the possibility of minimal use of external inputs even where contemporary use is high. This is evident in the mathematical definition of productivity,

$$\frac{Y}{X}$$

where X is the variable input and Y, the output, captures the influence of all inputs involved together, pretty much like the TFP. This is not a surprising flaw given that mainstream thinking seems to be obsessed with highlighting the plight, in this case food insecurity, of developing, "benighted" economies (for example, Wiebe *et al.* , 2001; United Nations, 2007; Kindred *et al.*, 2008) as argued above. Notice that the preponderance of studies such as Craig *et al.* (1994), Vollrath (2007) and others cited in Wiebe *et al.* (2001) measuring factors affecting this type of productivity helps neglect evaluating the sustainability of productivity gains. More importantly, correcting the weakness thus requires a measure that can evaluate productivity while holding, in principle, external input use at minimal levels.

Fischer *et al.* (2002) is one study that makes this correction at the global level. This study essentially utilises Geographical Information Systems (GIS) to predict agricultural production under different hypothetical scenarios which include varying levels of external input use. However, as noted above, their evidence may be strengthened through the application of multiple methods to provide multiple evidence. Besides, their approach suffers from technical deficiencies, notably that it models land suitability for cropping on a grid square by grid square basis across the globe, and ignores alternative uses like housing as well as the availability of water in terms of irrigation, not to mention discrepancies with ground knowledge or reality (Kindred *et al.*, 2008). Perhaps more crucially, Fischer *et al.* (2002) assess prospects for the future, which is very much experimental in nature, as opposed to reviewing sustainability in retrospect.

2.9 Summary and Conclusions

In broad terms, this chapter has interrogated dominant thinking and practice which espouses the thinking that the so-called scientific and technological advancement from the West can be used to undo the undesirable consequences of what would otherwise be unsustainable agricultural systems characteristic of so-called poorer countries. It has framed and contributed to a new form of debate which respects and is informed by alternative models of conceptualization and practice. Such alternatives include the thinking that naturally sustainable systems, like no (for example, Low

Input Agriculture or LIA) or low external input sustainable agriculture, should drive the way forward.

In the argumentation, a variety of notions of sustainable agriculture and its building blocks are recast in a framework of multiple knowledges, as opposed to the circular legitimization and justification of Western science and technology. It has been shown that the two strands of thinking mentioned above have evolved into the mainstream and the periphery, respectively, arguably under the auspices of a global project to set the epistemology and ontology of Western science and technology as equal to a singular, complete and unquestionable truth. This usually invisible primacy and dominance of Eurocentric knowledge is exposed and rendered challengeable, thereby signifying that current policy is narrowly informed. This makes it intellectually compelling and challenging to redefine and reassess the sustainability of world agriculture, not to mention the known advantages of the second strand of thinking in its own right. The discussion closed with a succinct review of methodological literature. It has been identified that there is need for a concomitant modification of the analytical framework and econometric modelling to embrace the epistemological and ontological position of pre-modernists. To sum it all, the chapter constitutes the requisite knowledge base from which to reassess the international production data under study.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter describes in detail and analyses the choice of research approach and methods that were used to achieve the study objectives. It is generally developed sequentially, beginning by discussing the ingredients to the ultimate methodological deployments, the empirical models and, more so, the estimation strategy. On the general picture, the methods deployed are two-fold. Firstly, there are methods that were adopted or adapted from the literature as per convention. The justifications for their use are provided. Then, there is a second set of methods, including the aggregation of output in tonnes and the theoretical model, which had somewhat barely defensible foundations in the literature. Their use was thus rather experimental, being based, at the onset, more on the author's intuition than directly on the literature. To be sure, it appears to have been based on the literature, as discussed in Chapter 2, albeit in a manner that arguably appeals more to intuition than logical induction or deduction. Interestingly, this latter set of methodological elements yielded empirically meaningful and plausible results, and in that way, their inclusion in this study became more justifiable. In the last section, Section 3.6, the study points out limitations of the study and suggests possible avenues for further direction of research.

3.2 Conceptual Framework

3.2.1 The meta-production function

According to Hayami and Ruttan (1971: 82), effectively a classical text in economic international quantitative agricultural production studies, "[t]he meta-production function can be regarded as the envelope of commonly conceived neoclassical production functions." It is based on the assumption that all producers in the different groups, say countries, potentially have access to the same technology and can reach some unique production frontier (Hayami & Ruttan, 1971). However, for this study, there is found to be little plausibility and necessity in the envelope hypothesis. It is postulated that it suffices to describe the meta-production function as a regional or zonal representation of the production path taken by a given zone as input use varies overtime and among the countries involved. Importantly, it may be perceived as a kind of weighted sum of modernist and pre-modernist farming micro-units in the three zones of interest here. Given the relative dominance of pre-modernist and modernist systems in the two polar zones, modernist patterns should repress pre-modernist patterns in the modernist zone while the converse should hold in the pre-modernist zone. The relaxation of Hayami and Ruttan's (1971) hypothesis also allows this study to model shifts in the function overtime as for Hayami and Ruttan (1971, 83-84), "it is operationally feasible to assume a reasonable degree of stability for a technical 'epoch', the time range relevant for many empirical analyses. Shifts in the meta-production function are much slower than adjustments along the surface, or to the surface from below, of the meta-production function." The irrelevance of these assumptions to the present study, and the postulate of this study are detailed in the development of theoretical and empirical models subsequently.

3.2.2 Measurement of elasticities

One may identify two approaches to measuring the productivity of land. In accordance with tradition (for example, Craig *et al.*, 1994, 1997; Wiebe *et al.*, 2001; Vollrath, 2007; Block, 2010), the influence of other conventional inputs like tractors and livestock as well as non-conventional inputs must be isolated. In this regard, this study has demonstrated that the input-quality line of argument easily collapses. This leaves the defensible role of these variables as increasing the statistical precision of the parameter estimates of interest as alluded to by Hayami and Ruttan (1971), among others.

Indeed, the present research interest essentially lies in determining the potential resilience of agricultural production to a sudden cut in the supply of non-land inputs, particularly external inputs, at any given point in time. The task is, therefore, that of analysing the *direct* effect of the shock on the systems as they are, and not as they would be. The influence of the extraneous conventional and non-conventional inputs must, therefore, be allowed to be reflected in the estimated elasticities of production, even if internal inputs are in turn influenced by external inputs. For example, this study would assess what changes in agricultural production or productivity would arise from zero chemical fertilizer application and/or tractor use in a given year in modernist societies while holding constant the contemporary levels of, say, pesticide use, average farm size, land inequality, and research and development expenditure[2]. This carries the advantage that it represents a drift towards a holistic approach that

[2] However, the suggested impact of the shock will reflect the short term and will be conservative. As alluded to by Wiebe *et al.* (2001), the resulting productivity loss, and possibly production loss, is expected to be more pronounced if and as the shock persists.

accounts for environmental trade-offs while potentially offering options for an integrated approach to environmental protection within agriculture (Lewis & Tzilivakis, 1998). In principle, the inclusion of the socio-economic variables would, therefore, have a confounding effect. Thus, to borrow Craig *et al.*'s (1994: 23) language, the research task reduces to that of "imposing some structure, through the use of a meta-production function," on observed output (in tonnes, wheat units and monetary units, separately), land allocation (in 1000 ha), chemical fertiliser consumption (in tonnes), tractor use (in numbers), livestock (in cow equivalents) and agricultural labour (in numbers). Importantly, this orientation entails the need to identify alternative and effective ways of reducing the heterogeneity within the datasets, for meaningful and reliable insights. This issue is addressed in the outline of empirical models that follows.

3.2.3 Operationalisation of variables (mostly adopted from FAO (2011))

This sub-section defines the major factors of production used in the regression analysis in this study. It delineates the specific elements of production covered as well as the methods of measurement employed. The variables discussed include land allocation, fertiliser consumption, livestock, tractors and labour. Most of the definitions are adopted from FAO (2011), as the data is mostly from FAO's (2011) FAOSTAT, and utilise insights drawn from previous users of this data source.

Land allocation refers to agricultural area. This category is the sum of areas under:

(a) arable land - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallowed (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for arable land is not meant to indicate the amount of land that is potentially cultivable;

(b) permanent crops - land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees);

(c) permanent meadows and pastures - land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

Fertilizer consumption is the total metric tonnes of plant nutrients used, measured in equivalent nutrient units of nitrogen, phosphorous, and potash (Craig *et al.*, 1997). Traditional nutrients, animal and plant manures, are not included.

Livestock is the number of cow equivalents, a measure commonly used in the cross-country literature (Vollrath, 2007). Vollrath (2007) explains that it is calculated using weights obtained from Hayami and Ruttan (1985), cited in Vollrath (2007). The weighting is as follows: 1 horse = 1 mule = 1 buffalo = 1.25 cattle = 1.25 asses = 0.9 camels = 5 pigs = 10 sheep = 10 goats = 100 chickens = 100 ducks = 100 geese = 100 turkeys (Vollrath, 2007). For a few cases with no cow equivalent units in this list, the weight of the perceived closest biological relative was used instead (see Table A-8 of Appendix A).

Tractors is measured by the number of tractors in use in agriculture which are all assumed to be 30 horsepower (Vollrath, 2007). This measure excludes two-wheeled tractors and garden tractors and so is not a perfect measure of capital services available (*ibid.*). However, this is the only dataset on capital services in agricultural production that covers a wide range of countries and time periods (*ibid.*).

Labour is measured as the total economically active population in agriculture. However, as lamented by Craig *et al.* (1997), these labour statistics include workers in crop and livestock agriculture, forestry, and fisheries rendering them not entirely compatible with the agricultural output measures used in this study. However, as noted by Craig *et al.* (1997), data limitations again resign us to this fate, as it would be.

3.2.4 Measurement of output

As mentioned in Chapter 1, a commonly maintained hypothesis in international productivity studies is that measuring output by summing over weight or volume is not very meaningful as the outputs involved are not directly comparable (Craig *et al.*, 1994; Zepeda, 2001; Vollrath, 2007). Consequently, aggregate output in agriculture is commonly measured in monetary units such as the international dollar and, to a lesser extent, in wheat units (Craig *et al.*, 1994; Block, 1994, 2010; Zepeda, 2001; Vollrath, 2007). Wheat units are essentially a fixed set of weights that denote the prices of different commodities relative to wheat in some reference countries over a base period (Hayami & Ruttan, 1971). As discussed below, however, each of these two latter measures has its own weaknesses as well.

To begin with, monetary units suffer from the fact that agricultural markets are imperfect and have often favoured developed, modernist economies (Lanning & Mueller, 1979; Escobar, 1995; Angeles, 2007). Thus, price movements and differences intrinsic to agricultural value added would be expected to bias estimates in favour of such economies. Besides the imperfections observed in the product markets, exchange rate changes, say due to devaluation, can also introduce differentiation between value-based relationships and the underlying physical relationships that are of present interest (Block, 1994). Block (1994) observes that while substituting purchasing power parity (PPP) exchange rates such as the international dollar for nominal exchange rates reduces the bias caused by exchange rate disequilibria, it does not resolve the agricultural price difference/changes problem noted above.

As for wheat units, it is observed that preferences change with time. In this regard, the question arises as to whose perspective (among the different populations covered by the study period) deserves to set the basis for valuation intended for the assessment of the sustainability of agricultural systems. In a way, this question could readily be extended to the more common monetary units through the following questions. Do changes in preferences always account for the sustainability of the structure of production that they promote? If not, then there should be a set of valuation structures that are more prudent than others and thus deserving of use for output aggregation. How to identify such structures, and based on what criteria is not inconceivably bound to be too difficult and may yield a multiplicity of answers, some contradicting.

Further, the premise underlying wheat unit and the more common monetary valuation is that man's value perceptions as captured by the market can provide a useful benchmark for output aggregation. The traditionally documented imperfections of the market notwithstanding, this assumption readily collapses in the face of the self-extinction or bounded rationality premise as described in Chapters 1 and 2. Man is simply not perfectly rational and can engage in self-destroying activities. However, if this is assumed away under the common and somewhat defensible justification of analytical expediency, then tonnage readily qualifies as a measure for output aggregation. Indeed, if man can be rational enough as to set the valuation benchmark when he enters the market on the consuming end, then to some extent, man should also be considered rational enough for the same purpose when he appears on the producing end. In other words, man will produce what is needed, in a manner that reflects contemporary demand and preferences.

Furthermore, monetary and wheat unit valuation does not necessarily reflect the nutritive value of the foodstuffs as a pre-modernist would demand. Ideally, from a pre-modernist perspective, nutritive value and social acceptability should be reflected in the appropriate measure. However, available data is insufficient for this purpose and so tonnage may be used as a proxy for these qualities. The maintained hypothesis here is that at the aggregate, zone level, where a multiplicity of crops and livestock is produced, tonnage will be strongly, positively correlated with nutrition-wise valuable and socially acceptable foods, in a similar though not identical fashion among the zones.

As a corollary to the foregoing, wheat units and tonnage should depict patterns as though one were some fixed proportion of the other. This is indeed roughly the case for world total[3] agricultural production over the 1961-2009 period as depicted in Figure 3.1. Figure 3.1 provides the graphs of per capita net production (defined as total net agricultural production divided by total human population) as measured in

[3] "Total" is loosely used to refer to all crop and livestock products data reported by FAOSTAT, and particularly in the context of the present study's output aggregation methods. No intention is held to imply that this dataset is a true and accurate reflection of actual production.

the international dollar, tonnes and wheat units as defined by the present study. Notice that all three graphs are similar (more so the tonnage and wheat unit graphs) when scale is ignored so that tonnage does not perform so poorly with reference to the popular measures. Incidentally, the international dollar graph seems to depict the value production versus physical production disconnect, as discussed above, in the sense that it denotes faster agricultural growth in its having a relatively more flatter than curved-in shape.

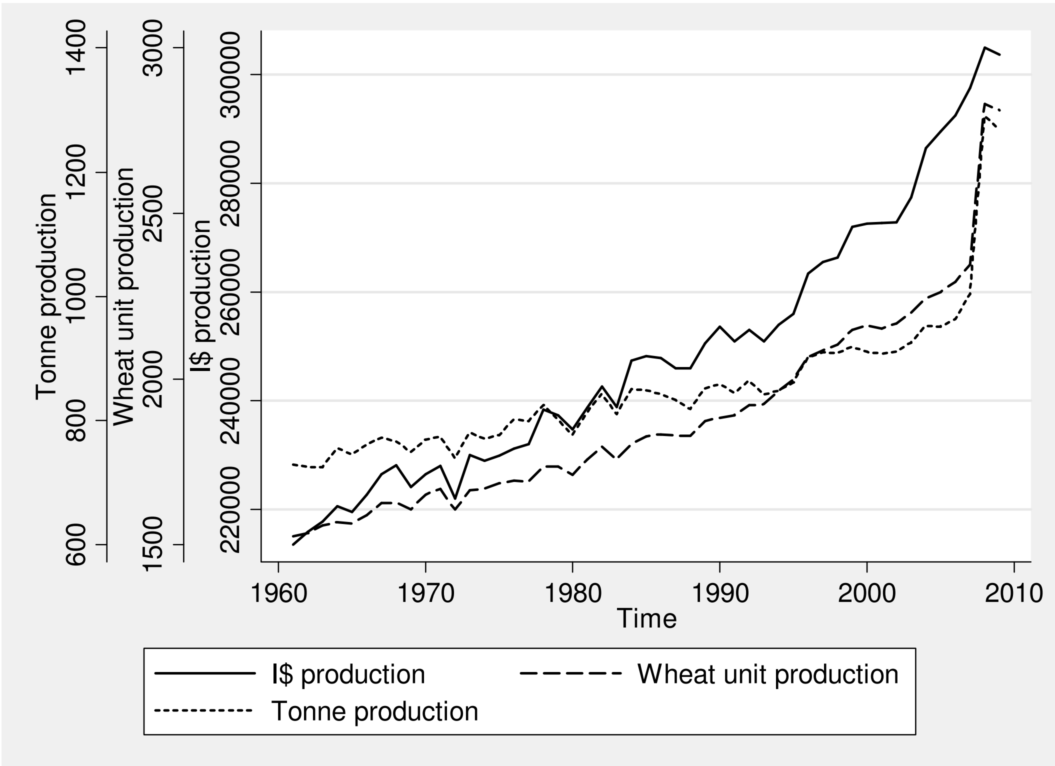

Figure 3.1 Graphs of world per capita production
Source: Author's own construction based on FAOSTAT data

Importantly, wheat units thus become a theoretically prime unit for output aggregation, among the three units of measurement considered here. The analysis so far shows that the wheat unit effectively addresses the substantive interests of the pre-modernist philosophy, as argued above, while it remains one of the measures that have gained some formal acceptance in the scientific community as depicted by the literature. Moreover, it arguably most closely meets the requirements of what Craig *et* *al*. (1991) call the ideal approach to aggregating multiple commodities – as per index number theory – which requires that a vector of base-year local commodity prices expressed in dollars be multiplied by a vector of quantities of individual commodities, for a given country and year (Craig *et al*., 1991 cited in Block, 2010).

Against the background set thus far, agricultural production data in this study are thus aggregated over tonnes, wheat units and the international dollar as obtained from FAOSTAT. FAOSTAT provides already aggregated values of net agricultural production by country. This is defined as the total value of all crops and livestock products originating in each country after deductions for feed and seed (FAO, 2011). Practically all products are covered, with the main exception of fodder crops (FAO, 2011). Data for tonnage and wheat unit aggregation refer to the actual primary production from crops and livestock excluding harvesting and threshing losses, and that part of crop or livestock not harvested for any reason. Production therefore includes the quantities of the commodity sold in the market (marketed production) and the quantities consumed or used by the producers (auto-consumption).

For the latter two aggregation approaches, however, only feed[4] (both domestically produced and imported) was deducted for the following reasons. First, for most crops, one would say a seed multiplies itself exponentially to produce output in terms of mass. Second, seed may be considered equivalent to other factors of production like pesticides which are not traditionally deducted from output. Finally, total seed used this year may be considered to be some proportion of last year's production. Effectively, seed becomes one of the alternative uses to which man puts output. Thus,

[4] Feed for deduction was measured in the same units as output. For example, it was measured in wheat units when agricultural output was measured in wheat units.

seed need not introduce double-counting as with feed. Furthermore, the fore-going reasons, particularly the first and third imply that the inclusion or deduction of seed need not change the results of the present analysis substantially. Tables A-5, A-6 and A-7 in Appendix A provide the crops, livestock and feeds used in the study for wheat unit and tonnage aggregation, along with their wheat-relative prices.

3.2.5 Demarcation of zones

Zones were defined in terms of the sample countries' levels of use of chemical fertilizers and agricultural tractors over the entire 1961-2005 period, so as to serve as a proxy of the cumulative effect of modernization on agriculture, that has occurred in the respective countries. The level of use of each of these conventional inputs per 1000 hectares was evaluated for each country and each year. Then, the geometric mean for each pair of the resulting values, by country and time, was determined. Finally, these were represented by the country-level arithmetic means of the geometric means for the entire 1961-2005 period, such that each country then had one final average value. These temporal averages of the geometric means were arranged in decreasing order and cut-off points determined such that all zones should be of roughly equal size in terms of number of countries. This resulted in the identification of high external input using countries (HIs) (with the highest average geometric mean values), low external input using countries (LIs) (with the lowest average geometric mean values), and the intermediate (with intermediate average geometric mean values). The assumption underlying the use of the geometric mean was that bias in identification that would have arisen from a low value(s) from one temporal series of per hectare input use within a country, say due to some transient shock or wrong data, would be cancelled out, to some extent, by the determination of the geometric means of the two series.

3.2.6 Theoretical model

This sub-section extends and expounds on the study's reconstruction of Hayami and Ruttan's (1971) meta-production function hypothesis. To this end, the Cobb-Douglas (C-D) production function is adopted because it has been extensively used for international (agricultural) production studies over a long period of time and produced results that are empirically plausible to the extent that they tally with actual, ground observations (Hayami & Ruttan, 1971; Braun, 1998; Wiebe *et al.*, 2001; Vollrath, 2007; Kazungu, 2009; Block, 2010). Furthermore, given the simplicity of the C-D specification relative to more sophisticated functions such as the translog function, the C-D offered the researcher the opportunity to keep abreast with the mechanisms underlying produced output of analysis. Indeed, as Wilmott (2000) would argue, the alternative was to blindly engage with esoteric sophistication that transcends his current imaginative and cognitive power. For instance, the researcher found it easy and very valuable to cognitively capture or visualize the geometric form of the C-D output even in more than two dimensions. It is argued that the alternative, esoteric models would have inhibited his capacity to engage in independent thinking.

A useful entry point towards the construction of the new meta-production function hypothesis comprises biological and anthropological findings reported by Moyo (2008, 2010). Moyo documents the experience of smallholder farmers in northern Malawi by which the farmers have observed that once chemical fertiliser is applied to a field, the field tends to yield less than its pre-fertiliser yield level when fertiliser application is discontinued. He supports this observation with the scientific identification that soil pH changes resulting from the application of fertiliser can affect and, at times, can upset the microbial activities in the soil that decompose dry matter. The upshot, for us, is that in the common case where changes in land, or changes in production seasons on the same amount of land, are coupled with changes in other inputs such as chemical fertilizers, it becomes difficult to sustain Hayami and Ruttan's hypothesis. Indeed, such cases defy the conceptualization of a unique, fixed production function, as adopted by several authors including Hayami and Ruttan (1971), Vollrath (2007), Kazungu (2009) and Block (2010), for a simple reason that is elaborated next.

Let us begin with a hypothetical unit of production operating in Stage II of the neoclassical production function as all estimation results of international agricultural production known to the author have depicted diminishing returns (Hayami & Ruttan, 1971; Wiebe *et al.*, 2001; Vollrath, 2007; Kazungu, 2009; Block, 2010). In a single product, single factor system, the C-D would take the following geometrical conformation (Figure 3.2):

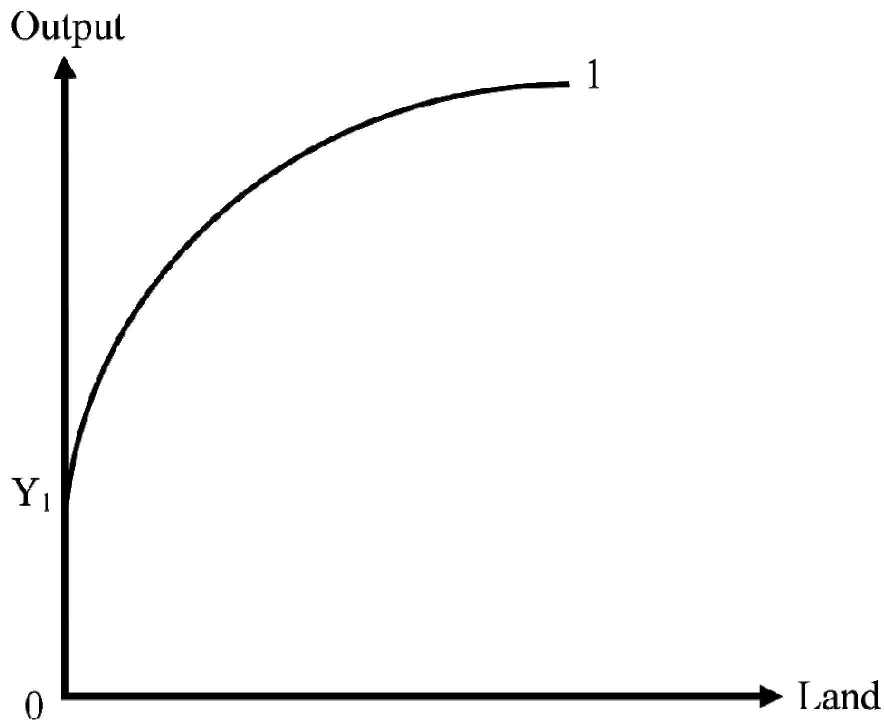

Figure 3.2 A Cobb-Douglas production function depicting diminishing returns

Indeed, Figure 3.2 is a hypothetical graph depicting diminishing returns. That is, the marginal physical productivity of land falls as land is increased along Function 1. Under Hayami and Ruttan's (1971) hypothesis, it would depict a fixed (inter-temporal) relationship between land and output, to which countries operating below the frontier could gravitate through the invention and diffusion of appropriate agricultural technologies. More importantly, this hypothesis implies that once the full range of technological alternatives described by the meta-production function is exploited, an agricultural unit will operate along the frontier from year to year as long as we remain within a given "epoch". As demonstrated by Hayami and Ruttan (1971), Vollrath (2007), Kazungu (2009) and Block (2010), such "epochs" could cover periods of fifteen years or more. This contradicts the non-geometric observations by farmers and scientists, as reported by Moyo (2008, 2010), which suggest that agricultural production overtime, which is typically supported by chemical fertilisers, is characterized by shifts in the production function. Indeed, a piece of land that has lost part of its productive capacity should be characterized by a lower production function than it had at first.

For this reason, our hypothesis holds that the meta-production function only represents the zonal production path taken by the represented zone as land increases, say from country to country. Indeed, only a path for it would be contrary to practice to contend that the function represents fixed production possibilities within a technical "epoch", as argued above. In practice, changes in land, or changes in production seasons on the same amount of land, usually go hand-in-hand with changes in other inputs such as chemical fertilizers. Such accompanying changes are bound to change the productive capacity of land with the effect that it becomes difficult, if not impossible, to retrace the same production path with further changes in land and/or time. This contention is hypothetically depicted in Figure 3.3, which is a rather crude illustration deemed necessary for expository purposes. More rigorous modelling is presented subsequently.

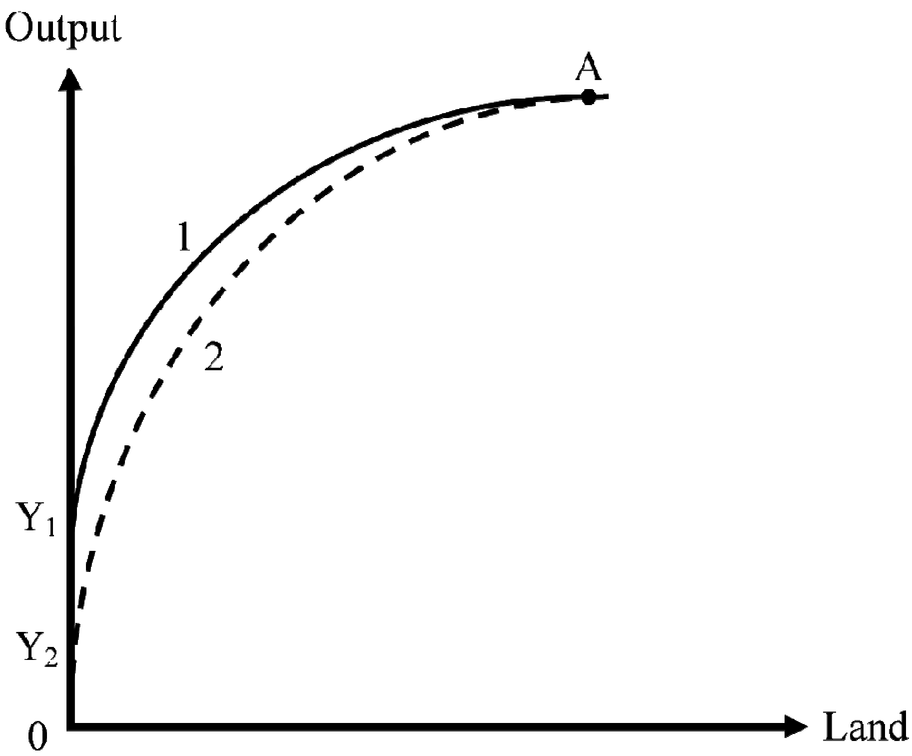

Figure 3.3 A crude illustration of the shift in production function with increasing land but falling land productivity

In Figure 3.3, a unit operating at the higher tip of Function 1 (point A) fails to retrace its original path (Function 1) as it decreases land employed for primary agricultural production. This unit has degraded its land with inappropriate use of inorganic inputs such as chemical fertilizers and inorganic pesticides. As such, the smaller amount of land now yields less than before. As a result, the reverse path is represented by Function 2. However, the increasing use of the non-land inputs could support production in place of land, and result in higher production even with smaller amounts of land. This scenario is illustrated in Figure 3.4.

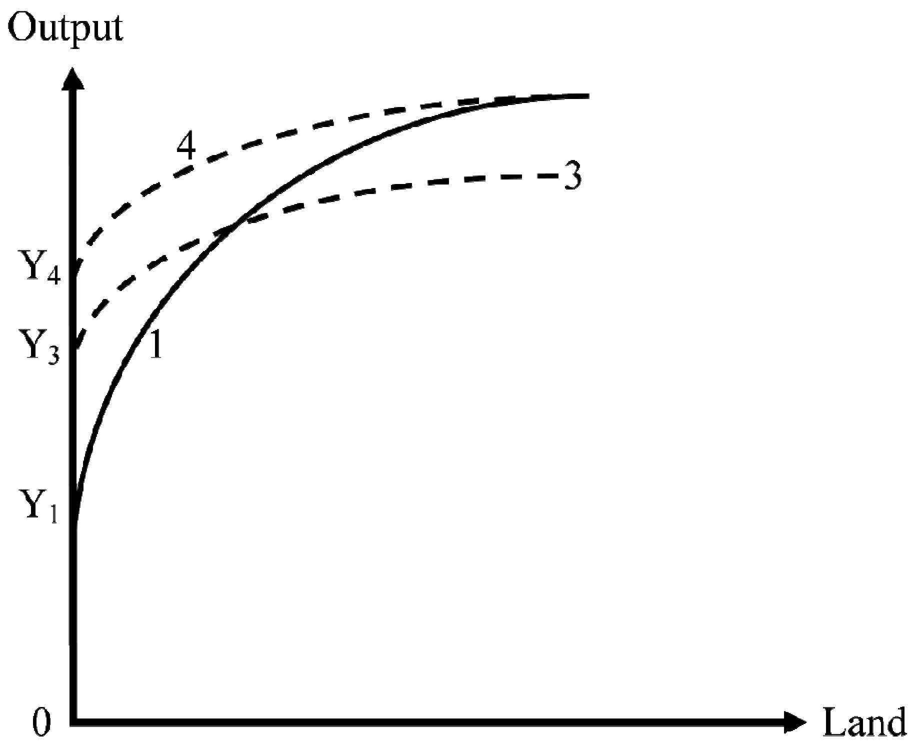

Figure 3.4 An illustration of production gains supported by non-land inputs with falling land productivity

In Figure 3.4, a unit operating at the intersection of Functions 1 and 3, or Functions 1 and 4, along Function 1 operates along Function 3 or 4 with decreasing land. As depicted by the changing point of anchorage of the production function from Y_1 to Y_3 or Y_4, the smaller amounts of land are capable of producing more due to a productive push from non-land factors. However, it is important to note that movement along both Functions 3 and 4 depicts eroded productive capacity of land. This becomes readily visible if one mentally anchors these two functions at Y_1, in which case the same amount of land would then produce less output along Functions 3 and 4 compared with Function 1. It should be noted that in light of this conceptualization, what may appear as movement along one curve onto its flatter parts (overtime) will actually usually be movement onto higher but flatter production functions. In other words, the ease of reversibility of changes in the productive capacity of land implicit in the neoclassical production function usually does not hold in practice where its fundamental assumptions are evidently violated. Similarly, where changes in land are coupled with increases in other (conventional or non-conventional) factors of production, it becomes somewhat easy to misinterpret increasing average physical productivity as increases in the productive capacity of land. On the contrary, flatter production functions, even if higher than the starting function, represent movement onto higher scaffolding that is arguably more weakly constructed. Indeed, drops in non-land inputs within such scaffolding could spawn drastic drops in output (for example, movement from anchorage at Y_4 to anchorage at Y_1 for Function 4 in Figure 3.4). This argument is more clearly illustrated in Figure 3.5 in which Function 4 is raised to yield Function 5.

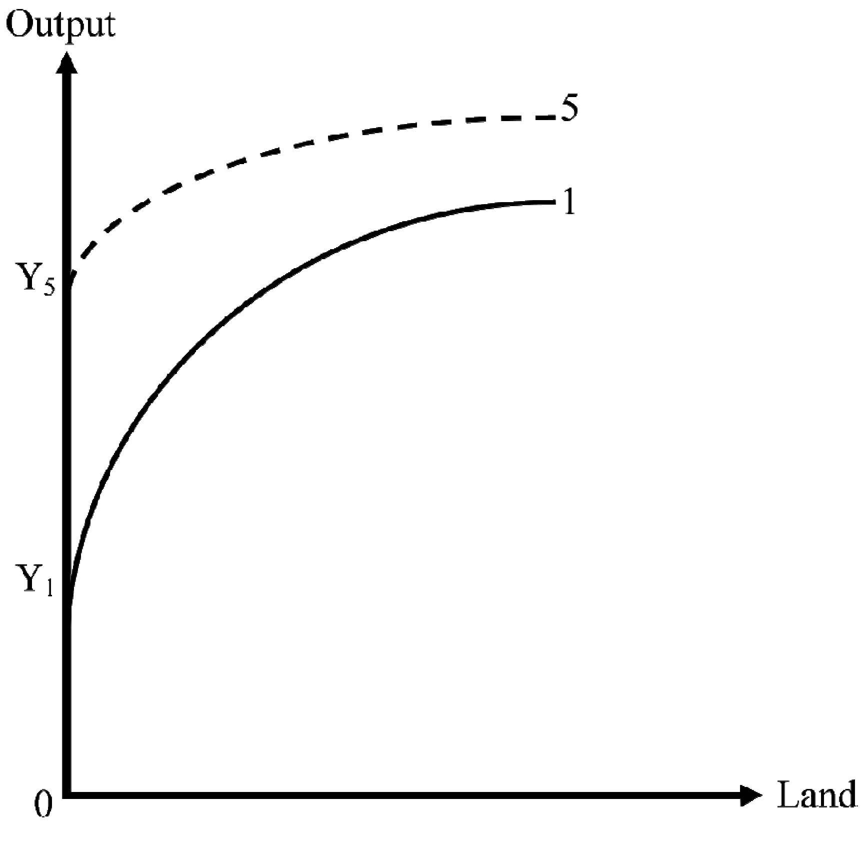

Figure 3.5 An alternative illustration of production gains supported by non-land inputs with falling land productivity

For a practical perspective on this, the study brings to bear the case of Malawi's aggregate food and cereal production in the face of the SAPs. SAPs refers to reform programmes that many developing countries were compelled to implement under aid conditionalities set by the International Monetary Fund and the World Bank (Chirwa & Zakeyo, 2006; Kazungu, 2009). A neo-liberalist approach informed the reform directions. In the present context, a critical component of these measures included the liberalisation of agricultural input markets with the effect that external inputs like fertilisers were pushed out of reach for many a smallholder farmer. This was due to the removal or reduction of government regulation of markets, as well as government-sponsored input and credit subsidies, among other things. As it has been rather well documented, such projects have produced some damaging results in some parts of the world (Escobar, 1995; Moyo, 2010; Howitt *et al.*, 2012).

Chirwa and Zakeyo (2006) demonstrate that the indices of aggregate cereal and food production per capita experienced steady falls with the implementation of the SAPs. This fits well with our theoretical conceptualization as depicted in Figure 3.5. It may be argued that with subsidized chemical fertilizers, Malawi had moved to Function 5 where the productive capacity of the land had been eroded by the polluting effects of the fertilizers. With the removal of the fertilizer subsidies under SAPs, the weak scaffolding represented by $(Y_5 - Y_1)$ had collapsed, hence the marked drops in output. One might want to argue that the same effect would result from a reverse shift from Function 5 to Function 1. However, that would be contrary to the evidence that land has tended to lose its productive capacity, as per Figure 3.5, when one attempts to raise production through the application of chemical fertilizers (Moyo, 2010).

At this point, the study defines two possible paths for increasing total production on a unit of land. On the one hand, one could move onto steeper functions while maintaining the point of anchorage or while moving onto higher points of anchorage. This is illustrated in Figure 3.6 where a unit raises its meta-production function from Function 1 to Function 6 (with a fixed point of anchorage) or Function 7 (with a higher point of anchorage). It should be observed that Functions 6 and 7 represent enhanced productive capacity of the land.

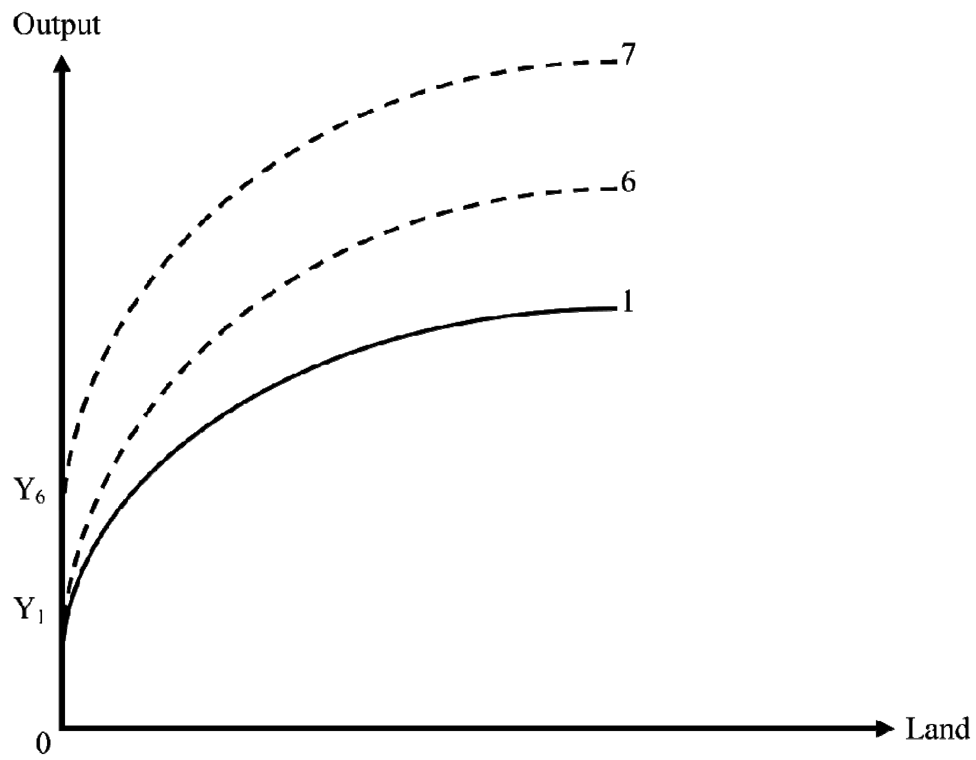

Figure 3.6 An illustration of production gains supported by gains in land productivity as well as gains associated with non-land inputs

On the other hand, one could move onto higher but flatter production functions as depicted in Figure 3.5; or indeed a function such as Function 3 in Figure 3.4 where a unit experiences higher total production (versus the counterpart land use level on Function 1) as it changes to lower amount of land used along Function 3 from the point of intersection of Function 3 with Function 1.

Two further observations are in order. First, the requirement of maintaining natural capital as a prerequisite for sustainable production supports the steeper-functions approach to increasing production. Second, the marginal physical productivity (MPP) of land becomes a useful indicator for assessing adherence to this sustainability requirement. Indeed, MPP rises as one moves from one function to steeper functions for a fixed amount of land. This observation also implies that MPP can be used to determine which of the two possible paths have been taken to increase total output. In this regard, it should be noted that declining MPP with declining amount of land unambiguously denotes declining productive capacity of land.

Furthermore, it should be indicated that the afore-going figures and discussion only present a microcosmic representation of the diverse patterns that reality can produce. However, it should be possible to extend the breath of the arguments to different scenarios. For example, output can rise by moving from one function to a steeper function with a lower point of anchorage. This would hold where the point of intersection of these two functions occurs at a point representing less land than is currently in use.

The concept of (point of) anchorage becomes readily comprehensible when we turn to the algebra of the foregoing. The base meta-production function, with conventional inputs only, has generally been mathematically specified as follows at least since Hayami and Ruttan's (1971) effectively classical text (Hayami & Ruttan, 1971; Wiebe *et al.*, 2001; Vollrath, 2007; Kazungu, 2009; Block, 2010):

$$Y_{it} = \alpha Lan_{it}^{\beta_1} Lab_{it}^{\beta_2} Liv_{it}^{\beta_3} Fer_{it}^{\beta_4} Tra_{it}^{\beta_5} \quad (1)$$

where Y_{it} is the aggregate output produced by country *i* in time *t*, Lan_{it} is the amount of agricultural land used by country *i* in time *t*, Lab_{it} is the total economically active population in agriculture in country i in time t, Liv_{it} is the number of livestock in country i in time t, Fer_{it} is the consumption of chemical fertilizers by country i in time t and Tra_{it} is the number of tractors in use in agriculture in country i in time t, and α and β_j are coefficients that are estimated. Notice that for given levels of labour, livestock, fertilizers and tractors, equation 1 reduces to equation 2.

$$Y_{it} = \theta {Lan_{it}}^{\beta_1} \tag{2}$$

where θ may be considered a constant or point of anchorage that expands to equation 3.

$$\theta = \alpha {Lab_{it}}^{\beta_2} {Liv_{it}}^{\beta_3} {Fer_{it}}^{\beta_4} {Tra_{it}}^{\beta_5} \tag{3}$$

3.3 Empirical Models

Following many researchers like Hayami and Ruttan (1971), Craig *et al.* (1994), Lee and Zepeda (2001), Velazco (2001), Vollrath (2007), Kazungu (2009) and Block (2010), as well as several others cited in Wiebe *et al.* (2001), an econometric structure was imposed on the variables of interest using the production function specified as Cobb-Douglas with inputs land (Lan), labour (Lab), livestock (Liv), chemical fertilisers (Fer) and tractors (Tra):

$$Y_{it} = \alpha {Lan_{it}}^{\beta_1} {Lab_{it}}^{\beta_2} {Liv_{it}}^{\beta_3} {Fer_{it}}^{\beta_4} {Tra_{it}}^{\beta_5} \tag{4}$$

where Y is aggregate agricultural output in wheat units, tonnes or the international dollar, Lan is total agricultural area in 1000 hectares, Lab is the total economically active population in agriculture, Liv is the number of cow equivalents, Fer is total chemical fertilizer consumed in tonnes, Tra is the number of agricultural tractors in use, and the subscripts i and t denote country and year, respectively, while α and β_j are the coefficients that were estimated.

In linear and general panel data regression form, equation 4 may be written as

$$lnY_{it} = \beta_0 + \beta_1 lnLan_{it} + \beta_2 lnLab_{it} + \beta_3 lnLiv_{it} + \beta_4 lnFer_{it} + \beta_5 lnTra_{it} + \mu_i + \lambda_t + \upsilon_{it} \quad (5)$$

where μ_i denotes the unobservable individual-specific effect, λ_t denotes the unobservable time effect and υ_{it} denotes the remainder stochastic disturbance which "can be thought of as the usual disturbance in the regression" (Baltagi, 2005: 11). The panel data formulation is believed to have conferred several benefits over comparable cross-sectional and time series formulations. For instance, Kazungu (2009) notes that by using data on both the inter-temporal dynamics and the individuality of the entities, it is capable of controlling the effects of missing or unobserved variables. He also refers to Hsiao's (2005, cited in Kazungu, 2009) argument that panel data generates more accurate predictions for individual outcomes by pooling the data rather than generating predictions of individual outcomes using only the data on the individual in question. The specific sources of accuracy are two-fold. First, it arises from efficiency gains from the more degrees of freedom and more sample variability relative to the constituting time series and cross-sectional data. Second, if individual behaviours are similar conditional on certain variables, panel data provides the possibility of obtaining a more accurate description of an individual's behaviour by supplementing the observations of the individual in question with data on other individuals (Kazungu, 2009).

This study was effectively a retrospective characterization of selected countries with no initial intention of generalizing the regression results to out-of-sample countries and time periods. This pointed towards the Fixed Effects Model (FEM) as the appropriate model, as opposed to the Random Effects Model (REM). Moreover, by controlling for time-invariant differences between individuals or zones, FEM would allow the study of causes of changes within an individual or zone. It would allow the study to use the changes in the variables overtime to analyze the relationships between the independent variable and the dependent variable (Kazungu, 2009). Indeed, interpretation of the counterpart REM coefficients is tricky since they include both the within-entity and the between-entity effects. Moreover, FEM has been widely used in similar country-level productivity studies (for example, Vollrath, 2007; Kazungu, 2009; Block, 2010) with some finding support for FEM by the Hausman specification test (for example, Vollrath, 2007; Kazungu, 2009).

To be sure, the choice between FEM and REM should first be theoretical as done above. Adopting REM for research questions that can be adequately be addressed by the "less inferential" FEM makes no sense. Gujarati (2004: 546-547) alludes to this point by invoking quotes from experienced researchers, like Kennedy's (1998) "Ten Commandments of Applied Econometrics" and Martin Feldstein's (1982) warning:

> There is no question that model building is an art as well as a science. A practical researcher may be bewildered by theoretical niceties and an array of diagnostic tools. But it is well to keep in mind Martin Feldstein's caution that "The applied econometrician, like the theorist, soon discovers from experience that a useful model is not one that is 'true' or 'realistic' but one that is parsimonious, plausible and informative."

On a more statistical note, however, this study still recognizes that in the absence of cluster confounding and endogeneity of level-1 independent variables (that is, variables which vary both within and across clusters), REM confers efficiency gains over FEM. The study might thus gain robustness, on the statistical front, from testing for the presence/absence of these estimation problems. Indeed, Block (2010) hints that production theory makes the endogeneity problem more expected than unexpected. Bartels (undated) relates a more general concern among practitioners that since a level-1 variable varies both within and between clusters, unobserved heterogeneity will almost always be correlated with such independent variables. To this end, the Hausman (1978) specification test was conducted on the 1981-2005 wheat-unit-aggregated regression data not so much in search of a substantively more preferable model, as to allay potential criticism from the more statistical eye.

Indeed, as Gujarati (2004) would contend, the appropriateness of FEM should ultimately be checked with reference to the empirical plausibility of its output. Furthermore, the inclusion of time dummies in this model produced insignificant estimates so that the model represented by equation 5 reduced to equation 6 after adding zonal dummies.

$$lnY_{it} = \gamma_{zT}Z + \beta_{1zT}lnLan_{it} + \beta_{2zT}lnLab_{it} + \beta_{3zT}lnLiv_{it} + \beta_{4zT}lnFer_{it} + \beta_{5zT}lnTra_{it} + v_{it} \qquad (6)$$

where capital Z is the zonal dummy, γ_{zT} is a coefficient to be estimated, and subscripts z and T denote the zth zone and Tth 5-year period, respectively. In equation 6, the coefficients on zonal dummies, γ_{zT},, and slope coefficients were allowed to vary with time, changing every five years. In addition, the slope coefficients were allowed to vary by zone.

Notice that zonal dummies take the place of the more commonly used country dummies. This is dictated by the present conceptual framework which requires a zonal differentiation of the meta-production functions, as well as the statistical contention that the zonal dummies perform essentially the same role in the regression as country dummies would (Craig *et al*., 1997).

It should also be noted that due to the particular focus on sample countries, these countries effectively constituted the statistical population of interest although the results could be extended to similar out-of-sample countries by non-statistical or less statistical considerations. For this reason, hypothesis tests on estimated coefficients were really tests of statistical reliability of the estimates rather than for purposes of inferring to some larger population.

3.4 Estimation Strategy

Taking after Block (2010), equation 6 was actually estimated as a system of seemingly unrelated equations using seemingly unrelated regression (SUR), employing the method of feasible generalized least-squares (FGLS), in order to take advantage of cross-equation correlation of the error terms for estimation efficiency gains as well as ease of running cross-equation hypothesis tests on estimated coefficients (Wooldridge, 1999). The strategy here was to specify the same production function for each set of five year panel datasets and applying the SUR estimator without imposing any constraints on all coefficients except the coefficients of intercept dummies which were not statistically significant (which were equated to zero). As shown by Zellner (1962), the efficiency gains occur over estimating each production function separately, or pooling all of the data together and estimating a single equation. The five year intervals were adopted mainly to avert the challenge of micronumerosity but also because they were considered to be a reasonable production "epoch", in Hayami and Ruttan's (1971) terms as described above. The SUR system of production functions thus took the following form:

$$\begin{aligned} lnY_{it,(81/85)} = {} & \gamma_{z(81/85)}Z_z + \beta_{1z(81/85)}lnLan_{it} + \beta_{2z(81/85)}lnLab_{it} \\ & + \beta_{3z(81/85)}lnLiv_{it} + \beta_{4z(81/85)}lnFer_{it} + \beta_{5z(81/85)}lnTra_{it} \\ & + v_{it,(81/85)} \end{aligned}$$

$$\begin{aligned} lnY_{it,(86/90)} = {} & \gamma_{z(86/90)}Z_z + \beta_{1z(86/90)}lnLan_{it} + \beta_{2z(86/90)}lnLab_{it} \\ & + \beta_{3z(86/90)}lnLiv_{it} + \beta_{4z(86/90)}lnFer_{it} + \beta_{5z(86/90)}lnTra_{it} \\ & + v_{it,(86/90)} \end{aligned}$$

$$\begin{aligned} lnY_{it,(91/95)} = {} & \gamma_{z(91/95)}Z_z + \beta_{1z(91/95)}lnLan_{it} + \beta_{2z(91/95)}lnLab_{it} \\ & + \beta_{3z(91/95)}lnLiv_{it} + \beta_{4z(91/95)}lnFer_{it} + \beta_{5z(91/95)}lnTra_{it} \\ & + v_{it,(91/95)} \end{aligned}$$

$$\begin{aligned} lnY_{it,(96/00)} = {} & \gamma_{z(96/00)}Z_z + \beta_{1z(96/00)}lnLan_{it} + \beta_{2z(96/00)}lnLab_{it} \\ & + \beta_{3z(96/00)}lnLiv_{it} + \beta_{4z(96/00)}lnFer_{it} + \beta_{5z(96/00)}lnTra_{it} \\ & + v_{it,(96/00)} \end{aligned}$$

$$\begin{aligned} lnY_{it,(01/05)} = {} & \gamma_{z(01/05)}Z_z + \beta_{1z(01/05)}lnLan_{it} + \beta_{2z(01/05)}lnLab_{it} \\ & + \beta_{3z(01/05)}lnLiv_{it} + \beta_{4z(01/05)}lnFer_{it} + \beta_{5z(01/05)}lnTra_{it} \\ & + v_{it,(01/05)} \end{aligned}$$

In order to increase the statistical reliability or precision of the parameter estimates, two dummy variables were added to each equation as a heterogeneity-reducing mechanism. One dummy variable, *pdmmy*, represented outliers lying above the estimated surface, while the other, *ndmmy*, represented those lying below the estimated surface[5]. The final SUR system of production functions thus became:

[5] This approach to dealing with outliers was adapted from Zerfu (2002).

$$lnY_{it,(81/85)} = \gamma_{z(81/85)}Z_z + \beta_{1z(81/85)}lnLan_{it} + \beta_{2z(81/85)}lnLab_{it} + \beta_{3z(81/85)}lnLiv_{it} + \beta_{4z(81/85)}lnFer_{it} + \beta_{5z(81/85)}lnTra_{it} + \varphi_{p(81/85)}pdmmy_{it} + \varphi_{n(81/85)}ndmmy_{it} + v_{it,(81/85)}$$

$$lnY_{it,(86/90)} = \gamma_{z(86/90)}Z_z + \beta_{1z(86/90)}lnLan_{it} + \beta_{2z(86/90)}lnLab_{it} + \beta_{3z(86/90)}lnLiv_{it} + \beta_{4z(86/90)}lnFer_{it} + \beta_{5z(86/90)}lnTra_{it} + \varphi_{p(86/90)}pdmmy_{it} + \varphi_{n(86/90)}ndmmy_{it} + v_{it,(86/90)}$$

$$lnY_{it,(91/95)} = \gamma_{z(91/95)}Z_z + \beta_{1z(91/95)}lnLan_{it} + \beta_{2z(91/95)}lnLab_{it} + \beta_{3z(91/95)}lnLiv_{it} + \beta_{4z(91/95)}lnFer_{it} + \beta_{5z(91/95)}lnTra_{it} + \varphi_{p(91/95)}pdmmy_{it} + \varphi_{n(91/95)}ndmmy_{it} + v_{it,(91/95)}$$

$$lnY_{it,(96/00)} = \gamma_{z(96/00)}Z_z + \beta_{1z(96/00)}lnLan_{it} + \beta_{2z(96/00)}lnLab_{it} + \beta_{3z(96/00)}lnLiv_{it} + \beta_{4z(96/00)}lnFer_{it} + \beta_{5z(96/00)}lnTra_{it} + \varphi_{p(96/00)}pdmmy_{it} + \varphi_{n(96/00)}ndmmy_{it} + v_{it,(96/00)}$$

$$lnY_{it,(01/05)} = \gamma_{z(01/05)}Z_z + \beta_{1z(01/05)}lnLan_{it} + \beta_{2z(01/05)}lnLab_{it} + \beta_{3z(01/05)}lnLiv_{it} + \beta_{4z(01/05)}lnFer_{it} + \beta_{5z(01/05)}lnTra_{it} + \varphi_{p(01/05)}pdmmy_{it} + \varphi_{n(01/05)}ndmmy_{it} + v_{it,(01/05)}$$

where φ_{lT} is a coefficient to be estimated, and l is either n or p. Outliers were defined as points lying beyond the value of the standard deviation of the estimated residuals from the first SUR system. After the dummy variable control for outliers in the second SUR system, the study estimated values of squared residuals for the purpose of eliminating data points that were still outlying. In this regard, a cut-off point of intuitive appeal to the researcher, based on scatter plots of squared residuals against predicted output, was picked and all data points with values of squared residuals beyond this cut-off point were eliminated from the estimation sample. Unfortunately, due to the rectangular, wide form (as opposed to long form) of SUR data, the elimination of one observation effectively eliminated all observations of the concerned country ahead of it in time by five year intervals. For instance, if the 1985 case of Malawi were identified as an "untreatable" outlier, then Malawi cases at 1990, 1995, 2000 and 2005 would also be deleted. Fortunately, the deletion was at fixed intervals so that it is not expected to be seriously damaging to the estimates. Further, there were several cases in which a country would be such an outlier in several, most or even all of such equally spaced observations.

The analysis was, for the most part, restricted to the 1981-2005 period, first due to the limited availability of labour data. The FAOSTAT dataset used had labour figures running from 1980 onwards, for most countries. Further, as mentioned above, a dataset for the SUR system needs to be of a rectangular shape for successful estimation, at least in Stata, the program used for this analysis. That is, Stata's SUR estimation procedure, like for several other regression procedures, uses case-wise deletion to handle missing values. It thus became difficult for the researcher to fit the remaining two years, 2006 and 2007, for which sufficient data was available, into the SUR dataset. Moreover, SUR has the weakness that biased estimation in one equation can bias the entire SUR set of parameter estimates. In this regard, the relatively short two-year period that was omitted was bound to suffer from micronumerosity, at least relative to the other periods, yielding relatively unreliable estimates that can deviate more from the "true" parameters and thus "pollute" the entire system.

As regards the issue of a limited available dataset for labour, the SUR system based on wheat unit output aggregation was run without the labour variable for the period 1961-2005 and the results compared with those for the 1981-2005 period. The idea was to check whether the exclusion of labour would change the results significantly, failing which, the 1961-1980 estimates from the 1961-2005 results could well be considered to be an extrapolation of the labour-inclusive 1981-2005 results. This approach was motivated by Kazungu's (2009) (including the authors cited therein as previous users of modelling that includes only land as a conventional input) knowing or unknowing allusion to the notion that where land is included as an explanatory variable for agricultural output, it becomes difficult to conceptualize the significant existence of missing variables. Indeed, the conformations of the excluded variables, especially where these are not too many, should manifest in changes in the productivity of land without significantly introducing bias to the patterns depicted. For instance, fertilized land should be more productive than unfertilized land, *ceteris paribus*. In our case, where anthropogenic pressures erode agricultural productivity per unit land, this should be able to still show where labour (representing an increasing population engaged in primary agricultural production) is excluded from the analysis, more so where the parameter estimates are allowed to vary with time.

Following the econometric estimation, measures of marginal physical/value productivity[6] of land were then obtained using equation 7 for the labour-inclusive case and equation 8 for the labour-exclusive case.

$$\left({}^{dY}/_{dLan}\right)_{zit} = \alpha_{zT}.\beta_{1zT}Lan_{it}{}^{(\beta_{1zT}-1)}.Lab_{it}{}^{\beta_{2zT}}.Liv_{it}{}^{\beta_{3zT}}.Fer_{it}{}^{\beta_{4zT}}.Tra_{it}{}^{\beta_{5zT}} \quad (7)$$

$$\left({}^{dY}/_{dLan}\right)_{zit} = \alpha_{zT}.\beta_{1zT}Lan_{it}{}^{(\beta_{1zT}-1)}.Liv_{it}{}^{\beta_{3zT}}.Fer_{it}{}^{\beta_{4zT}}.Tra_{it}{}^{\beta_{5zT}} \quad (8)$$

where $\left({}^{dY}/_{dLan}\right)_{zit}$ is the marginal physical/value productivity of land on the z^{th} zone's production curve at time *t* for values of factor inputs given by the actual values of factor inputs used by country *i* at time *t*, and α_{zT} is defined as follows:

$$\alpha_{zT} = e^{(\gamma_{zT}+\varphi_{pT}+\varphi_{nT})} \quad (9)$$

---

[6] Marginal physical productivity refers to the case where output is measured in wheat units or tonnes while marginal value productivity refers to the international dollar equivalent.

where e is the base of the natural log.

3.5 Data Sources and Manipulation

The agricultural data including output, land, labour, livestock, fertiliser consumption, feed and tractor numbers were obtained from FAOSTAT database. The data for 132 countries and the period 1961-2007 on all variables but fertilizer was perfectly balanced; that is, it had no missing values. The fertilizer data had very few cases of missing values which were linearly interpolated and extrapolated as applicable. The interpolation and extrapolation strategies employed equation 10.

$$Fer_s = Fer_t + (s - t)(Fer_{t+n} - Fer_t)/n \qquad (10)$$

where Fer_s is the estimated consumption level at time s which falls between, before or after actual observations at times t and $(t + n)$. Vollrath's (2007) constant-growth-rate assumption was considered and dropped because it produced outlying estimates in certain cases, while estimates based on equation 10 were generally considered plausible.

Last but not least, an original set of wheat relative prices was evaluated and employed for the aggregation of output in wheat units. Hayami and Ruttan's (1971) dataset was insufficient as many commodities are not overtly covered, while Hayami and Ruttan's (1985) dataset, cited by Vollrath (2007), proved difficult to access. The procedure employed was very similar to the one used by Hayami and Ruttan (1971), whose 1985 results were also used by Block (1994), among others. Guided by the availability of price data[7], a fixed set of base-year prices of all commodities relative to wheat was evaluated from the 1961-2008 averages of world trade export values (in 1000 US$ per tonne) as obtained from FAOSTAT. Next, the quantity (in tonnes) of each commodity *i* in country *j* was multiplied by its wheat-relative price to give an equivalent quantity of wheat. Aggregate output in country *j* then became the sum of the wheat-equivalent quantities of all commodities produced that year in that country.

3.6 Limitations and Areas for further Research

Despite generating plausibly indicative evidence (Chapter 4), this study suffers from several limitations that future studies need to improve on for more rigorous and, hopefully, more insightful analysis. These include but may not be limited to the following:

1. There is need for better valuation methods which can account for attributes that the market overlooks or undervalues but are important (for example, taste of hybrid maize versus local maize in Malawi), especially with regard to their variation across countries or even zones, for example, Malawi versus the USA.
2. The adequacy of the model specification developed by the present study for prediction, planning and policy purposes needs to be assessed and, preferably

[7] Using a few specific countries and a shorter time period as done by Hayami and Ruttan (1971) was problematic because several commodities ended up having no price attached to them. This problem was also encountered with the world trade prices but at a much more limited scale. The problematic commodities were then put at the same price level as closely similar commodities. The deviation from Hayami and Ruttan's (1971) approach in this regard is considered acceptable because the basic idea underlying the wheat unit is to attach some base relative value level to the various commodities. Indeed, Hayami and Ruttan (1971: 309) alluded to this point when they conceded that their use of price data for the U.S.A., Japan and India was, to be sure, arbitrary and that the selection of their criteria for such analysis was guided by "the availability of data rather than theory".

improved on. The improved models may need to account for time lags in the impacts of inputs, and attempt to enhance estimation precision through the informed inclusion of further variables in appropriate specifications.

3. "Non-conforming" countries as identified in this study (Chapter 4), like Egypt, warrant further critical examination not least to learn in detail the dynamics that allow them to raise the MPP of land whilst using what appears to be relatively high external input levels.
4. Better datasets need to be developed and utilized. The current FAOSTAT dataset suffers from validity and reliability weaknesses not least because of the validity of the data collection methods (FAO, 2011), possible accuracy loss due to scaling of the data, and the aggregation. Similarly, operational concepts such as the cow equivalent may be improved upon in recognition of the diverse use and roles of livestock in different areas and at different times, for example.
5. The definition of sustainability may need to be broadened to more fully and more overtly account for the multidimensional nature of sustainability.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results from the econometric analysis as outlined in Chapter 3. The study relates the results to the research objectives as outlined in Chapter 1, as well as the literature as discussed in Chapter 2. In terms of structure, the next section (Section 4.2) describes and discusses the quantitative results, thereby addressing specific objectives 1 and 2, and generally relates them to the literature. The subsequent section then addresses specific objective 3 more thoroughly, by consolidating the efforts of Section 4.2 with a more thorough illustration of how the literature explains the findings of this study.

4.2 Productivity Patterns

To begin with, Table 4.1 presents a list of the 124 countries included in the analysis by zone, after the elimination of outliers[8].

[8] The designations employed and the presentation of the material in this study do not imply the expression of any opinion whatsoever on the part of the author concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Table 4.1 List of countries under study by zone

High external input countries	Intermediate countries	Low external input countries
Albania	Algeria	Angola
Austria	Argentina	Benin
Bahamas	Australia	Bolivia (Plurinational State of)
Barbados	Bangladesh	Botswana
Belize	Brazil	Burkina Faso
Bulgaria	Chile	Burundi
Canada	China	Cambodia
Cuba	Colombia	Cameroon
Cyprus	Costa Rica	Cape Verde
Democratic People's Republic of Korea	Dominican Republic	Central African Republic
Egypt	Ecuador	Chad
Fiji	El Salvador	Congo
France	French Polynesia	Côte d'Ivoire
Germany	Guatemala	Democratic Republic of the Congo
Greece	Guyana	Equatorial Guinea
Hungary	Honduras	Gabon
India	Indonesia	Gambia
Israel	Iran (Islamic Republic of)	Ghana
Italy	Jordan	Guinea
Jamaica	Kenya	Guinea-Bissau
Lebanon	Lesotho	Haiti
Mauritius	Libya	Lao People's Democratic Republic
New Zealand	Malawi	Liberia
Norway	Mexico	Madagascar
Pakistan	Morocco	Mali
Poland	Myanmar	Mauritania
Portugal	Nepal	Mongolia
Republic of Korea	New Caledonia	Mozambique
Romania	Nicaragua	Namibia
Saint Kitts and Nevis	Panama	Niger
Saint Lucia	Peru	Nigeria
Saint Vincent and the Grenadines	Philippines	Paraguay
Spain	Seychelles	Rwanda
Sri Lanka	South Africa	Samoa
Sweden	Swaziland	Senegal
Switzerland	Syrian Arab Republic	Sierra Leone
Thailand	Tunisia	Sudan
Turkey	United Arab Emirates	Togo
United Kingdom	Uruguay	Uganda
United States of America	Venezuela (Bolivarian Republic of)	United Republic of Tanzania
Viet Nam	Zimbabwe	Yemen
		Zambia

Figure 4.1 is a map of the world showing the geographical distribution of these countries. Notice that the map depicts the North-South divide in the modernization of agriculture as outlined by authors like Rigby and Caceres (1997). Most HIs are situated in the global North while the global South mostly comprises the intermediate and LIs. In this manner, the figure vindicates the method of zone demarcation used by this study.

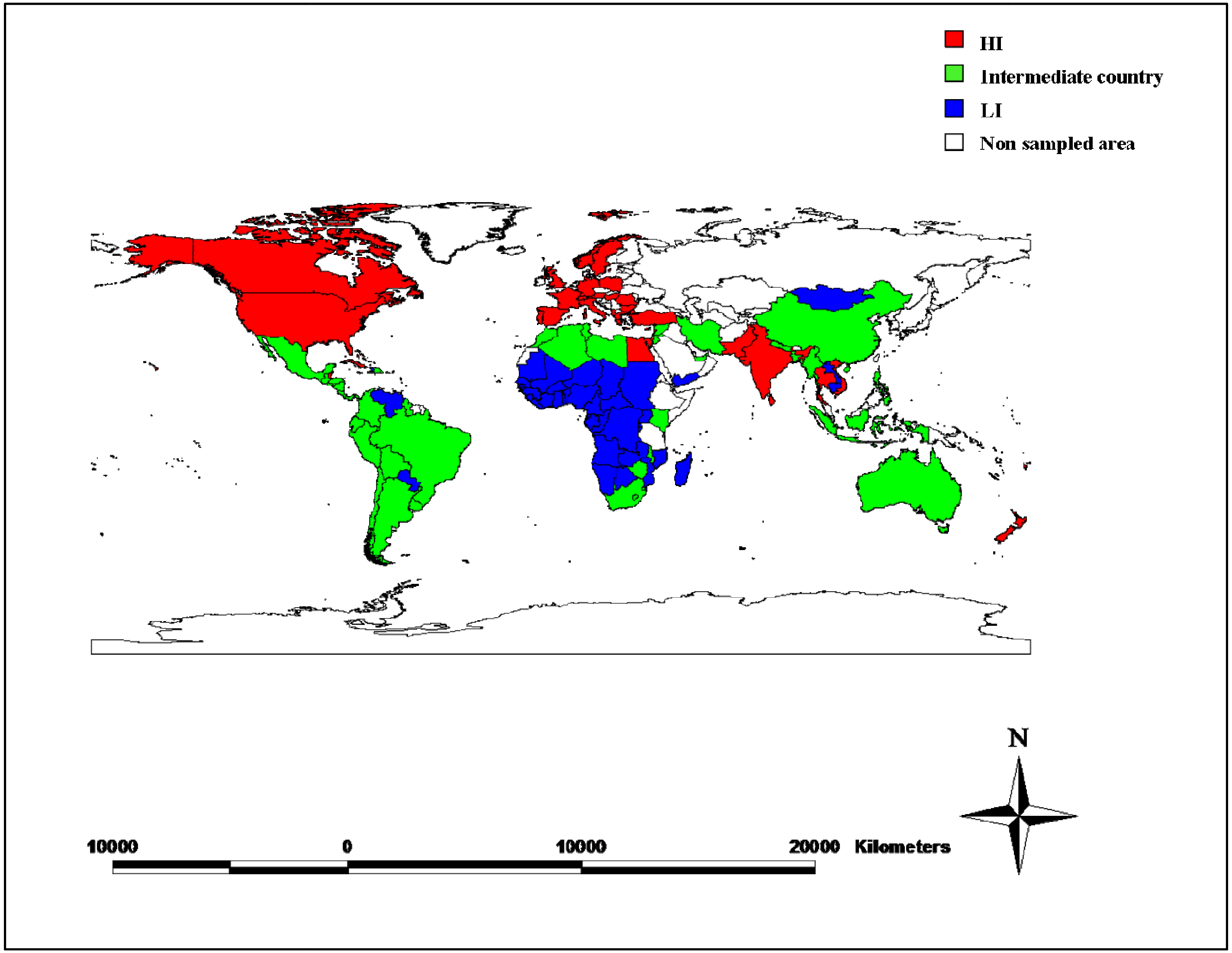

Figure 4.1 A map of the world showing the geographical distribution of sample countries by zone

Tables 4.2-4.5 present summary statistics for all major variables used in the quantitative analysis. Table 4.2 provides the summary for all countries pooled together, whilst Tables 4.3-4.5 provide this summary by zone, beginning with LIs, followed by intermediate countries and then HIs. Table 4.2 results show that the total population comprised 5535 observations, the large number depicting a key advantage conferred by panel data usage (Baltagi, 2005; Kazungu, 2009). When disaggregated by zone, this dataset gives 1890 observations for the 42 countries of the LI zone (Table 4.3), and 1800 for the 41-country intermediate zone (Table 4.4) and 1845 for the 41-country HI zone (Table 4.5).

The ratios of output in wheat units or the international dollar to output in tonnes across Tables 4.3-4.5 crudely depict the bias introduced by the international dollar as argued by Block (1994) and by this study in Chapter 3. The values of the ratio when output is measured in wheat units are 2.79 for LIs (Table 4.3), 2.26 for the intermediate zone (Table 4.4) and 2.20 for HIs (Table 4.5). These values present the ratios for the case where a fixed set of base-year prices is used to aggregate output across all three zones. On the other hand, the ratios for I$ output are 256, 259 and 316 for the same order as before. It seems that there is an increasing bias as one moves from LIs to the intermediate and then to HIs, especially from the intermediate to HIs. These results lend some credence to the hypothesis that I$ aggregation biases results in favour of higher levels of external input use, and thus may be misleading. Interestingly, by the same breath, wheat units exhibit the reverse order of bias, as it were. It would seem that this scenario somewhat justifies the use of varied means of output aggregation as adopted by this study.

Table 4.2 Summary statistics for regression data, all sample countries, 1961-2005

Variable	Observations	Mean	s.e.	Min	Max
Output in wheat units (I)	5535	6.510×10^7	2.890×10^6	3.617×10^4	3.840×10^9
Output in tonnes (J)	5535	2.870×10^7	1.190×10^6	3.043×10^3	1.180×10^9
Output in 1000 I$ (K)	5535	8.246×10^6	3.495×10^5	5.000×10^3	4.230×10^8
Agricultural land (1000 ha)	5535	3.132×10^5	1.014×10^4	5.000×10^1	5.473×10^6
Labour (number)	5535	5.064×10^6	4.725×10^5	0.000×10^0	4.990×10^8
Livestock (cow equivalents)	5535	1.430×10^7	5.482×10^5	2.643×10^3	3.600×10^8
Fertilizer (tonnes)	5535	7.183×10^5	3.914×10^4	0.000×10^0	4.710×10^7
Tractors (number)	5535	1.369×10^5	6.698×10^3	2.000×10^0	5.470×10^6
Crop production in wheat units	5535	5.400×10^7	2.320×10^6	1.984×10^4	2.960×10^9
Livestock production in wheat units	5535	2.320×10^7	1.063×10^6	3.363×10^3	1.310×10^9
Feed consumption in wheat units (L)	5535	1.210×10^7	4.611×10^5	0.000×10^0	4.230×10^8
Crop production in tonnes	5535	3.190×10^7	1.325×10^6	7.536×10^3	1.320×10^9
Livestock production in tonnes	5535	4.192×10^6	1.661×10^5	2.940×10^2	1.310×10^8
Feed consumption in tonnes (M)	5535	7.318×10^6	3.227×10^5	0.000×10^0	2.710×10^8
Ratio, I/J		2.27			
Ratio, K/J		287.33			
Ratio L/I		18.59			
Ratio, M/J		25.50			

Table 4.3 Summary statistics for regression data, low external input countries, 1961-2005

Variable	Observations	Mean	s.e.	Min	Max
Output in wheat units (I)	1890	1.5400×10^7	6.943×10^5	8.1789×10^4	3.4300×10^8
Output in tonnes (J)	1890	5.5232×10^6	2.381×10^5	9.7650×10^3	1.1500×10^8
Output in 1000 I$ (K)	1890	1.4160×10^6	5.984×10^4	9.4800×10^3	3.1200×10^7
Agricultural land (1000 ha)	1890	2.2714×10^5	6.611×10^3	6.5000×10^2	1.4068×10^6
Labour (number)	1890	1.5530×10^6	6.126×10^4	0.0000×10^0	1.5000×10^7
Livestock (cow equivalents)	1890	4.4055×10^6	1.462×10^5	8.2973×10^3	5.8700×10^7
Fertilizer (tonnes)	1890	1.3813×10^4	8.232×10^2	0.0000×10^0	4.6100×10^5
Tractors (number)	1890	2.5174×10^3	9.074×10^1	2.0000×10^0	4.8193×10^4
Crop production in wheat units	1890	1.4800×10^7	8.010×10^5	6.1934×10^4	4.3500×10^8
Livestock production in wheat units	1890	2.3935×10^6	8.023×10^4	3.3632×10^3	4.0400×10^7
Feed consumption in wheat units (L)	1890	1.8270×10^6	1.733×10^5	0.0000×10^0	1.1500×10^8
Crop production in tonnes	1890	5.9116×10^6	2.861×10^5	3.0809×10^4	1.5000×10^8
Livestock production in tonnes	1890	3.2558×10^5	1.565×10^4	2.9400×10^2	9.2074×10^6
Feed consumption in tonnes (M)	1890	7.1396×10^5	5.801×10^4	0.0000×10^0	3.7600×10^7
Ratio, I/J		2.79			
Ratio, K/J		256.36			
Ratio L/I		11.86			
Ratio, M/J		12.93			

Table 4.4 Summary statistics for regression data, intermediate countries, 1961-2005

Variable	Observations	Mean	s.e.	Min	Max
Output in wheat units (I)	1800	8.9900×10^{7}	7.328×10^{6}	3.6173×10^{4}	3.8400×10^{9}
Output in tonnes (J)	1800	3.9700×10^{7}	2.722×10^{6}	3.0430×10^{3}	1.1800×10^{9}
Output in 1000 I$ (K)	1800	1.0300×10^{7}	8.087×10^{5}	5.0000×10^{3}	4.2300×10^{8}
Agricultural land (1000 ha)	1800	4.7819×10^{5}	2.490×10^{4}	5.0000×10^{1}	5.4734×10^{6}
Labour (number)	1800	9.2375×10^{6}	1.310×10^{6}	0.0000×10^{0}	4.9900×10^{8}
Livestock (cow equivalents)	1800	2.0200×10^{7}	1.102×10^{6}	2.6425×10^{3}	3.6000×10^{8}
Fertilizer (tonnes)	1800	8.0257×10^{5}	8.866×10^{4}	0.0000×10^{0}	4.7100×10^{7}
Tractors (number)	1800	6.3049×10^{4}	3.550×10^{3}	3.0000×10^{0}	1.4106×10^{6}
Crop production in wheat units	1800	7.4400×10^{7}	5.920×10^{6}	1.9842×10^{4}	2.9600×10^{9}
Livestock production in wheat units	1800	2.6500×10^{7}	2.355×10^{6}	3.9276×10^{3}	1.3100×10^{9}
Feed consumption in wheat units (L)	1800	1.1100×10^{7}	8.986×10^{5}	0.0000×10^{0}	4.2300×10^{8}
Crop production in tonnes	1800	4.3600×10^{7}	3.118×10^{6}	7.5360×10^{3}	1.3200×10^{9}
Livestock production in tonnes	1800	3.4617×10^{6}	2.315×10^{5}	5.6000×10^{2}	1.3100×10^{8}
Feed consumption in tonnes (M)	1800	7.2786×10^{6}	6.299×10^{5}	0.0000×10^{0}	2.7100×10^{8}
Ratio, I/J		2.26			
Ratio, K/J		259.45			
Ratio L/I		12.35			
Ratio, M/J		18.33			

Table 4.5 Summary statistics for regression data, high external input countries, 1961-2005

Variable	Observations	Mean	s.e.	Min	Max
Output in wheat units (I)	1845	9.1800×10^7	4.637×10^6	9.8891×10^4	1.2900×10^9
Output in tonnes (J)	1845	4.1800×10^7	2.278×10^6	2.8882×10^4	7.7700×10^8
Output in 1000 I$ (K)	1845	1.3200×10^7	6.571×10^5	5.3800×10^3	1.9900×10^8
Agricultural land (1000 ha)	1845	2.4053×10^5	1.638×10^4	5.0000×10^1	4.4751×10^6
Labour (number)	1845	4.5901×10^6	5.975×10^5	0.0000×10^0	2.5300×10^8
Livestock (cow equivalents)	1845	1.8700×10^7	1.202×10^6	7.6875×10^3	3.5600×10^8
Fertilizer (tonnes)	1845	1.3577×10^6	7.623×10^4	0.0000×10^0	2.8500×10^7
Tractors (number)	1845	3.4675×10^5	1.884×10^4	2.4000×10^1	5.4700×10^6
Crop production in wheat units	1845	7.4200×10^7	3.624×10^6	7.9676×10^4	1.2000×10^9
Livestock production in wheat units	1845	4.1200×10^7	2.115×10^6	7.4858×10^3	7.0800×10^8
Feed consumption in wheat units (L)	1845	2.3500×10^7	9.923×10^5	1.1629×10^2	2.5400×10^8
Crop production in tonnes	1845	4.7000×10^7	2.428×10^6	2.5510×10^4	7.5100×10^8
Livestock production in tonnes	1845	8.8665×10^6	4.203×10^5	6.4300×10^2	1.2600×10^8
Feed consumption in tonnes (M)	1845	1.4100×10^7	7.121×10^5	1.8200×10^2	2.3700×10^8
Ratio, I/J		2.20			
Ratio, K/J		315.79			
Ratio L/I		25.60			
Ratio, M/J		33.73			

Tables 4.2-4.5 also provide the ratios, in percentages, of feed consumption to total output for output aggregated by the wheat unit and output aggregated by tonnage. The respective, relevant percentages of 18.6% and 25.5% for the pooled dataset (Table 4.2), 11.9% and 12.9% for LIs (Table 4.3), 12.4% and 18.3% for the intermediate (Table 4.4), and 25.6% and 33.7% for HIs (Table 4.5) suggest two important things.

First, given that there is no constant proportionality between the ratios across zones when output is differentially aggregated, then tonnage and wheat unit aggregation may not be strictly considered proxies of each other particularly across zones. However, if we maintain the assumption that this difference is not replicated overtime for each zone, then its impact on the present analysis becomes negligible. The results of the associated analysis, presented in Table 4.6, crudely support this assumption. The proportions of the ratios of feed consumption to output when output is differentially measured in wheat units and tonnes show rather little variation overtime for all zones. However, the intermediate zone exhibits a structural break in the pattern, with stability first over 1961 to 1975, then another rather unique set of fairly stable ratios with lower values than before from 1976 to 2005. Caution thus need be exercised with regard to this zone. It was, however, decided to maintain the assumption in question particularly because the break in the intermediate pattern may be ascribed to the fact that the identification of outliers for tonnage data was only run for the period 1981-2005 for which regression was required. Furthermore, to be sure, the assumption in question is really subjective and crude not least because the judgement has no objective cut-off points. Further analysis is required.

The second important thing depicted by the ratios of feed consumption to total output, for differential output aggregation by the wheat unit and then output aggregated by tonnage, is that feed for further primary production constitutes an arguably important fraction of total output. As a result, there is indeed bound to be serious double-counting if feed is not subtracted from total output.

Table 4.6 Proportions associated with the ratios of feed consumption to output when output is differentially measured in wheat units and tonnes

Period	Ratio of feed consumption to output (%), based on wheat units (I)			Ratio of feed consumption to output (%), based on tonnage (J)			Proportionality of ratios (I/J)		
	LIs	Intermediate	HIs	LIs	Intermediate	HIs	LIs	Intermediate	HIs
1961-65	9.41	14.30	36.30	10.51	16.81	42.02	0.90	0.85	0.86
1966-70	9.97	15.06	33.91	10.99	18.27	41.87	0.91	0.82	0.81
1971-75	9.88	14.50	29.81	11.15	18.22	39.57	0.89	0.80	0.75
1976-80	9.81	13.80	28.19	10.83	18.78	36.32	0.91	0.73	0.78
1981-85	9.68	12.88	25.86	10.89	18.44	33.56	0.89	0.70	0.77
1986-90	10.86	12.00	24.06	12.26	17.61	32.82	0.89	0.68	0.73
1991-95	12.33	11.28	21.56	13.37	18.67	29.92	0.92	0.60	0.72
1996-00	12.11	11.03	20.74	13.48	18.71	29.03	0.90	0.59	0.71
2001-05	16.73	11.51	21.67	17.16	18.42	29.91	0.97	0.63	0.72

Tables 4.7-4.10 separately provide the estimated regression results with output aggregated in wheat units (beginning with the 1981-05 estimation then that for 1961-05 subsequently), tonnes and the international dollar. The least-squares dummy variable (LSDV) estimation procedure was used. The specific countries excluded from the regression samples as outliers are presented in Appendix A (Tables A-1 to A-4) along with the specific years of exclusion. The estimated coefficients bear plausible signs and are mostly significant at the 10% significance level, even at 5% for most. However, care should be taken in reading these coefficient estimates which are presented exactly as they are modelled in the SUR systems outlined in Chapter 3. For instance, the coefficient on Ln Land should be taken to represent the elasticity of production with respect to land in LIs, whereas Ln Land (Int) is a slope dummy that should be added to Ln Land before it gives the elasticity estimate for intermediate countries. This is demonstrated in the evaluation of the elasticities for the wheat unit 1981-2005 regression analysis as per Table 4.7. The elasticities are given in Table 4.11, where only significant estimates on dummies (at 10% significance level) are used. All LI estimates, however, are adopted regardless of significance as a zero elasticity value would be hard to justify practically.

In some cases, agricultural land bears a negative sign especially for LIs. This finding corroborates the findings of authors like Kazungu (2009). For instance, Kazungu (2009) found negative relationships between the value of output per unit area and area under cultivation for several crops in Tanzania. He explained this as evidence in support of the existence of diminishing returns, due to the use of what he called primitive techniques of production. Without agreeing with his explanations, it may be indicated that the negative sign on land and its characteristic of occurring only for the LIs thus becomes not surprising.

However, the results presented also produce the same sign in an ostensibly uncharacteristic case involving the 1986-90 production elasticity with respect to tractors in HIs (Table 4.7). Indeed, it was difficult to find corroborating evidence for this from other studies. However, as indicated in Chapter 3, the meta-production function may be considered to be only a convenient way of depicting the general path taken by the production of the countries involved. In view of the instability of the “actual” meta-production function overtime for reasons detailed in the theoretical model in Chapter 3, explaining such findings in terms of concepts such as diminishing returns as Kazungu (2009) does thus becomes challenged. In this regard, the occurrence of a negative relationship in any production “epoch” may actually only mean that in that “epoch”, the factor concerned exhibited an erosive effect on aggregate production. That is, controlling for the other regression predictors, a smaller quantity of that factor produced more than a larger quantity of the same, an effect similar to operating in Stage III of the neoclassical production function. This would not be surprising in a farm-level analysis but might warrant further analysis for the present international analysis.

Incidentally, notice that the negative sign on land in Table 4.7 occurs in only three out of the five epochs. The three epochs correspond, first, roughly to the SAPs era, and then the 2001-2005 period. Interestingly, the 2001-2005 scenario, in the case of Malawi, corresponds to a period battered by (severe) droughts, floods and national hunger (Mhango & Dick, 2010). This may suggest that diminishing returns are indeed not intrinsic to “primitive” agricultural systems but rather reflect only transient shocks suffered by the systems at certain points in time. The analysis of the patterns of the MPP of land, discussed subsequently, appears to support this identification.

The "R-squared" values for each equation across all systems are above 90%, showing that over 90% of the variance of the output is explained by the predictors. However, to be sure, "R-squared" is not a well defined concept when feasible generalized least-squares (FGLS) estimation is applied as in the case of the SUR estimator employed here (StataCorp, 2009b). More importantly, the corresponding χ^2 values were all significant at 1% significance level, indicating that all the coefficients in each of the production functions are jointly significant. The Breusch–Pagan tests for independent equations yielded χ^2 values that were all significant at 1% significance level, thereby making SUR estimation the preferred estimation strategy over individual production function estimation.

The Hausman (1978) test was also conducted for the 1981-2005 wheat unit regression, as per Chapter 3. The test is based on the difference between the fixed effects and random effects estimators. The null hypothesis tested is that there is no significant systematic difference between the coefficients obtained via the FEM approach as compared with the REM approach. It is predicated on the assumption that the FEM estimator is consistent whether or not the exogeneity hypothesis of $Cov(X_{it}, \mu_i) = 0$ holds, where X_{it} is a level-1 independent variable while μ_i is the random individual-specific effects term. On the other hand, the REM estimator is efficient and consistent under the exogeneity hypothesis in question, but inconsistent otherwise. Under these assumptions, rejection of the null hypothesis favours adoption of FEM, and vice-versa.

However, among several other caveats, Baltagi (2005) rightly warns that this dyadic interpretation of the Hausman test is itself predicated on several other assumptions, notably the absence of significant autocorrelation and/or heteroscedasticity, and that the model parameter restrictions inherent in the FEM are valid as per Chamberlain (1984), cited in Baltagi (2005). Fortunately, our model relaxes these parameter restrictions in having coefficients that vary over time and space.

The results of tests for autocorrelation[9] (denoted as *d* statistics) and heteroscedasticity[10] (denoted as B-P/C-W), as well as those of a link test for model specification[11], are reported alongside the Hausman test results presented in Table 4.7. The covariance matrices used in the Hausman test were based on the estimated disturbance variance from the REM estimator. According to StataCorp (2009a), this specification is recommended when comparing fixed-effects and random-effects linear regressions because it is much less likely to produce a non–positive-definite-differenced covariance matrix. Since the p-values of the Hausman test statistics, taken to be distributed as χ^2 with *K* degrees of freedom[12], are each less than 1%, the study rejects the null hypothesis of no significant systematic difference between the coefficients obtained via the FEM approach as compared with the REM approach. Further, given that the relevant tests fail to reject the hypotheses of no autocorrelation, homoscedasticity and that the model is correctly specified (by the link test as well as the Durbin-Watson statistic), the study thus generates evidence in support of using the FEM approach as opposed to the REM approach.

The double-pronged test for detecting the presence of degrading near dependencies or (multi)collinearity as suggested by Belsley *et al.*, (2004) was also conducted on the

---

[9] based on the Durbin–Watson *d* statistic to test for first-order autocorrelation.

[10] as per Breusch–Pagan (1979) and Cook–Weisberg's (1983) normal version as represented by StataCorp (2009a).

[11] following Pregibon's (1979) form as represented by StataCorp (2009a). The test statistics are the coefficients for the variable of squared prediction.

[12] *K* denotes the number of variables in the regression, excluding the constant.

1981-2005 wheat unit analysis regression data (corresponding to Table 4.7). The test results, comprising condition indices and attendant variance-decomposition proportions, are presented in Tables B-1 – B-5 of Appendix B. On the face of it, the results suggest the presence of degrading collinearity. This is particularly suggested by the existence of at least two "high" variance decomposition proportions associated with "high" condition indices[13].

In response to the associated risk of harm to regression estimates, the regression represented by Table 4.7 was re-run using a smaller dataset of 543 observations (representing a data loss of about 9%) per five-year cross-section. This number of observations was arrived at by eliminating outlying observations (Table B-7 of Appendix B) by the method described in Section 3.4. This approach offered two advantages. Firstly, the elimination of outlying observations arguably reduces the risk of such observations masking the harmful effects of ill-conditioning (Belsley *et al.*, 2004). Secondly, the deletion of the observations corresponds to deletion of rows of the data matrix, by which the existence of harmful ill-conditioning is expected to result in substantial changes in regression parameter estimates (*ibid.*).

For the present purpose, while there were changes in coefficients observed (Table B-6 of Appendix B compared with Table 4.7), the importance of the changes should be judged against changes in the patterns of MPP of land which are of central interest. In this regard, the study found that the graphs of MPP growth paths corresponding to the trimmed dataset (Figures B-1 – B-3 of Appendix B) closely resemble those of the

---

[13] Following Belsley *et al.*'s (2004) suggestions, a "high" variance-decomposition proportion has a value that exceeds 50% while "low" is conversely defined. A "high" condition index must exceed 10 (*ibid.*).

Table 4.7 dataset, which follow (Figures 4.2 – 4.4). Given this resemblance and the resemblances of the MPP/MVP growth paths based on the differential modes of output aggregation as discussed in the sequel, the study found evidence suggesting that the ill-conditioning suggested above may be degrading but not harmful, an effect that is not unusual in econometric applications (Belsley *et al.*, 2004; Gujarati, 2004). This may be due to low variance levels associated with the regression coefficients as suggested by Belsley *et al.* (2004). The low variances may be ascribed, at least in part, to the estimation efficiency gains arising from the use of the SUR estimator. In addition, the present study finds it compelling to draw the reader's attention to an alternative possible explanation, which seems to be evident in the information presented in Tables B-1 – B-5 of Appendix B, and may warrant further exploration.

In particular, notice that the "high" condition index values in these tables are commonly associated with "low" variance-decomposition ratios or "high" ratios that typically lie below 75%. In one case (Table B-1), a "high" condition index of 76.39 is associated with only one "high" variance-decomposition ratio of 92% (associated with the coefficient of "Ln Fertilizer (HI"). One might then argue that the presence of multiple near-dependencies with competing or dominating effects as defined by Belsley *et al.* (2004) might have a similar masking effect to that of outlying observations as indicated above. This might explain what Belsley *et al.* (2004) consider as an arbitrary distribution of the variances of affected regression coefficients among such near dependencies. However, fortunately, the near dependency is not an atypical, let alone possibly accidental, feature of the dataset. It is not a feature that can easily be undone, say, by dropping some observations or partitioning the dataset accordingly. It is part and parcel of the data and thus need not cause instability of the regression coefficients nor bloated variance estimates. If this is true, the multiple near dependencies might actually represent disguised blessings for analyses like the present study's MPP analysis.

Indeed, both the low variance levels suggested by Belsley *et al.* (2004) and this good-multiple-near-dependency hypothesis would, conceivably, have the effect that the estimated production surfaces would have shapes and relative positions that are sufficiently robust to "small data changes". Our visual "tests" thus remain conclusive so that there is no harmful collinearity (Belsley *et al.*, 2004). Furthermore, the superiority of known alternative estimation procedures, like ridge regression and Bayesian estimation (which are particularly liable to producing estimation bias), in this case, thus remains a further empirical question that is open for exploration.

Table 4.7 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of aggregate output in wheat units

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	-0.0658 (0.0174)	0.0000	-0.0425 (0.0178)	0.0170	0.0035 (0.0173)	0.8390	0.0419 (0.0183)	0.0220	-0.0046 (0.0179)	0.7960
Ln Fertilizer	0.0119 (0.0048)	0.0130	0.0162 (0.0053)	0.0020	0.0294 (0.0048)	0.0000	0.0282 (0.0049)	0.0000	0.0180 (0.0059)	0.0020
Ln Tractors	0.1429 (0.0115)	0.0000	0.1414 (0.0120)	0.0000	0.1308 (0.0119)	0.0000	0.1048 (0.0121)	0.0000	0.1011 (0.0115)	0.0000
Ln Labour	0.6945 (0.0156)	0.0000	0.6788 (0.0144)	0.0000	0.6776 (0.0145)	0.0000	0.6655 (0.0149)	0.0000	0.6817 (0.0148)	0.0000
Ln Livestock	0.1425 (0.0163)	0.0000	0.1239 (0.0169)	0.0000	0.0963 (0.0168)	0.0000	0.0846 (0.0182)	0.0000	0.1447 (0.0188)	0.0000
Ln Land (Int)	0.2193 (0.0353)	0.0000	0.1981 (0.0362)	0.0000	0.1037 (0.0336)	0.0020	0.1778 (0.0339)	0.0000	0.2263 (0.0332)	0.0000
Ln Fertilizer (Int)	0.0445 (0.0148)	0.0030	0.0422 (0.0137)	0.0020	0.0585 (0.0124)	0.0000	0.0543 (0.0140)	0.0000	0.0488 (0.0139)	0.0000
Ln Tractors (Int)	-0.0707 (0.0239)	0.0030	-0.0487 (0.0233)	0.0370	-0.0373 (0.0218)	0.0880	-0.0754 (0.0215)	0.0000	-0.0582 (0.0202)	0.0040
Ln Labour (Int)	-0.4564 (0.0216)	0.0000	-0.4272 (0.0205)	0.0000	-0.4516 (0.0201)	0.0000	-0.4344 (0.0213)	0.0000	-0.4201 (0.0209)	0.0000
Ln Livestock (Int)	0.2630 (0.0296)	0.0000	0.2691 (0.0289)	0.0000	0.3468 (0.0281)	0.0000	0.3134 (0.0305)	0.0000	0.2603 (0.0306)	0.0000

Standard errors are given in parentheses. HI and Int denote high external input and intermediate countries, respectively. N/A denotes coefficients restricted to zero due to their statistical insignificance.

(continued)

Table 4.7 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of aggregate output in wheat units (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land (HI)	0.5253	0.0000	0.3938	0.0000	0.3713	0.0000	0.3681	0.0000	0.3792	0.0000
	(0.0340)		(0.0339)		(0.0319)		(0.0331)		(0.0339)	
Ln Fertilizer (HI)	0.0662	0.0010	0.1566	0.0000	0.1118	0.0000	0.0428	0.0190	0.0626	0.0000
	(0.0196)		(0.0217)		(0.0183)		(0.0183)		(0.0177)	
Ln Tractors (HI)	-0.1161	0.0000	-0.1541	0.0000	-0.1184	0.0000	-0.0538	0.0140	-0.0258	0.2420
	(0.0203)		(0.0212)		(0.0207)		(0.0220)		(0.0221)	
Ln Labour (HI)	-0.5256	0.0000	-0.5454	0.0000	-0.5199	0.0000	-0.5158	0.0000	-0.5255	0.0000
	(0.0220)		(0.0216)		(0.0206)		(0.0205)		(0.0202)	
Ln Livestock (HI)	-0.0408	0.2940	0.0800	0.0400	0.0883	0.0170	0.1118	0.0020	0.0617	0.1060
	(0.0388)		(0.0389)		(0.0370)		(0.0364)		(0.0382)	
Int Dummy	0.4255	0.0140	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	(0.1734)		N/A		N/A		N/A		N/A	
HI Dummy	3.4825	0.0000	2.6483	0.0000	2.6993	0.0000	2.6330	0.0000	2.8475	0.0000
	(0.2314)		(0.2094)		(0.2073)		(0.2180)		(0.2233)	
P Dummy	0.5061	0.0000	0.4515	0.0000	0.4654	0.0000	0.4921	0.0000	0.5493	0.0000
	(0.0216)		(0.0221)		(0.0221)		(0.0242)		(0.0257)	
N Dummy	-0.5206	0.0000	-0.4606	0.0000	-0.4320	0.0000	-0.4642	0.0000	-0.4927	0.0000
	(0.0226)		(0.0232)		(0.0225)		(0.0251)		(0.0261)	
Constant	3.6679	0.0000	3.8679	0.0000	3.7265	0.0000	3.8651	0.0000	3.4206	0.0000

(continued)

Table 4.7 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of aggregate output in wheat units (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Observations	599		599		599		599		599	
“R-squared”	0.9825		0.9813		0.9807		0.9786		0.9801	
χ^2 statistic	43119	0.0000	40561	0.0000	40999	0.0000	36247	0.0000	37121	0.0000
B-P test statistic	2106.86	0.0000								
Link test statistic	0.0004	0.8120	0.0021	0.2440	0.0002	0.9090	0.0026	0.1500	-0.0008	0.6550
d statistic	1.9626		2.0654		2.0085		2.1019		2.0639	
B-P/C-W	2.6300	0.1048	0.9200	0.3371	2.4000	0.1216	0.0400	0.8470	0.5900	0.4434
Hausman test statistic	134.26	0.0000	142.67	0.0000	146.72	0.0000	179.66	0.0000	171.94	0.0000

Table 4.8 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of aggregate output in tonnes

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	-0.1338 (0.0244)	0.0000	-0.1353 (0.0247)	0.0000	-0.0622 (0.0224)	0.0060	-0.0466 (0.0201)	0.0210	-0.0586 (0.0198)	0.0030
Ln Fertilizer	0.0070 (0.0071)	0.3190	0.0314 (0.0084)	0.0000	0.0347 (0.0070)	0.0000	0.0258 (0.0057)	0.0000	0.0179 (0.0068)	0.0080
Ln Tractors	0.1310 (0.0162)	0.0000	0.1572 (0.0167)	0.0000	0.1404 (0.0155)	0.0000	0.1217 (0.0132)	0.0000	0.1253 (0.0125)	0.0000
Ln Labour	0.8440 (0.0227)	0.0000	0.7576 (0.0220)	0.0000	0.8134 (0.0191)	0.0000	0.8160 (0.0163)	0.0000	0.8201 (0.0164)	0.0000
Ln Livestock	0.1078 (0.0227)	0.0000	0.1196 (0.0234)	0.0000	0.0459 (0.0218)	0.0350	0.0449 (0.0199)	0.0240	0.0889 (0.0205)	0.0000
Ln Land (Int)	0.2786 (0.0508)	0.0000	0.2617 (0.0527)	0.0000	0.1153 (0.0453)	0.0110	0.3084 (0.0381)	0.0000	0.3345 (0.0373)	0.0000
Ln Fertilizer (Int)	0.0917 (0.0235)	0.0000	0.0955 (0.0226)	0.0000	0.2113 (0.0187)	0.0000	0.1329 (0.0167)	0.0000	0.0805 (0.0161)	0.0000
Ln Tractors (Int)	-0.1482 (0.0334)	0.0000	-0.1046 (0.0326)	0.0010	-0.1047 (0.0287)	0.0000	-0.1932 (0.0237)	0.0000	-0.1642 (0.0223)	0.0000
Ln Labour (Int)	-0.6156 (0.0316)	0.0000	-0.5022 (0.0304)	0.0000	-0.6144 (0.0265)	0.0000	-0.6254 (0.0236)	0.0000	-0.5763 (0.0235)	0.0000
Ln Livestock (Int)	0.3834 (0.0443)	0.0000	0.3444 (0.0457)	0.0000	0.4215 (0.0378)	0.0000	0.4152 (0.0345)	0.0000	0.3732 (0.0347)	0.0000

Standard errors are given in parentheses. HI and Int denote high external input and intermediate countries, respectively. N/A denotes coefficients restricted to zero due to their statistical insignificance.

(continued)

Table 4.8 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logs of aggregate output in tonnes (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land (HI)	0.4876	0.0000	0.5446	0.0000	0.5987	0.0000	0.5108	0.0000	0.5143	0.0000
	(0.0485)		(0.0479)		(0.0425)		(0.0365)		(0.0373)	
Ln Fertilizer (HI)	0.1316	0.0000	0.0854	0.0130	0.0864	0.0020	0.0602	0.0090	0.0298	0.1560
	(0.0303)		(0.0343)		(0.0276)		(0.0232)		(0.0210)	
Ln Tractors (HI)	-0.1767	0.0000	-0.1976	0.0000	-0.2300	0.0000	-0.1534	0.0000	-0.1087	0.0000
	(0.0292)		(0.0310)		(0.0284)		(0.0254)		(0.0249)	
Ln Labour (HI)	-0.6853	0.0000	-0.6044	0.0000	-0.6162	0.0000	-0.6249	0.0000	-0.6069	0.0000
	(0.0313)		(0.0313)		(0.0270)		(0.0223)		(0.0222)	
Ln Livestock (HI)	0.1258	0.0310	0.0747	0.1900	0.0473	0.3510	0.1392	0.0010	0.0679	0.1080
	(0.0583)		(0.0571)		(0.0508)		(0.0408)		(0.0423)	
Int Dummy	0.6544	0.0210	-0.9173	0.0020	N/A	N/A	N/A	N/A	N/A	N/A
	(0.2846)		(0.2957)		N/A		N/A		N/A	
HI Dummy	3.7068	0.0000	3.3130	0.0000	3.9041	0.0000	3.1927	0.0000	3.8671	0.0000
	(0.3457)		(0.3524)		(0.2890)		(0.2453)		(0.2506)	
P Dummy	0.6774	0.0000	0.5457	0.0000	0.5051	0.0000	0.6184	0.0000	0.6404	0.0000
	(0.0374)		(0.0365)		(0.0307)		(0.0272)		(0.0289)	
N Dummy	-0.6153	0.0000	-0.6911	0.0000	-0.5493	0.0000	-0.6090	0.0000	-0.6862	0.0000
	(0.0334)		(0.0347)		(0.0304)		(0.0278)		(0.0290)	
Constant	1.8971	0.0000	2.6431	0.0000	2.1455	0.0000	2.1606	0.0000	1.6750	0.0000
	(0.2370)		(0.2427)		(0.1763)		(0.1494)		(0.1466)	
Observations	578		578		578		578		578	
“R-squared”	0.9699		0.9707		0.9733		0.9782		0.9790	
χ^2 statistic	22564	0.0000	23009	0.0000	26648	0.0000	33193	0.0000	33044	0.0000
B-P test statistic	1452.660	0.0000								

Table 4.9 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of Aggregate output in constant (2004-2006) 1000 International Dollars

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	-0.0437 (0.0157)	0.0050	-0.0539 (0.0154)	0.0000	-0.0277 (0.0148)	0.0620	-0.0035 (0.0158)	0.8220	-0.0092 (0.0143)	0.5180
Ln Fertilizer	0.0053 (0.0044)	0.2280	0.0114 (0.0049)	0.0200	0.0061 (0.0043)	0.1600	0.0140 (0.0043)	0.0010	0.0121 (0.0050)	0.0160
Ln Tractors	0.1319 (0.0103)	0.0000	0.1386 (0.0104)	0.0000	0.1282 (0.0104)	0.0000	0.1067 (0.0106)	0.0000	0.0998 (0.0092)	0.0000
Ln Labour	0.5109 (0.0143)	0.0000	0.5072 (0.0136)	0.0000	0.5297 (0.0123)	0.0000	0.5501 (0.0125)	0.0000	0.5489 (0.0117)	0.0000
Ln Livestock	0.2871 (0.0148)	0.0000	0.2873 (0.0149)	0.0000	0.2891 (0.0148)	0.0000	0.2543 (0.0159)	0.0000	0.2812 (0.0153)	0.0000
Ln Land (Int)	0.1502 (0.0317)	0.0000	0.1868 (0.0311)	0.0000	0.1610 (0.0292)	0.0000	0.2114 (0.0292)	0.0000	0.2050 (0.0264)	0.0000
Ln Fertilizer (Int)	0.0801 (0.0144)	0.0000	0.0691 (0.0126)	0.0000	0.0800 (0.0116)	0.0000	0.0701 (0.0128)	0.0000	0.0960 (0.0126)	0.0000
Ln Tractors (Int)	-0.0600 (0.0212)	0.0050	-0.0583 (0.0199)	0.0030	-0.0469 (0.0189)	0.0130	-0.0720 (0.0186)	0.0000	-0.0541 (0.0159)	0.0010
Ln Labour (Int)	-0.2896 (0.0197)	0.0000	-0.2829 (0.0186)	0.0000	-0.3221 (0.0171)	0.0000	-0.3537 (0.0179)	0.0000	-0.3169 (0.0165)	0.0000
Ln Livestock (Int)	0.1877 (0.0268)	0.0000	0.1607 (0.0266)	0.0000	0.1794 (0.0244)	0.0000	0.2008 (0.0262)	0.0000	0.1422 (0.0246)	0.0000
Ln Land (HI)	0.3185 (0.0301)	0.0000	0.3220 (0.0288)	0.0000	0.3521 (0.0274)	0.0000	0.3357 (0.0280)	0.0000	0.3351 (0.0266)	0.0000

Standard errors are given in parentheses. HI and Int denote high external input and intermediate countries, respectively. N/A denotes coefficients restricted to zero due to their statistical insignificance.

(continued)

Table 4.9 Panel Data LSDV Estimation under SUR, 1981-2005: Dependent Variable is the natural logarithms of Aggregate output in constant (2004-2006) 1000 International Dollars (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Fertilizer (HI)	0.1493	0.0000	0.1947	0.0000	0.1660	0.0000	0.0503	0.0020	0.0404	0.0090
	(0.0178)		(0.0188)		(0.0167)		(0.0164)		(0.0155)	
Ln Tractors (HI)	-0.0254	0.1580	-0.0469	0.0090	-0.0209	0.2380	0.0317	0.0890	0.0504	0.0040
	(0.0180)		(0.0180)		(0.0177)		(0.0186)		(0.0173)	
Ln Labour (HI)	-0.4181	0.0000	-0.4250	0.0000	-0.4397	0.0000	-0.4649	0.0000	-0.4616	0.0000
	(0.0197)		(0.0191)		(0.0174)		(0.0171)		(0.0158)	
Ln Livestock (HI)	0.0074	0.8300	-0.0177	0.5930	-0.0602	0.0580	0.0578	0.0610	0.0546	0.0690
	(0.0344)		(0.0331)		(0.0318)		(0.0308)		(0.0300)	
Int Dummy	-0.3990	0.0270	-0.4438	0.0120	N/A	N/A	N/A	N/A	N/A	N/A
	(0.1807)		(0.1764)		N/A		N/A		N/A	
HI Dummy	1.6754	0.0000	1.6848	0.0000	2.4243	0.0000	2.1146	0.0000	2.0277	0.0000
	(0.2101)		(0.2063)		(0.1767)		(0.1829)		(0.1735)	
P Dummy	0.4112	0.0000	0.3474	0.0000	0.3611	0.0000	0.3910	0.0000	0.4477	0.0000
	(0.0194)		(0.0180)		(0.0182)		(0.0209)		(0.0208)	
N Dummy	-0.3330	0.0000	-0.3566	0.0000	-0.3457	0.0000	-0.4050	0.0000	-0.3887	0.0000
	(0.0212)		(0.0218)		(0.0229)		(0.0249)		(0.0236)	
Constant	1.6710	0.0000	1.8011	0.0000	1.2812	0.0000	1.3876	0.0000	1.1894	0.0000
	(0.1510)		(0.1486)		(0.1074)		(0.1106)		(0.0997)	
Observations	565		565		565		565		565	
"R-squared"	0.9890		0.9888		0.9884		0.9872		0.9894	
χ^2 statistic	63977	0.0000	64757	0.0000	64333	0.0000	57303	0.0000	67535	0.0000
B-P test statistic	1694.740	0.0000								

Table 4.10 Panel Data LSDV Estimation under SUR, 1961-2005: Dependent Variable is the natural logarithms of Aggregate output in wheat units

	1961-65		1966-70		1971-75		1976-80	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	0.1876	0.0000	0.1918	0.0000	0.1515	0.0000	0.1913	0.0000
	(0.0257)		(0.0237)		(0.0249)		(0.0275)	
Ln Fertilizer	0.0417	0.0000	0.0524	0.0000	0.0588	0.0000	0.0116	0.1060
	(0.0077)		(0.0072)		(0.0090)		(0.0072)	
Ln Tractors	0.0478	0.0020	0.0691	0.0000	0.0941	0.0000	0.0869	0.0000
	(0.0156)		(0.0138)		(0.0145)		(0.0162)	
Ln Livestock	0.2455	0.0000	0.2268	0.0000	0.2749	0.0000	0.3034	0.0000
	(0.0217)		(0.0188)		(0.0191)		(0.0215)	
Ln Land (Int)	-0.0154	0.7250	-0.0574	0.1390	0.0221	0.5700	-0.0056	0.9010
	(0.0438)		(0.0389)		(0.0389)		(0.0450)	
Ln Fertilizer (Int)	-0.0015	0.9160	-0.0012	0.9220	0.0031	0.8180	0.0966	0.0000
	(0.0145)		(0.0123)		(0.0136)		(0.0171)	
Ln Tractors (Int)	-0.0502	0.0290	-0.0670	0.0020	-0.1028	0.0000	-0.1169	0.0000
	(0.0230)		(0.0213)		(0.0224)		(0.0273)	
Ln Livestock (Int)	0.3574	0.0000	0.3953	0.0000	0.3112	0.0000	0.2498	0.0000
	(0.0392)		(0.0342)		(0.0335)		(0.0362)	
Ln Land (HI)	0.3065	0.0000	0.2772	0.0000	0.3074	0.0000	0.3037	0.0000
	(0.0535)		(0.0469)		(0.0468)		(0.0477)	
Ln Fertilizer (HI)	0.0749	0.0000	0.0951	0.0000	0.0922	0.0000	0.0972	0.0000
	(0.0187)		(0.0225)		(0.0238)		(0.0246)	
Ln Tractors (HI)	-0.1369	0.0000	-0.1502	0.0000	-0.1533	0.0000	-0.1470	0.0000
	(0.0220)		(0.0196)		(0.0209)		(0.0241)	

Standard errors are given in parentheses. HI and Int denote high external input and intermediate countries, respectively.

(continued)

Table 4.10 Panel Data LSDV Estimation under SUR, 1961-2005: Dependent Variable is the natural logarithms of Aggregate output in wheat units (continued)

	1961-65		1966-70		1971-75		1976-80	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Livestock (HI)	-0.0074	0.8840	0.0187	0.6720	-0.0146	0.7400	-0.0481	0.2920
	(0.0510)		(0.0441)		(0.0439)		(0.0456)	
Int Dummy	-4.6209	0.0000	-4.5420	0.0000	-3.9252	0.0000	-3.3740	0.0000
	(0.3161)		(0.2764)		(0.2715)		(0.2796)	
HI Dummy	-1.8845	0.0000	-2.0700	0.0000	-1.8987	0.0000	-1.1463	0.0000
	(0.3333)		(0.2896)		(0.2915)		(0.2962)	
P Dummy	0.6764	0.0000	0.6262	0.0000	0.6069	0.0000	0.5343	0.0000
	(0.0397)		(0.0310)		(0.0305)		(0.0313)	
N Dummy	-0.5866	0.0000	-0.5021	0.0000	-0.4835	0.0000	-0.4586	0.0000
	(0.0400)		(0.0325)		(0.0312)		(0.0334)	
Constant	9.3354	0.0000	9.3044	0.0000	8.8284	0.0000	8.4018	0.0000
	(0.2185)		(0.1888)		(0.1921)		(0.2002)	
Observations	582		582		582		582	
"R-squared"	0.9454		0.9561		0.9576		0.9535	
χ^2 statistic	13534	0.0000	18681	0.0000	20334	0.0000	18854	0.0000
B-P test statistic	5591.255	0.0000						

(continued)

Table 4.10 Panel Data LSDV Estimation under SUR, 1961-2005: Dependent Variable is the natural logarithms of Aggregate output in wheat units (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	0.1768	0.0000	0.1475	0.0000	0.1770	0.0000	0.2155	0.0000	0.1957	0.0000
	(0.0270)		(0.0267)		(0.0250)		(0.0262)		(0.0261)	
Ln Fertilizer	0.0206	0.0030	0.0316	0.0000	0.0377	0.0000	0.0242	0.0020	0.0092	0.2680
	(0.0070)		(0.0089)		(0.0083)		(0.0077)		(0.0083)	
Ln Tractors	0.1038	0.0000	0.1237	0.0000	0.1356	0.0000	0.1114	0.0000	0.1137	0.0000
	(0.0159)		(0.0163)		(0.0159)		(0.0158)		(0.0153)	
Ln Livestock	0.2913	0.0000	0.2912	0.0000	0.2910	0.0000	0.3006	0.0000	0.3268	0.0000
	(0.0210)		(0.0214)		(0.0227)		(0.0239)		(0.0244)	
Ln Land (Int)	0.0027	0.9550	-0.0156	0.7440	-0.0411	0.3580	-0.0247	0.5880	0.0237	0.6050
	(0.0476)		(0.0480)		(0.0448)		(0.0455)		(0.0458)	
Ln Fertilizer (Int)	0.0799	0.0000	0.0907	0.0000	0.1082	0.0000	0.1176	0.0000	0.0913	0.0000
	(0.0173)		(0.0184)		(0.0173)		(0.0189)		(0.0192)	
Ln Tractors (Int)	-0.1210	0.0000	-0.1220	0.0000	-0.1277	0.0000	-0.1258	0.0000	-0.1121	0.0000
	(0.0292)		(0.0288)		(0.0271)		(0.0267)		(0.0260)	
Ln Livestock (Int)	0.2907	0.0000	0.3184	0.0000	0.2922	0.0000	0.2586	0.0000	0.2609	0.0000
	(0.0362)		(0.0361)		(0.0372)		(0.0404)		(0.0405)	
Ln Land (HI)	0.2846	0.0000	0.2642	0.0000	0.2625	0.0000	0.2025	0.0000	0.1780	0.0000
	(0.0473)		(0.0456)		(0.0427)		(0.0440)		(0.0456)	
Ln Fertilizer (HI)	0.0944	0.0000	0.1693	0.0000	0.1439	0.0000	0.1186	0.0000	0.1124	0.0000

(continued)

Table 4.10 Panel Data LSDV Estimation under SUR, 1961-2005: Dependent Variable is the natural logarithms of Aggregate output in wheat units (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Tractors (HI)	-0.1504	0.0000	-0.1922	0.0000	-0.1870	0.0000	-0.0924	0.0010	-0.0507	0.0750
	(0.0247)		(0.0251)		(0.0254)		(0.0275)		(0.0285)	
Ln Livestock (HI)	-0.0085	0.8540	-0.0059	0.8940	-0.0090	0.8350	-0.0187	0.6730	-0.0105	0.8220
	(0.0460)		(0.0442)		(0.0432)		(0.0443)		(0.0468)	
Int Dummy	-3.9209	0.0000	-4.3710	0.0000	-3.8460	0.0000	-3.5299	0.0000	-3.9518	0.0000
	(0.2803)		(0.2897)		(0.3073)		(0.3158)		(0.3140)	
HI Dummy	-1.5601	0.0000	-2.0652	0.0000	-1.7753	0.0000	-1.5865	0.0000	-1.8866	0.0000
	(0.3028)		(0.3043)		(0.3127)		(0.3188)		(0.3318)	
P Dummy	0.5258	0.0000	0.5238	0.0000	0.5169	0.0000	0.5214	0.0000	0.6173	0.0000
	(0.0320)		(0.0322)		(0.0316)		(0.0333)		(0.0343)	
N Dummy	-0.4159	0.0000	-0.4527	0.0000	-0.4181	0.0000	-0.4420	0.0000	-0.5805	0.0000
	(0.0323)		(0.0347)		(0.0331)		(0.0406)		(0.0431)	
Constant	8.6148	0.0000	8.7915	0.0000	8.3794	0.0000	8.1748	0.0000	8.2069	0.0000
	(0.2026)		(0.2133)		(0.2301)		(0.2244)		(0.2295)	
Observations	582		582		582		582		582	
"R-squared"	0.9541		0.9598		0.9594		0.9558		0.9611	
χ^2 statistic	19938	0.0000	21561	0.0000	21702	0.0000	19281	0.0000	19682	0.0000

As a further test on the modelling, tests were carried out on the cross-equation equality of elasticity estimates from Table 4.7. As explained above, only statistically significant (at 10% significance level) coefficient estimates on dummies were used, while all LI estimates were adopted regardless of significance. In essence, the question asked was that of whether there is a unique meta-production function for each zone that would, in the statistical sense, explain the variation in aggregate output for the entire 25 year "epoch" as well as or even better than the break-down into the shorter 5 year "epochs". The results of these tests are summarized in Table 4.11. They show that several coefficients, across all three zones, had changed significantly at the 5% level of significance, let alone 10%. On the general picture, the study thus finds evidence in support of rejecting the fixed meta-production function hypothesis and thus adopts the 5-year technical "epoch" modelling.

Table 4.11 Estimates of factor elasticities of production and their temporal stability test results for each zone by time, based on wheat-unit output aggregation, 1981-2005

	1981-85 (A)	1986-90 (B)	1991-95 (C)	1996-00 (D)	2001-05 (E)	χ^2 (B-A)	$P>\chi^2$	χ^2 (C-B)	$P>\chi^2$	χ^2 (D-C)	$P>\chi^2$	χ^2 (E-D)	$P>\chi^2$	χ^2 (E-A)	$P>\chi^2$
Land	-0.0658	-0.0425	0.0035	0.0419	-0.0046	2.30	0.1297	8.20	0.0042	6.99	0.0082	10.27	0.0014	9.78	0.0018
Fertilizer	0.0119	0.0162	0.0294	0.0282	0.0180	0.50	0.4794	4.47	0.0344	0.04	0.8343	2.54	0.1111	0.68	0.4099
Tractors	0.1429	0.1414	0.1308	0.1048	0.1011	0.02	0.8887	0.87	0.3518	6.47	0.0110	0.14	0.7114	10.16	0.0014
Labour	0.6945	0.6788	0.6776	0.6655	0.6817	1.27	0.2595	0.01	0.9251	1.05	0.3065	1.90	0.1677	0.57	0.4515
Livestock	0.1425	0.1239	0.0963	0.0846	0.1447	1.64	0.2000	3.19	0.0740	0.65	0.4201	14.82	0.0001	0.01	0.9137
Land (Int)	0.1536	0.1556	0.1072	0.2197	0.2217	0.01	0.9431	2.67	0.1020	19.90	0.0000	0.01	0.9373	3.99	0.0458
Fertilizer (Int)	0.0564	0.0584	0.0879	0.0825	0.0669	0.02	0.8904	4.20	0.0404	0.16	0.6931	1.12	0.2909	0.34	0.5603
Tractors (Int)	0.0722	0.0927	0.0935	0.0294	0.0429	5.95	0.0148	2.08	0.1490	5.94	0.0148	2.24	0.1348	5.29	0.0215
Labour (Int)	0.2381	0.2516	0.2260	0.2310	0.2616	1.04	0.3078	3.62	0.0572	0.17	0.6810	6.28	0.0122	1.98	0.1598
Livestock (Int)	0.4055	0.3931	0.4431	0.3980	0.4050	0.30	0.5833	4.65	0.0310	4.30	0.0382	0.10	0.7539	0.00	0.9849
Land (HI)	0.4595	0.3514	0.3748	0.4100	0.3746	16.28	0.0001	0.72	0.3948	2.10	0.1474	2.12	0.1454	6.26	0.0123
Fertilizer (HI)	0.0781	0.1728	0.1411	0.0710	0.0806	18.35	0.0000	1.75	0.1860	12.99	0.0003	0.24	0.6217	0.01	0.9205
Tractors (HI)	0.0267	-0.0127	0.0124	0.0510	0.1011	5.95	0.0148	2.08	0.1490	5.94	0.0148	2.24	0.1348	5.29	0.0215
Labour (HI)	0.1689	0.1334	0.1577	0.1496	0.1562	6.24	0.0125	2.73	0.0987	0.45	0.5020	0.34	0.5621	0.57	0.4485
Livestock (HI)	0.1425	0.2039	0.1846	0.1963	0.1447	9.71	0.0018	0.33	0.5682	0.16	0.6859	0.13	0.7216	6.73	0.0095
Int Intercept	4.0934	3.8679	3.7265	3.8651	3.4206	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HI Intercept	7.1504	6.5162	6.4258	6.4980	6.2681	14.66	0.0001	0.06	0.8001	0.13	0.7202	1.29	0.2552	5.59	0.0181
P Dummy	0.5061	0.4515	0.4654	0.4921	0.5493	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N Dummy	-0.5206	-0.4606	-0.4320	-0.4642	-0.4927	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Constant	3.6679	3.8679	3.7265	3.8651	3.4206	1.73	0.1884	1.41	0.2347	1.52	0.2171	16.35	0.0001	2.04	0.1531

N/A = not available. HI and Int denote high external input and intermediate countries, respectively.

Being satisfied with the adequacy of the estimation results reported thus far, the analysis then calculated the MPP/MVP of land for each in-sample-observation as per equations 7 and 8 in Chapter 3. Again, only statistically significant (at 10% significance level) coefficient estimates on dummies were used, while all LI estimates were adopted regardless of significance. In short, the coefficients inputted into equations 7 and 8 were similarly constructed as those provided by Table 4.11.

Further, in order to enhance the comparability of the resulting country datasets across different levels of input use, these values were converted into percent values, with the first observation in time taking the place of the base value (i.e. equal to 100%) for each country. Additionally, as per the theoretical model in Chapter 3, changes in land become a useful indicator of changes in productive capacity when observed alongside the productivity changes. For this reason, graphs of changes in percent agricultural land (measured similarly to percent MPP/MVP) were superimposed on graphs of the percent MPP/MVP of land against time (measured as a time variable taking on values of 1,2,3,…,T with 1 equal to the first year of the relevant study period and T the last year).

Figure 4.2 presents the set of these graphs that correspond to the HI zone over the 1981-2005 period with output aggregated in wheat units. The graphs depict a generally declining MPP pattern that is consistent across all HIs. That is, percent MPP values around 2005 are consistently lower than the corresponding values around 1981. These results suggest that the productive capacity of land in these countries has declined over the study period. Indeed, MPP falls even in countries like Saint Lucia, where percent land has fallen over the study period. This observation counters the possibility that falling MPP might be due to "normal" diminishing returns with increasing land, as opposed to shifts in the production function. As indicated in the theoretical model in Chapter 3, the maintained assumption is that declining land productivity with declining agricultural land must, conceivably, be due to degenerative shifts in the production function.

However, notice that for certain countries, such as Switzerland, Egypt, Israel, Lebanon and Pakistan, one might defensibly choose to read the graphs as depicting unstable observations with neither an upward nor a downward drift. Nevertheless, such instability, more commonly observed among HIs, can hardly be consistent with agricultural resilience.

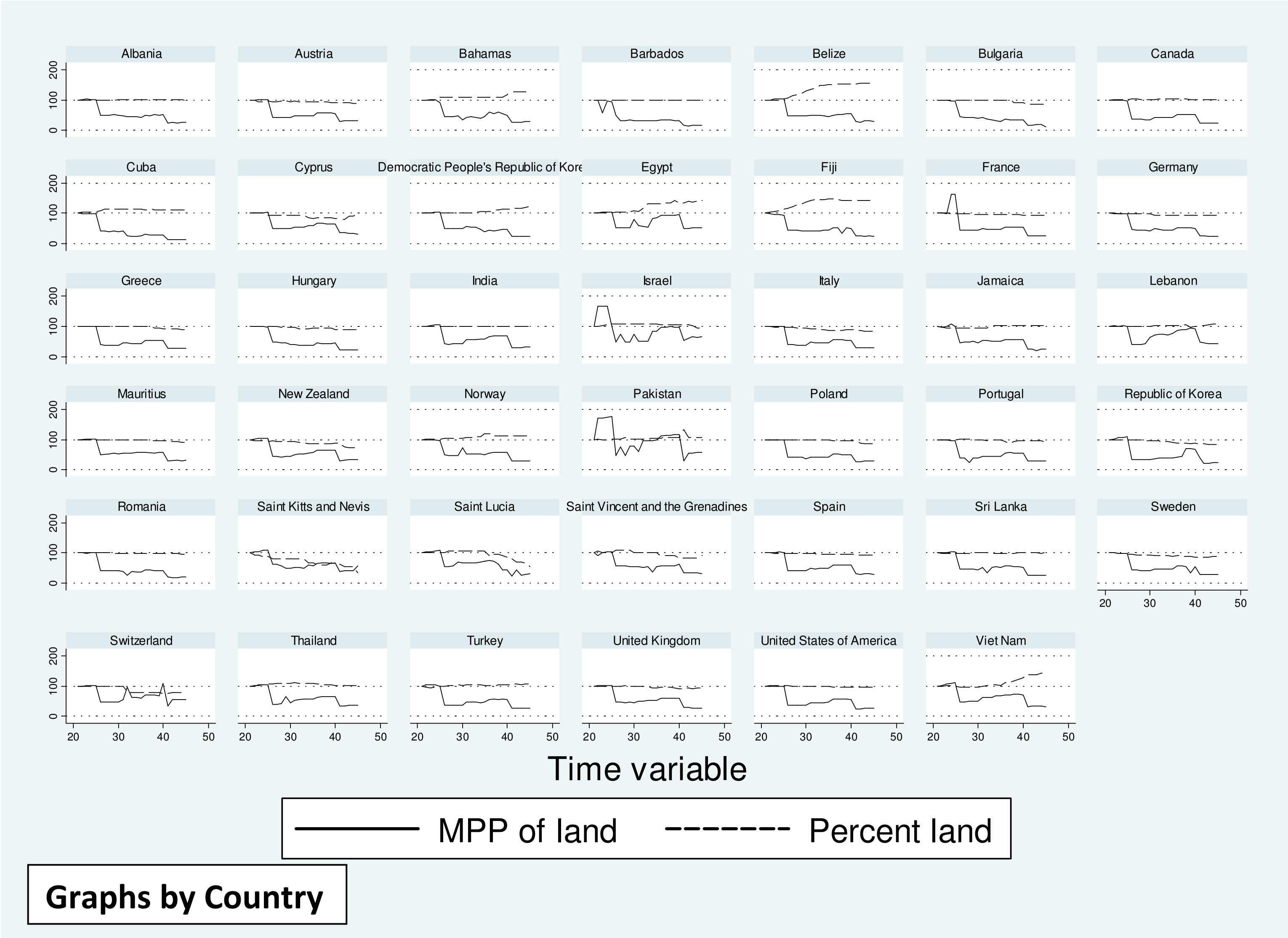

Figure 4.2 Growth paths of MPP of land, and land in high external input countries under wheat unit output aggregation, 1981-05

Figure 4.3 presents the counterpart graphs for the intermediate countries. The graphs show a reverse pattern. The intermediate countries have registered general rises in MPP consistently, across all in-sample countries. Notice that the MPP graphs of Lesotho and New Caledonia are missing because these were excluded from the relevant regression as outliers.

It is also observed that MPP rises even with rising percent land for countries like Malawi and the United Arab Emirates. This observation shows that MPP need not fall in such cases as per the notion of diminishing returns. Contrary to the reservations alluded to under the foregoing HI analysis, countries like Malawi might be demonstrating that there is a way agricultural production can be configured to give increasing MPP even when agricultural land expands.

It is also interesting to observe that the graphs indicate that these intermediate countries registered slow, and in some cases negative, MPP growth over the 1980s to 1990s, a period that generally corresponds to the SAPs era. Indeed, the fall in MPP in countries like Malawi corroborates the findings of researchers like Chirwa and Zakeyo (2006) and Moyo (2010) who, as mentioned in Chapter 3, suggest that the removal of the state-sponsored fertilizer subsidies under SAPs was deleterious to the productive capacity of Malawi’s agricultural land. Importantly too, these results support this study’s hypothesis that the zonal meta-production function may be sufficiently similar to country-level meta-production functions for inferences to be drawn about the resilience of the agricultural systems of the individual countries involved. Furthermore, the demonstrated congruence of the fore-going narrative, as dictated by our theoretical model, with the real world provides support for the relevance of this model for the assessment of agricultural resilience.

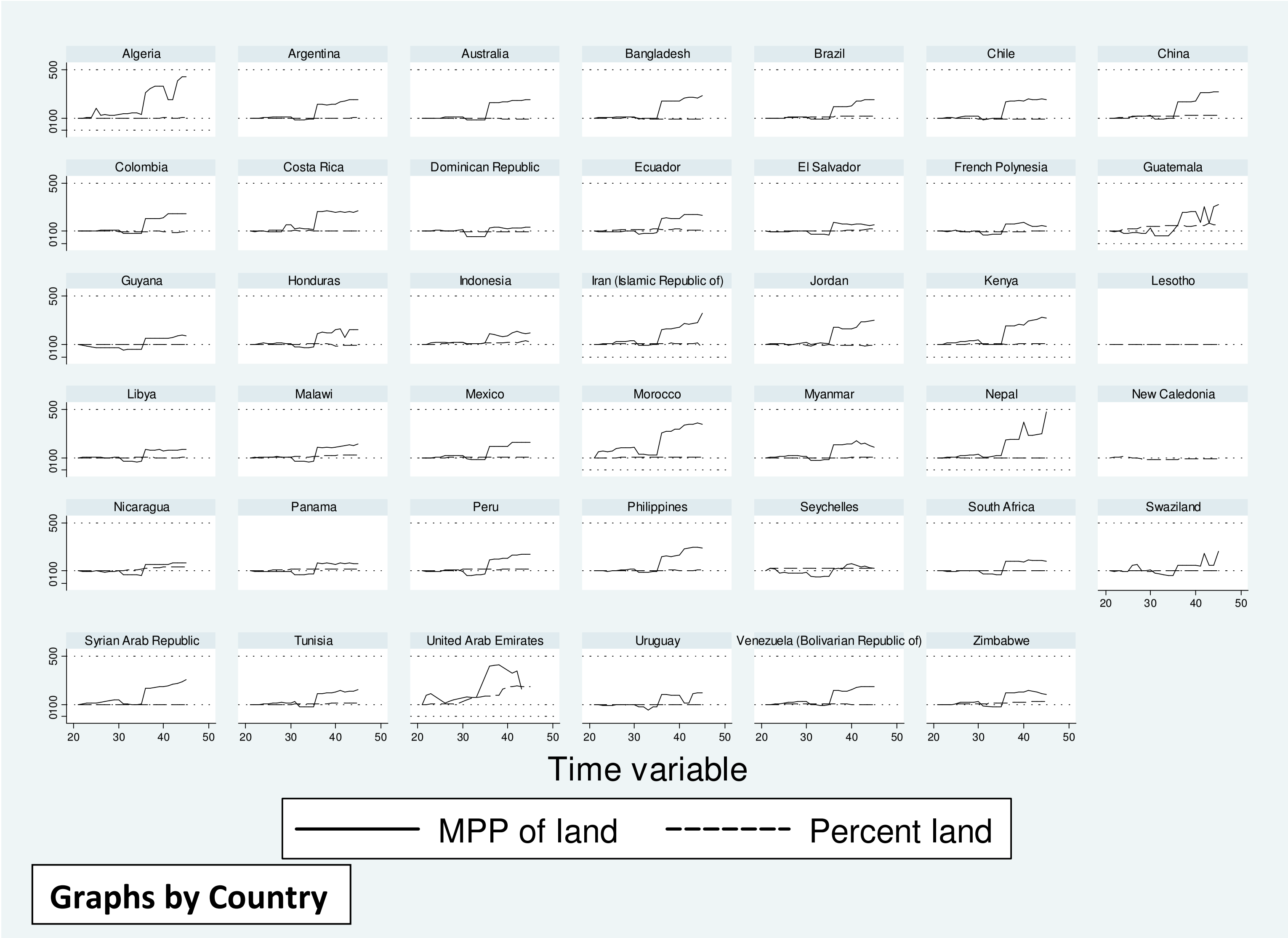

Figure 4.3 Growth paths of MPP of land, and land in intermediate countries under wheat unit output aggregation, 1981-05

Figure 4.4 presents the corresponding graphs for LIs. The results are generally similar in pattern to the intermediate case. However, while the LIs show less degeneration over the SAPs era, their percent MPP rises over the entire study period are smaller relative to the intermediate countries. It is also worth noting that the MPP graphs of these countries exhibit a tendency to burgeon before the end of the study period is reached. This tendency, also observed in fewer cases among HIs and the intermediate suggest that there has been a period of rising MPP just before it falls towards the year 2005.

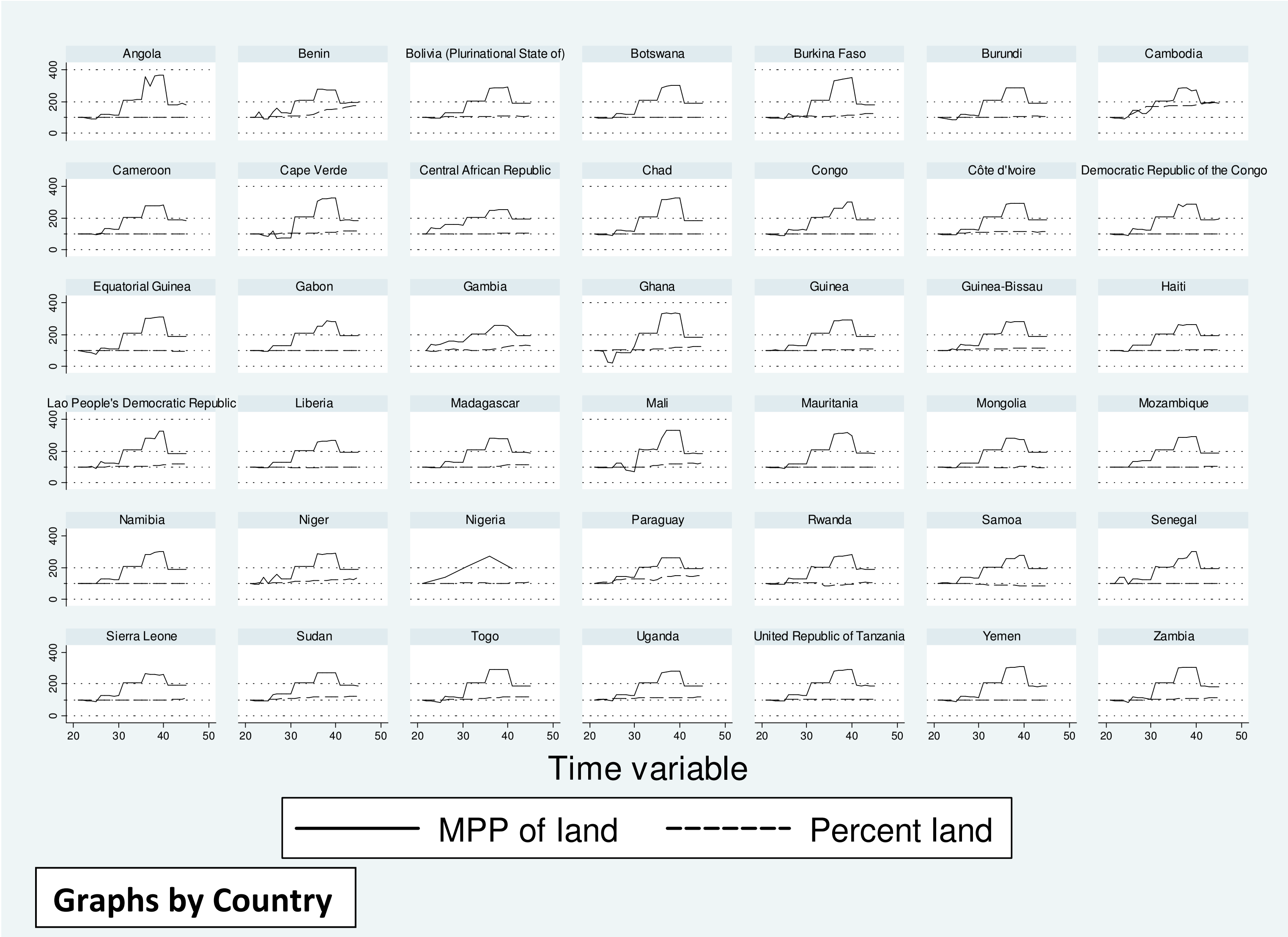

Figure 4.4 Growth paths of MPP of land, and land in low external input countries under wheat unit output aggregation, 1981-05

When the graphs presented in Figures 4.2-4.4 are generated for tonnage output aggregation, the patterns described above are generally repeated with arguably minor variations. These graphs are presented in Figures 4.5-4.7. The similarity of the tonnage-based graphs with the wheat-unit-based graphs somewhat supports the relevance of tonnage as a means for output aggregation. It demonstrates that the use of tonnes does not spawn substantial distortion of the relevant picture generated by the present analysis.

One further observation might be in order. The burgeoning effect described above gains in prominence among HIs when output aggregation shifts basis from wheat units to tonnage. The similarity of this effect, over time, among these countries as well as with the LIs warrants further analysis.

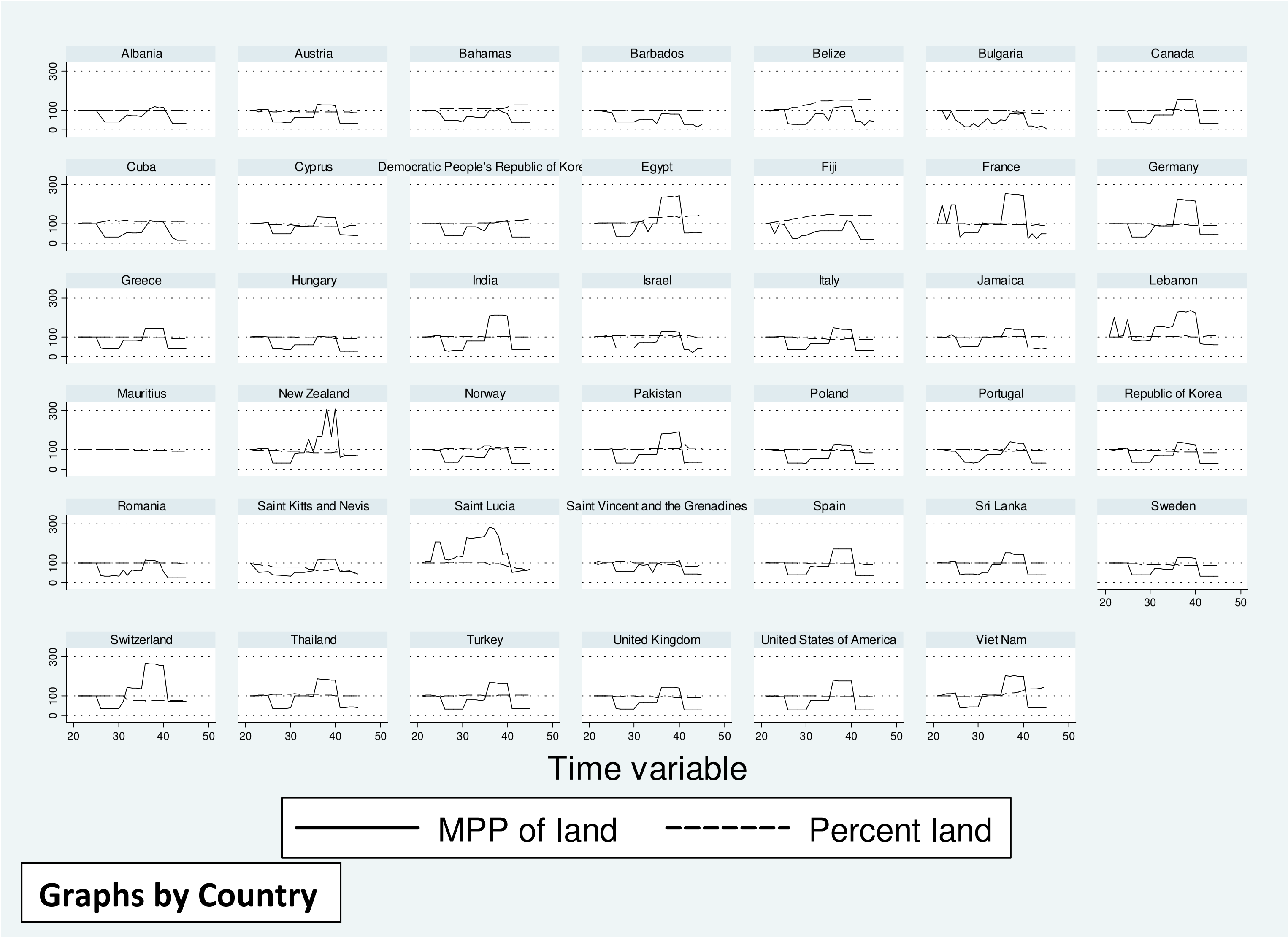

Figure 4.5 Growth paths of MPP of land, and land in high external input countries under tonnage output aggregation, 1981-05

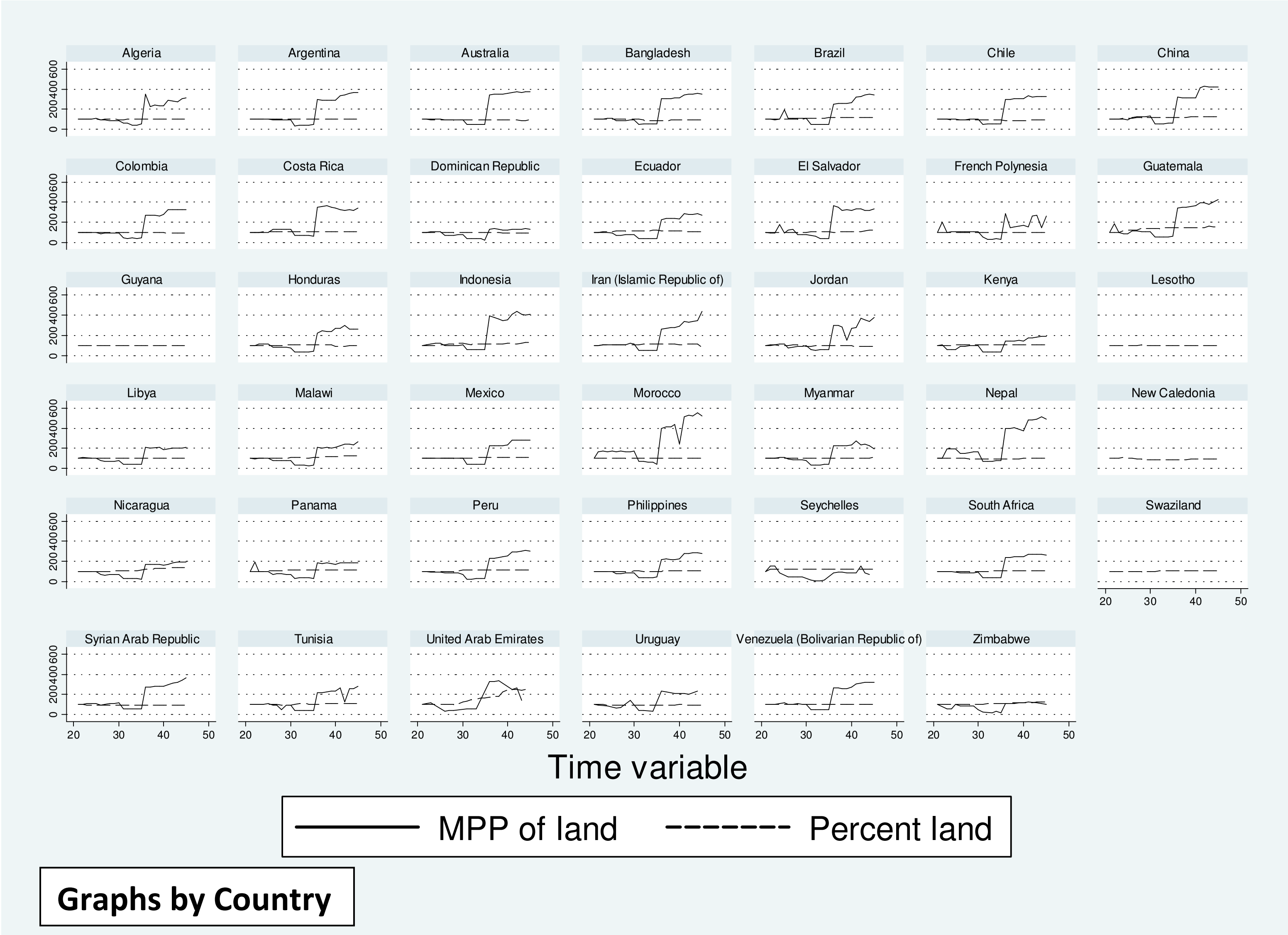

Figure 4.6 Growth paths of MPP of land, and land in intermediate countries under tonnage output aggregation, 1981-05

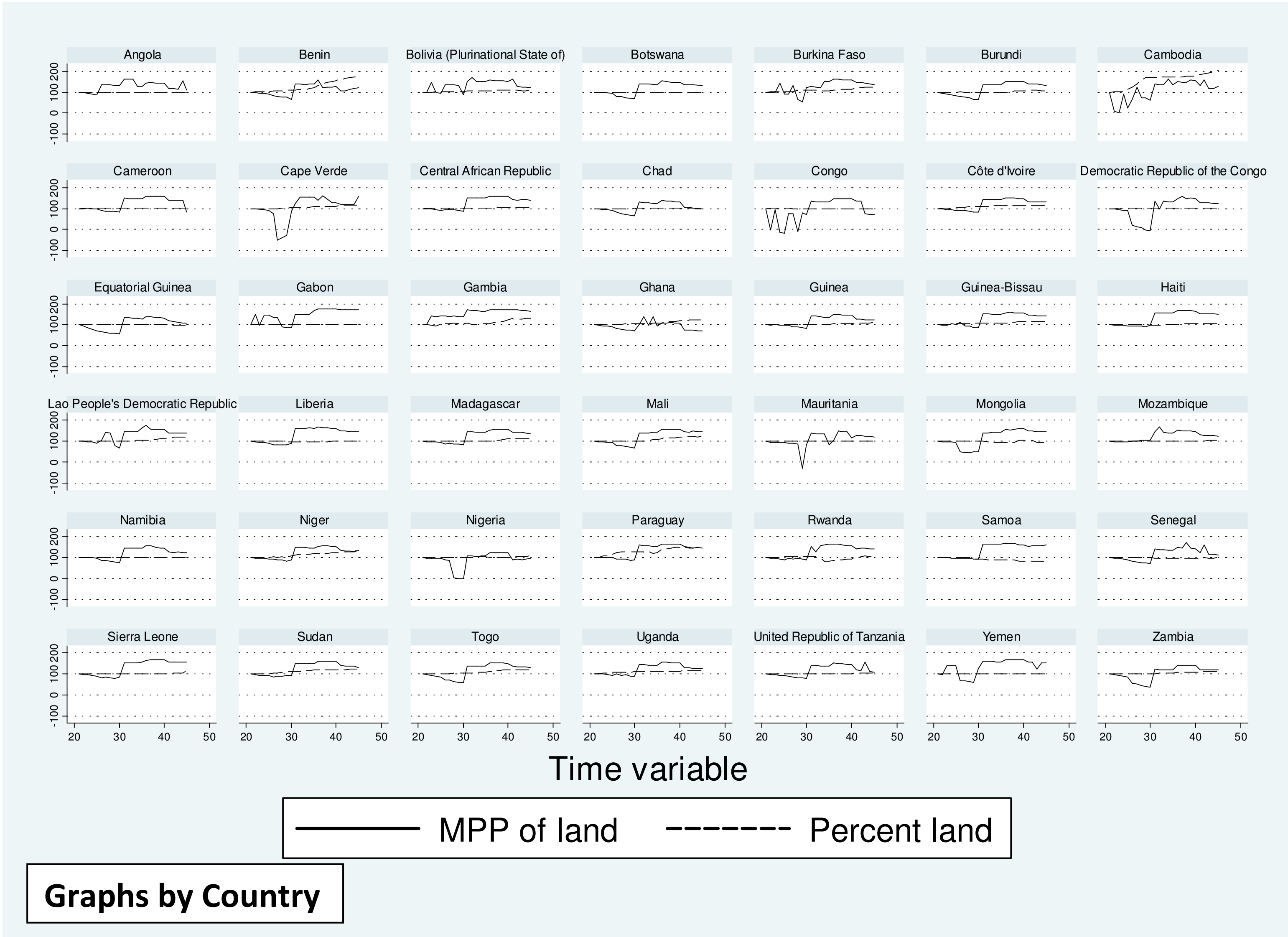

Figure 4.7 Growth paths of MPP of land, and land in low external input countries under tonnage output aggregation, 1981-05

Figures 4.8-4.10 recast the picture under discussion for the case of output aggregation using the international dollar. These graphs seem to meet the expectation that I$ aggregation would bias the results particularly in favour of the HIs. Indeed, most HI graphs now depict generally rising marginal value productivity (MVP). *Prema facie*, one would think that this represents challenging evidence to the general pattern reported so far, especially in view of the fact that the I$ remains an acceptable measure for output aggregation within the scientific community. On the contrary, as explained in the sequel, the graphs of Figures 4.8-4.10 may actually serve to show that the general patterns reported above are robust to changes in the method output of aggregation.

Notice that HI rises in MVP are typically from 100% to around 120% and below, even reaching percentages below 100% while a few reach the region immediately around 150% (Figure 4.8). Nine deviate and come to around 200% (Figure 4.8). These include Egypt, India, Lebanon, Pakistan, Republic of Korea, Saint Kitts and Nevis, Saint Lucia, Thailand, and Viet Nam. However, closer inspection of these countries readily reveals that they are all not developed countries (DCs), thereby presenting little, if any, challenge to the general picture as discussed below. Further, the fact that most, if not all, of these countries are associated with substantial irrigation, providing for multiple production seasons within what would otherwise be one agricultural season, may render irrigation recommendable in the pursuit of resilient agricultural systems.

On the other hand, virtually all intermediate countries rise in MVP to the region of 200%, all are above 100%, and some even reach very high values like around 700% for Jordan (Figure 4.9). Only a few LIs fall below 100%, otherwise most reach the vicinity of 160% (Figure 4.10). In general relative terms, therefore, the order of resilience then remains the intermediate as the most resilient, followed by LIs and then, lastly, HIs. It is also worth mentioning that the seemingly uncharacteristic non-DC HIs suggest that the analysis is robust to wrong zone demarcation. Indeed, this assertion is further supported by within zone variations in pattern which become pronounced under tonnage and I$ output aggregation. These variations suggest that fitting a common meta-production function as done in this study does not restrict any country to some fixed, “predetermined” pattern.

Also recall that international dollar aggregation, obtained from FAOSTAT, covers practically all crop and livestock products originating in each country, of course with the main exception of fodder crops. Contrast this with wheat unit and tonnage aggregation, as used in this study, which only covers primary agricultural production, again as defined by FAO (2011). It then seems reasonable to contend that the analysis based on the latter two measures of output, as opposed to the international dollar analysis, provides a picture that is more closely reflective of the interactions within the farmer-farm-environment nexus. At the same time, to the extent that this nexus constitutes the cornerstone of agriculture, without which further agricultural processing and value addition cannot occur, it may also be reasonable to argue that the wheat unit and tonnage analysis more strongly represents agricultural resilience. This is, by no means, to say that agricultural value addition beyond the farm-gate is not important, but rather to appreciate what appears to be the natural ordering of priorities within priorities. Notice that these strengths of wheat unit and tonnage aggregation are observed in addition to the theoretical appeal of the wheat unit as argued in Chapter 3.

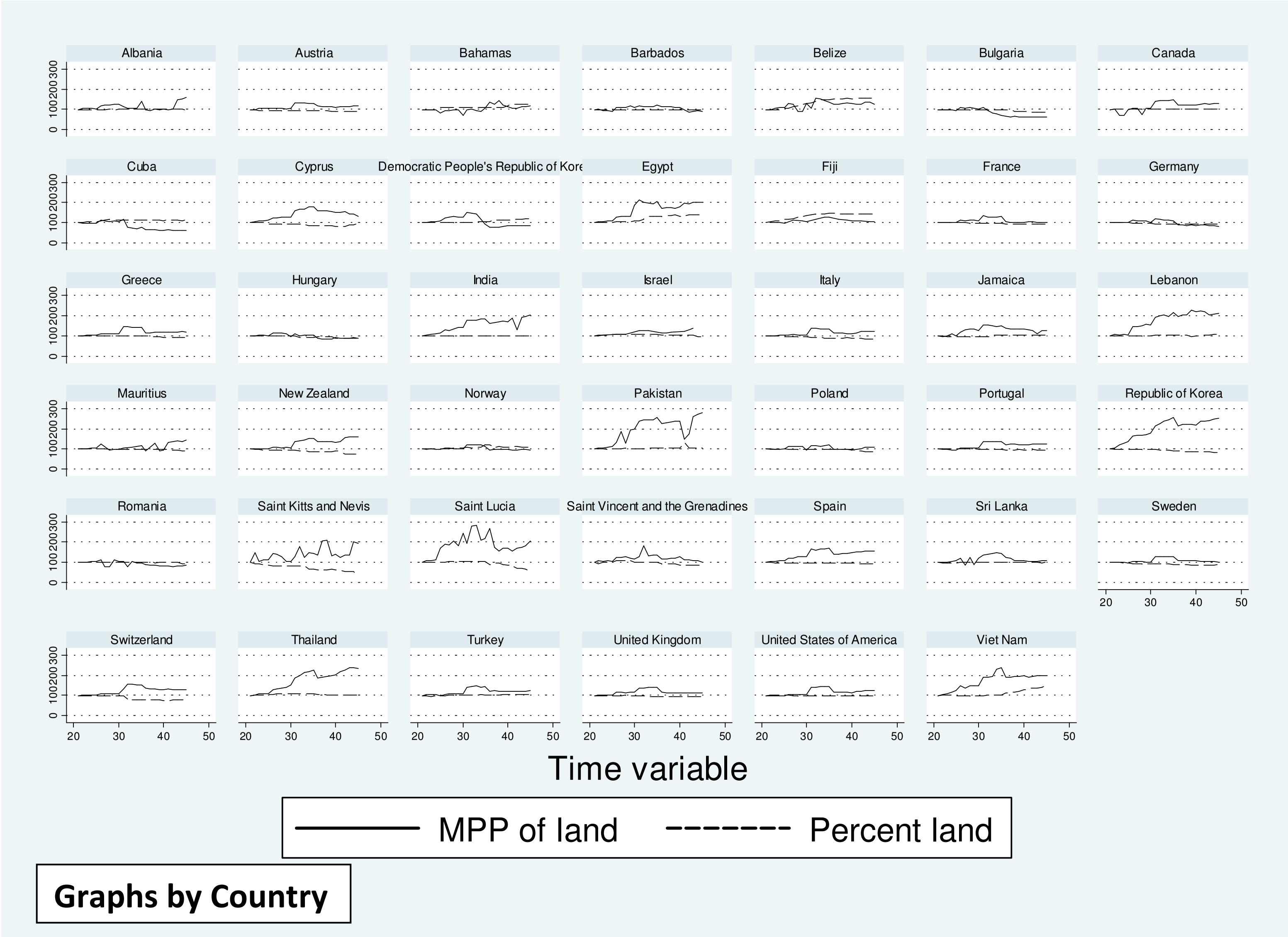

Figure 4.8 Growth paths of MPP of land, and land in high external input countries under I$ output aggregation, 1981-05

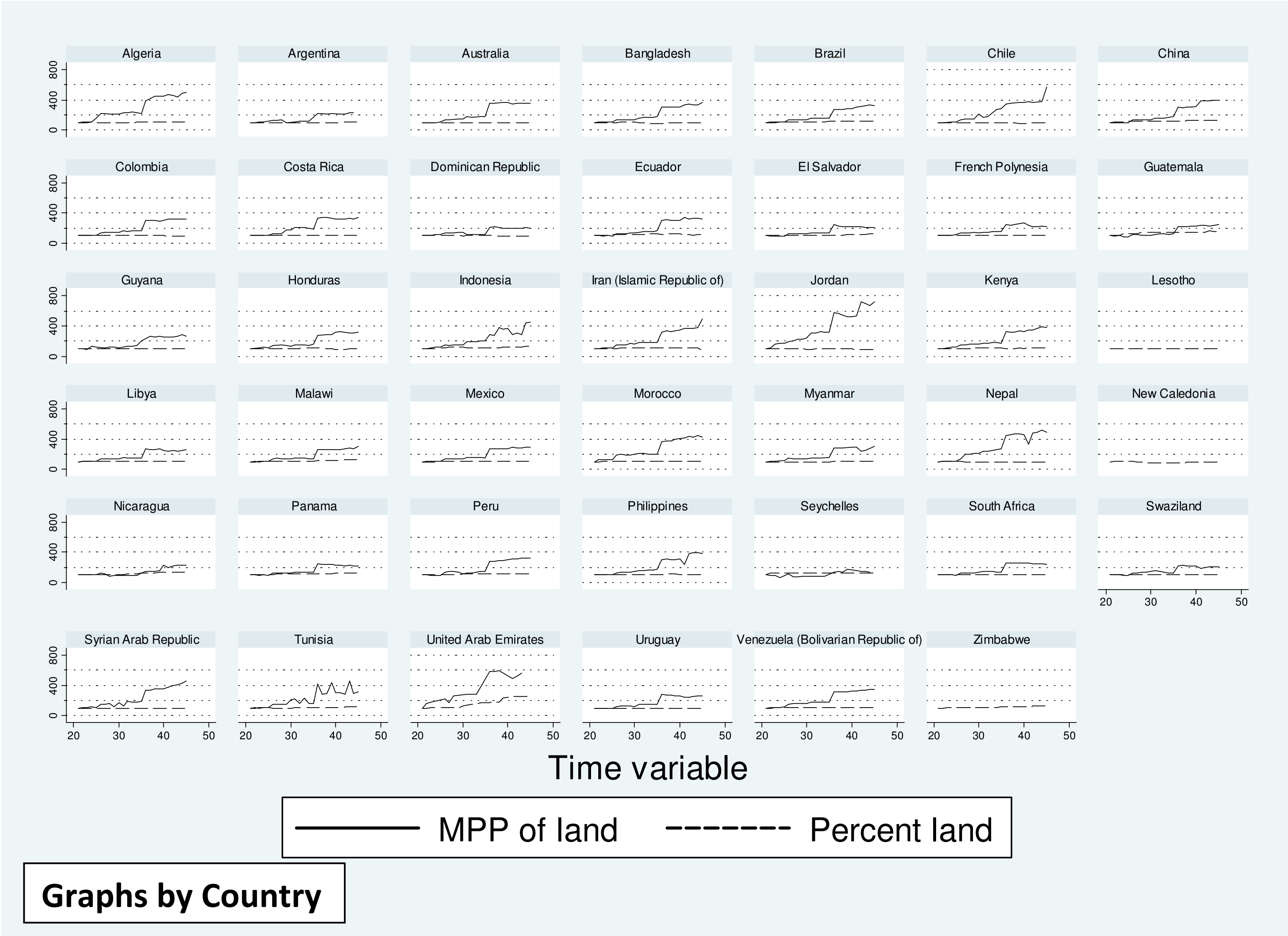

Figure 4.9 Growth paths of MPP of land, and land in intermediate countries under I$ output aggregation, 1981-05

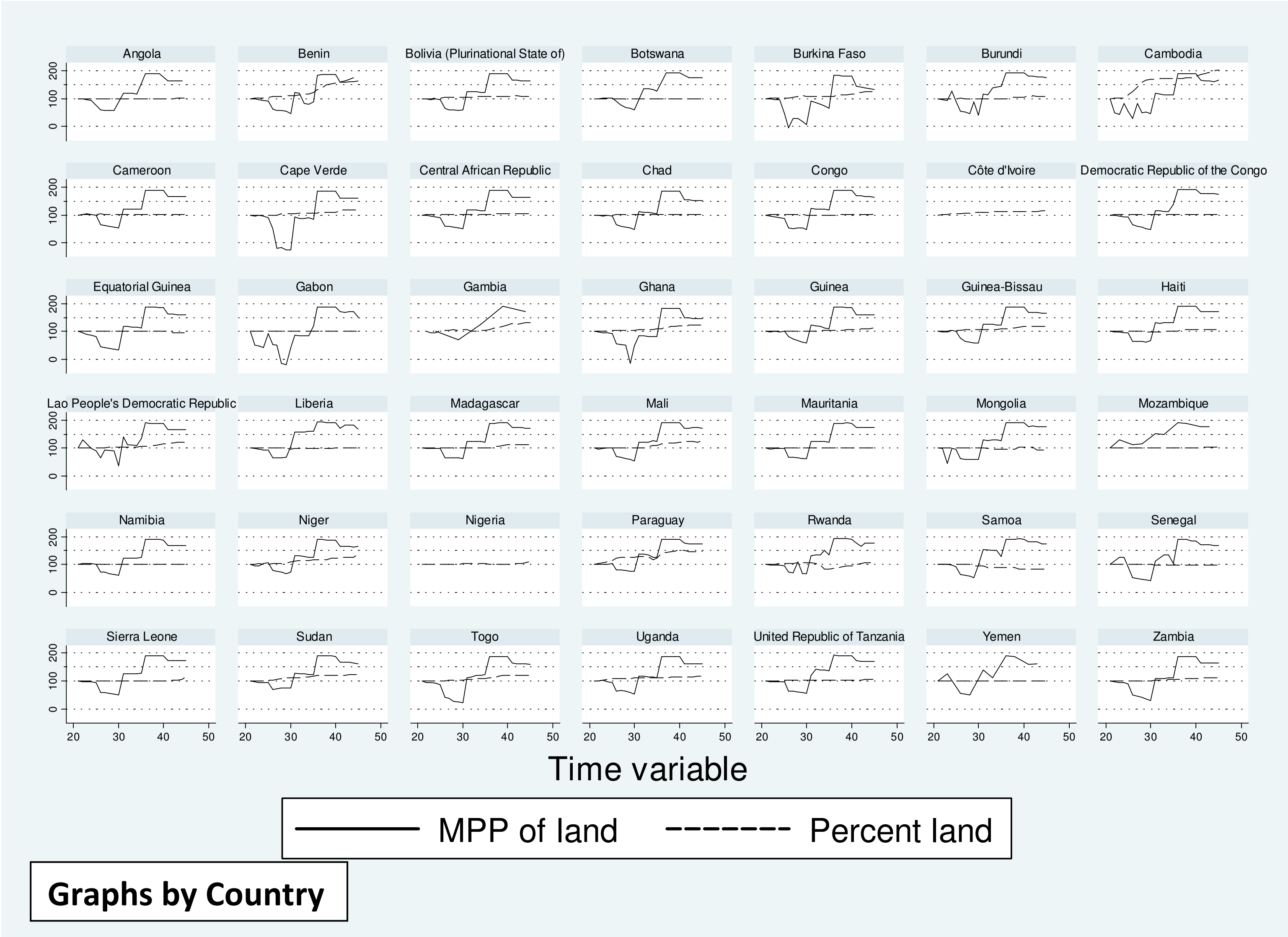

Figure 4.10 Growth paths of MPP of land, and land in low external input countries under I$ output aggregation, 1981-05

Finally, Figures 4.11-4.13 present the set of graphs for wheat output aggregation when the analysis runs over 1961-2005 while the labour variable is excluded. In general, the results seem to support the rejection of the hypothesis that the exclusion of labour would not bias our estimates, effectively giving an extrapolation of the 1981-2005 picture. Indeed, contrary to the picture generated by Figures 4.2-4.4, the current graphs depict general rising MPP patterns among several HIs, looked at beginning from 1981 as depicted by the vertical line lying in between values 0 and 50 of the time variable (Figure 4.11). Similarly, the same perspective shows that several intermediate countries now register substantially less MPP growth (Figure 4.12). However, it is interesting to note that the patterns for LIs have generally been better maintained in terms of rising MPP, although the magnitudes of the rises sometimes makes a dent in the resemblance with Figure 4.4 (Figure 4.13). This may be because the relationship of labour to the "primitive", highly labour-intensive production of LIs has been relatively stable overtime. For instance, on the general picture, one would expect the substitution of labour with machinery in primary agricultural production to have been the least among these countries when the three zones are compared. It then becomes reasonable to contend that the analysis is robust to the exclusion of the labour variable among most LIs, probably excluding only Benin and Gambia; in which case, it is observed that these countries have registered general rises in MPP over the period of 1961-2005. Of course, further analysis would be desirable to check if such reasoning can be extended to the currently seemingly non-conforming countries among the intermediate and HIs, which also depict remarkable resemblance with their 1981-2005 analysis patterns.

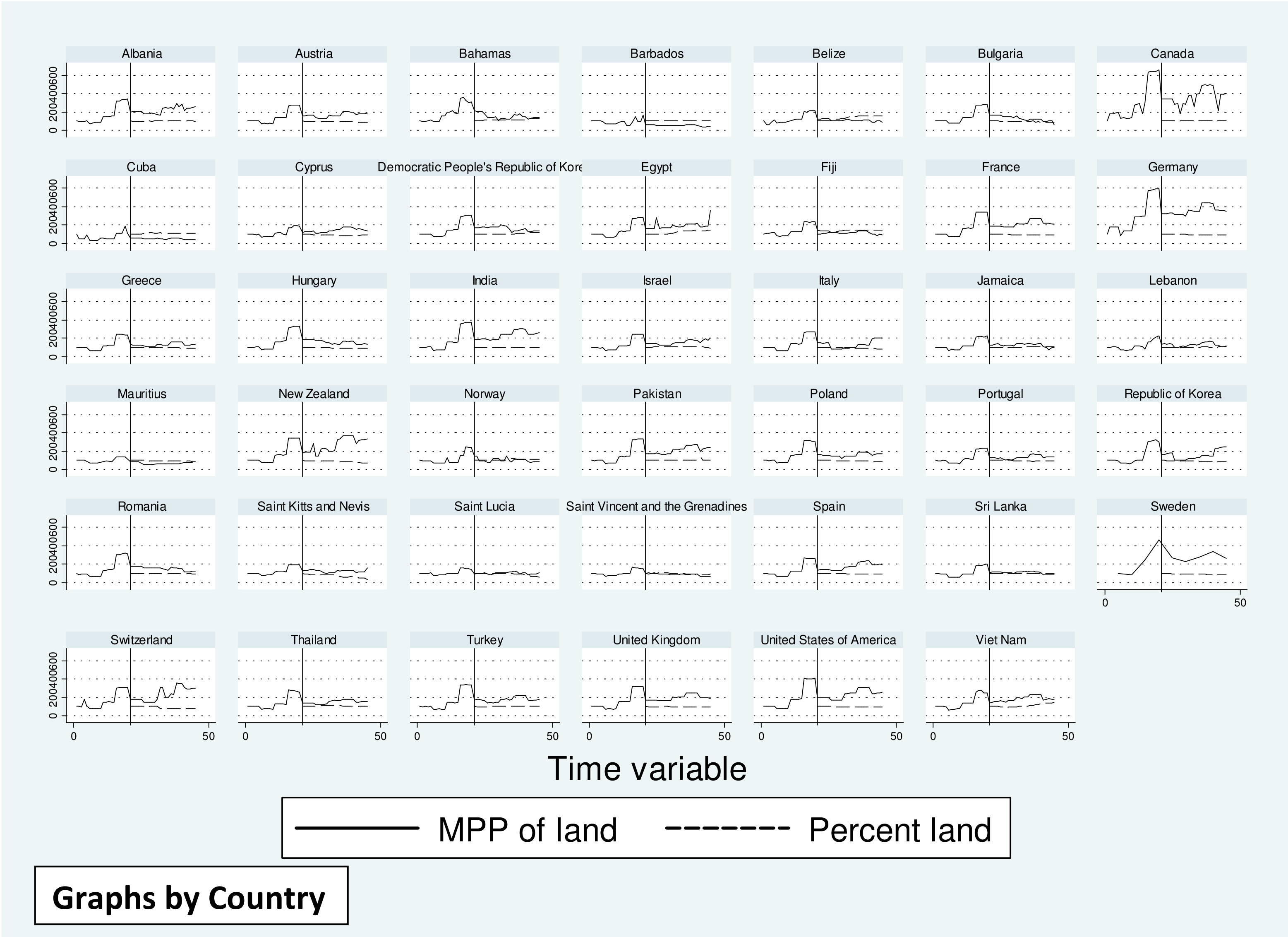

Figure 4.11 Growth paths of MPP of land, and land in high input countries under wheat unit output aggregation and the exclusion of labour, 1961-05

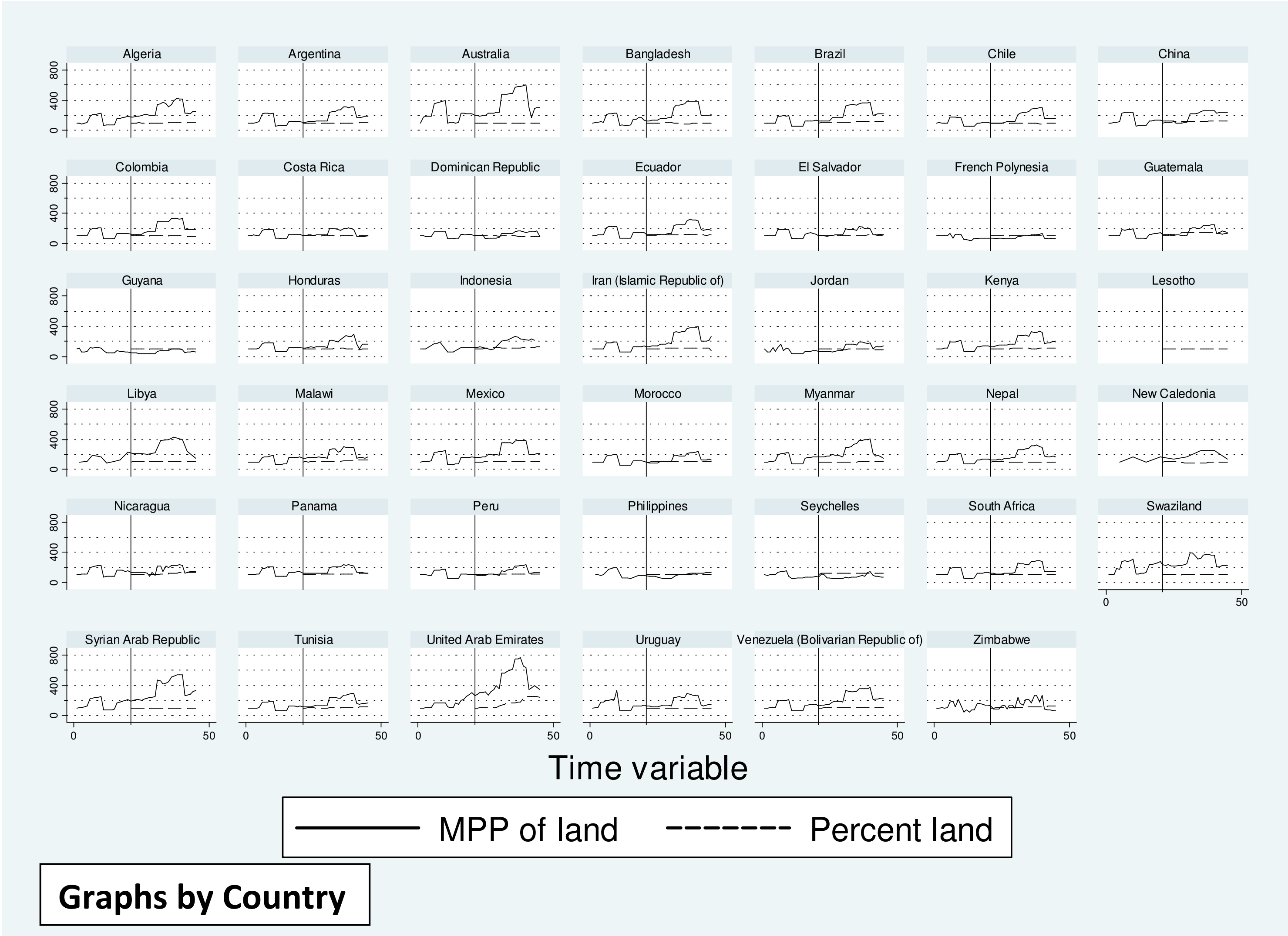

Figure 4.12 Growth paths of MPP of land, and land in intermediate countries under wheat unit output aggregation and the exclusion of labour, 1961-05

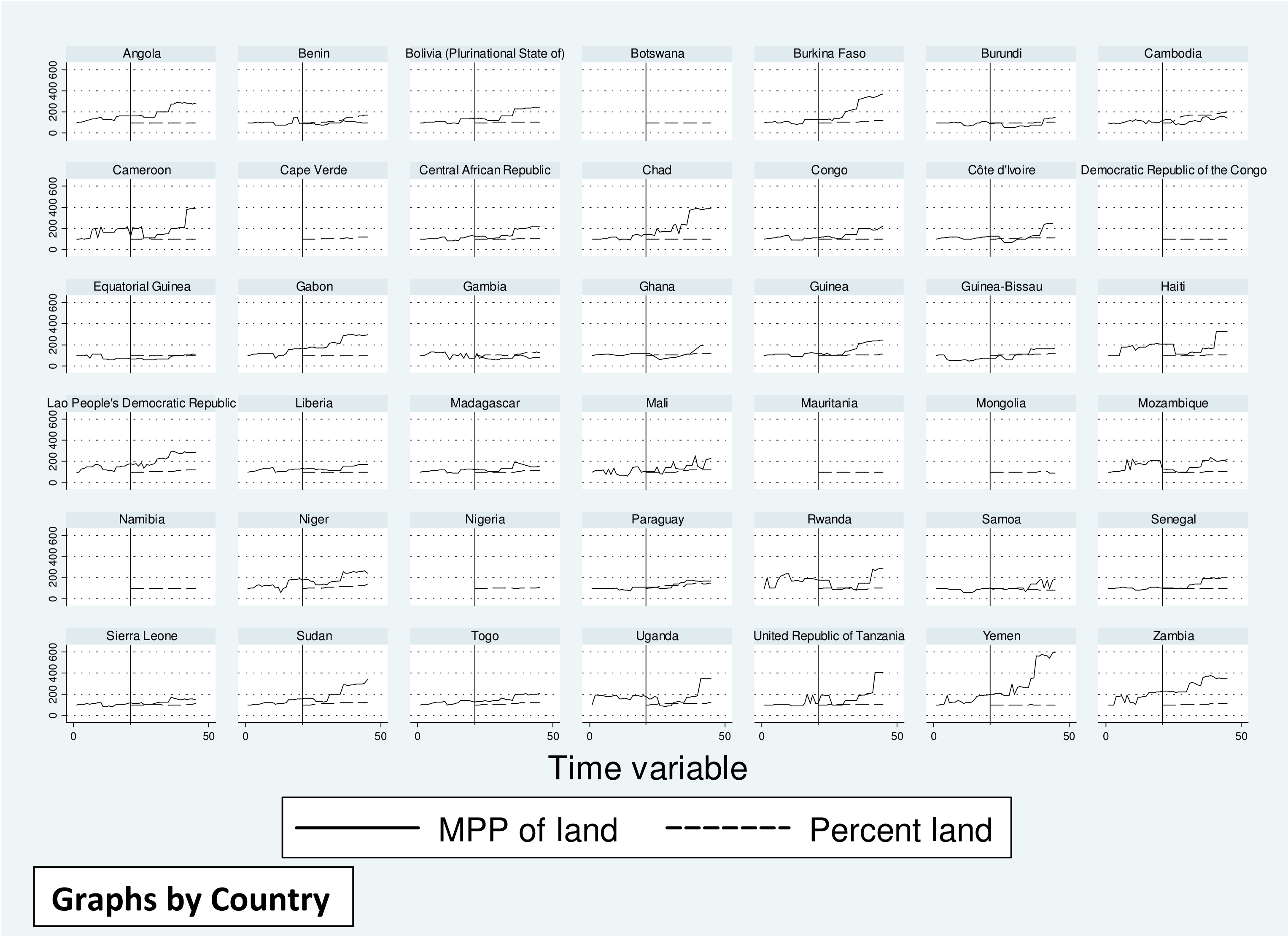

Figure 4.13 Growth paths of MPP of land, and land in low input countries under wheat unit output aggregation and the exclusion of labour, 1961-05

4.3 The Productivity Patterns in the Context of the Binary Tension Associated with Indigenous Knowledge, and Western Science and Technology

For a recap, this study has produced two major findings thus far. These findings meet the first two objectives of the study as indicated in Chapter 1. First and in response to specific objective 1, that the macroeconomic patterns of the MPP/MVP of agricultural land overtime suggest that the order of agricultural resilience, in declining order of resilience, is as follows: intermediate countries followed by LIs, and then HIs. Second and in line with specific objective 2, that this order is robust to changes to the methods of MPP/MVP evaluation; the changes including using three different methods of agricultural output aggregation, and the exclusion of labour from the set of regression predictors utilized. This section attempts to set these two findings in the context of the literature, pursuant to specific objective 3 of Chapter 1. Specifically, it illustrates that the literature on the binary tension associated with indigenous knowledge, and Western science and technology offers support to, and possible explanations for as well as extensions to the findings of the present study.

For instance, the demonstrated supremacy of the intermediate zone as mentioned above may be interpreted as showing that the increasing resilience of agricultural systems is indeed associated with the use and role of indigenous knowledge. More specifically, this is to say that farmers' continued, careful reworking of their indigenous knowledges with other sources of knowing like Western science and technology, as discussed in Chapter 2, does enhance the productive capacity of land (Escobar, 1995; Beckford, 2002; Moyo, 2009, 2010). The study thus generates evidence that supports the generalization of narratives from the spatially scattered cases of micro-environments as studied by authors like Beckford (2002).

Indeed, the literature indicates that although not always out of perceived absolute superiority, indigenous knowledge remains the dominating epistemological and ontological force among the majority of farmers using relatively low, sometimes zero, levels of external inputs (Escobar, 1995; Briggs *et al.*, 1999; Beckford, 2002; Tijani and Omodiagbe, 2006; Eriksen, 2007; Mwale *et al.*, 2005; Briggs, 2005; Riseth, 2007; Andriansen, 2008; Chambers, 2008; Krätli, 2008; Briggs & Sharp, 2004, 2009; Kazungu, 2009; Birch-Thomsen *et al.*, 2010; Mertz *et al.*, 2010; Moyo, 2010). Accounts such as Briggs' (2005) and Moyo's (2010) suggest that indigenous knowledge, in certain forms, is sometimes perceived as a stumbling block to progress among farmers practising it. Nevertheless, it remains the dominating force. It thus can hardly be implausible to contend that, on the general picture, decreasing external input use in a given country, over time, effectively becomes synonymous to the increasing use and role of indigenous knowledge.

At the same time, the study recognizes the records of the imperialistic "success" of external input use as a kind of total, hegemonic package that has in many cases gradually and increasingly replaced indigenous practices and systems with modern, Western science and technology (Escobar, 1995; Moyo, 2010; Howitt *et al.*, 2012). As Howitt *et al.* (2012) indicate, this replacement has not unusually been misinformed, replacing developmental practices with retrogressive ones. Moreover, as opposed to partial adoption, this replacement is not uncommonly necessary if one is to see the acclaimed gains of modernization (Hayami & Ruttan, 1971; Escobar, 1995; Chirwa and Zakeyo, 2006; Moyo, 2010). However, of present interest is the fact that the replacing effect arguably makes it plausible to associate increasing external input use with the dis-adoption, sometimes coupled with the denigration, of indigenous knowledge. Moreover, this is reinforced by the fact that the zonal demarcation employed by this study concurs with Rigby and Caceres' (1997) mapping of the geographical distribution of conventional and traditional agriculture. Together, the literature and the present study's findings thus suggest that it may not be implausible to associate increasing resilience of agricultural systems, particularly as denoted by the MPP/MVP of land, with the use and role of indigenous knowledge.

The literature also helps allay one important source of potential misunderstanding of the present study's results. In this regard, one would begin by noting that the MPP/MVP patterns shown in the preceding section demonstrate that the increasing use of external inputs overtime yields different results in LIs and intermediate countries, compared with HIs. On the other hand, researchers like Rigby and Caceres (1997), Chirwa and Zakeyo (2006), Moyo (2010), Taiwo and Oso (2004) cited in Moyo (2010), and Moyo (2011) have indicated and/or demonstrated that modernist practices like the use of chemical fertilizers and tractors erode the productive capacity of land. It would seem that this identification favours the modernist perspective that effectively tends to associate high productive capacity of land with pristine environments (Eriksen, 2007; Riseth, 2008). Such pristine environments are defined as being synonymous with the (virtual) exclusion of man from the ecosystem (*ibid.*). At this point, the MPP/MVP findings mentioned above and the fore-going literature, together ostensibly constitute a source of paradox and ambiguity.

To this, the literature helpfully indicates that the results of this study would be ill-understood and actually collapse if one were to link the increasing productive capacity of land with "pristine" environments. This is not to say that such environments do not exhibit high productive capacity as reported by Moyo (2010) for the case of Malawi. Rather, the results of the present analysis demonstrate that man's sound management can maintain and increase the agricultural gains from land at the margin, which translates to an increasing capacity to increase output by increasing land (that is, a steeper production function). Similarly, such management means that decreasing land can actually be associated with maintained output or even increasing output (for example, a steeper function with a higher point of anchorage). Clearly, such a system may be considered to be less dependent on external inputs than a system in which increases in output are virtually solely dependent on increases in non-land inputs (especially external inputs). The former system may thus be considered to be more resilient, say to shocks in the supply of external inputs, or in broad terms, more sustainable than the latter one.

The point being driven at is that increasing fertilizer and tractor use may not be deleterious to human survival *per se*. Their inappropriate use, however, might be. For example, while Malawian farmers in general, most of who are smallholder farmers, might have adopted the use of such external inputs in one way or the other, such adoption has occurred in the context of changes in associated variables. For instance, Moyo (2009) succinctly demonstrates that the modernization of farming methods by farmers in northern Malawi actually constitutes a careful combination of indigenous knowledge with Western science and technology. He further demonstrates that this combination of knowledges has worked to avert productivity losses that would otherwise occur under the unquestioning adoption of Western models as advised by local experts, due to local specificities such as the shortage of labour and capital (Moyo, 2008, 2009, 2010). The average Malawian farmer thus becomes a rational being, albeit in the bounded sense, who realises that higher productive capacity is not necessarily a function of moving towards a "pristine" environment, but more so a function of output per unit land. He further realises that what his need is is not necessarily to maintain the "natural" configuration of his soils by avoiding external inputs, but to set this adoption of external inputs in a careful configuration of other relevant variables. Such is what geographers like Briggs and Sharp (2009) have termed the utilitarian approach.

Indeed, Eriksen (2007) admirably demonstrates that a pristine environment should really not be one in which the human being is excluded. In her account of the political ecology of fire as a land management tool in rural Zambia, she demonstrates that the bush, left to its “own” mechanisms without man’s management, can yield to wild fire that can destroy the soils on which the bush itself is dependent. Krätli (2008) similarly demonstrates that what would appear to be the “natural” adaptation of cattle to their environment is actually, among the WoDaaBe, also due to the herders’ careful management that maintains economic gains. To be sure, if being “pristine” is associated with ecological completeness, then to the extent that man is also a bona fide member of the global ecology renders the definition of pristine as man-exclusive grossly inappropriate. Riseth (2007) demonstrates that the coercive alienation of man from his natural “habitats” generates systematic resistance that is, unsurprisingly, characteristic of all nature. Escobar (1995) and Howitt *et al.* (2012) also argue and demonstrate that such alienation or removal, including where the habitat is maintained but alien systems of livelihoods are introduced, can be disorienting and substantially erode the sustainability of (indigenous) livelihoods by increasing vulnerability to natural and unnatural disasters.

By way of extension, one would also argue that agricultural mechanization reduces the resemblance of agricultural systems to “naturally occurring” ecological systems where environmental management occurs at the small-scale before it constitutes the large scale. Such has been the nature of farming, often referred to as peasant agriculture, since historical times (Rodney, 1972). This denaturalization of the farming process, particularly when it is poorly informed and formulated, may constitute an ecological shock that weakens agricultural resilience and hence the observed relative position of HIs.

In demonstrating that agricultural resilience may be under threat in developed countries as well, this study signifies that the balance of the burden of averting the threat of global agricultural supply deficits needs to be readjusted. That is, the rhetoric and search for solutions need not only largely dwell on highlighting the "primitive" technologies characteristic of many areas of the global South. Rather, the degeneracy of modern agriculture, as established by this study, should also be underscored and given due attention. The unquestioned transfer of Western science and technology to correct the real and the imagined vices spawned by "primitive" agriculture may thus really constitute the opening of a Pandora's box of environmental problems and threats, rather than resolving the challenges at hand, as indicated in Chapter 2.

The so-called developed countries might thus need to slow down their project of colonizing the world by trying to impose a singular, totalizing and universal life-world based on Western science and technology. Rather, it becomes prudent not only for the sake of others but for themselves as well to engage in meaningful dialogue with other ways of knowing towards the generation of inclusive and better life-worlds or systems as argued in Chapter 2. This naturally calls for balanced research in disciplines and sub-disciplines such as quantitative international agricultural production studies.

Some final cautioning words may be in order. To begin with, the actual (as opposed to percent) MPP of Malawian land, like for LIs, was found to be low relative to other intermediate countries. For instance, the 2005 values under the 1981-2005 wheat unit analysis were determined as roughly 75 units for Malawi while Bangladesh registered 347 units. The idiosyncrasies of these countries notwithstanding, the study thus finds it prudent that Malawi seeks to continue with the rising MPP, even towards converging with the other intermediate countries or beyond. Based on the results, it is envisaged that this path would entail avoiding declines as observed over the SAPs era, in general, and enhancing the process of continuous, careful adaptation that farmers are currently engaged in. If this assertion holds, then sustainable agricultural growth might indeed be delayed or even derailed by the continued setting of indigenous knowledge in a context of binary tension or contestation with other sources of knowing, notably Western science and technology (Blaikie, 2000; Briggs & Sharp, 2004; Moyo, 2009, 2010; Howitt *et al.*, 2012).

Secondly and lastly, the timeframe under study is rather short. It is not inconceivable that the gains registered by LIs and the intermediate countries are but transient. Indeed, the biological and anthropological findings reported by Moyo (2008, 2010), referred to in Chapter 3, to the effect that chemical fertilizers erode the productive capacity of land need to be brought to bear. Moyo effectively demonstrates that the rises in MPP/MVP in Malawi may be occurring in the context of a degenerating land base. He shows that soils are being “burnt” by fertilizers. Against this background, it may be more meaningful and pragmatic to refine the argument of this study as follows. The combination of indigenous knowledge and the use of external inputs as prescribed by the modernist model might only have a mitigating effect on the damaging effect of such external inputs. That is, it is difficult to associate such external input use with the increasing inherent agricultural productive capacity of land. Rather, the mitigating effect just mentioned, as opposed to true growth in the productive capacity of land, has the effect that MPP/MVP shows more resilience in the intermediate countries than the rest, for example. For instance, land could keep registering increasing MPP every year (solely) because gains in yield due to improvements in varieties outweigh losses owing to the degeneration of land. If this holds, then HIs could represent the extreme case in which the degeneration of land has so risen that the variety effect fails to outweigh the land degeneration effect. There might, therefore, be more reason for the intermediate countries and LIs to seek ways of reversing the degeneration of their lands before much further damage is inflicted, than there is to continue with the somewhat semi-modernist model.

Importantly, farmers' indigenous knowledges might still offer a useful departure point in this quest. Indeed, largely indigenous industries such as the "mopane worm" of southern Africa attest to this assertion. Toms (2003) reports that this delicacy has been found to provide a more efficient harvest than cattle in the sense that it can yield one kilogram of worms from about three kilograms of feed. On the other hand, cattle farming requires up to ten kilograms of feed to generate one kilogram of beef, which has less protein content than the equivalent mass of the mopane worm (Toms, 2003). The mopane worm is actually a multi-million rand industry covering South Africa, Botswana, Zimbabwe and Namibia (Toms *et al.*, 2003; Kozanayi & Frost, 2002; GFU, undated). Similarly, gains in yield that come at the expense of other utility-defining parameters such as taste of food (Moyo, 2008, 2010) make it difficult to see the MPP/MVP gains as clear-cut positive developments. When such indigenous models are fully recognized, the scientist might help by, for example, cautioning against the adoption of the harmful external inputs and engaging in participatory research towards the identification of more sustainable alternatives.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter concludes the study and it is divided into two major sections as follows. In Section 5.2, it summarizes the main findings emanating from the results and discussion in Chapter 4, couching them in terms of the study's contribution to the literature. In Section 5.3, the study delineates policy implications, which to be sure, constitute further contributions to the literature.

5.2 Conclusions

In conclusion, in accordance with specific objective 1, this study has demonstrated that among 124 sample countries, the growth of the MPP/MVP of land has been greatest in the intermediate zone, followed by the LI zone and then, lastly, the HI zone. The patterns of the MPP of land depict remarkable congruence with the real world, being able to depict the effect of SAPs on agricultural resilience for example. This reinforces the study's assumption that the MPP of land obtained from the meta-production function is a useful indicator of the resilience or sustainability of an agricultural system. Based on this assumption, the fore-going order has thus been adopted as the relevant order of the resilience or sustainability of the broad agricultural systems involved. This is considered to be an evidence-based generalization of the narratives of micro-level case studies that posit similar arguments.

As regards specific objective 2, the study has demonstrated that the ranking is generally robust to the method of output aggregation employed. Three measures of output were used in this regard, namely, tonnes (which is a new introduction in economic quantitative international agricultural production studies), wheat units, and the international dollar as provided by FAO (2011). The study also suggests that this robustness might extend to wrong zone demarcation and the exclusion of the labour variable. Excluding the labour variable was particularly not significantly influential among LIs.

More importantly, pursuant to specific objective 3 and research question 1, the study thus fails to find evidence to the effect that the divergence of evidence and perspectives on the resilience of different agricultural systems as presented by micro-level, indigenous knowledge based case studies in comparison with economic quantitative international productivity studies, is a function of divergent realities. On the contrary, our evidence indicates that the differential perspectives may actually be a result of differential methodological foci.

5.3 Recommendations

Turning to research question 2, and in accordance with specific objective 3, the reconciliation of these two strands of evidence and the attendant reinforcement of the pro-indigenous knowledge perspective of the micro-level case studies has several implications for countries like Malawi. Indeed, the results show that such countries which have usually shouldered the burden of the blame of low agricultural productivity need not denigrate their indigenous systems in favour of modernization. Rather, sustainable agricultural growth might be dependent on carefully encouraging and enhancing farmers' present practices of selectively reworking their indigenous systems in the face of other forms of knowing, as well as climate change and weather variability, among other forces. This quest must be framed based on the understanding that the farmers' indigenous knowledge model is not infallible either, and may need help not least in the search for better alternatives than external inputs like chemical fertilizers. At the same time, the so-called First World and the concerned scientific community might need to balance their quest for transferring modern science and technology from the "development metropoles" to the "development colonies", with learning from and engaging in fair dialogue with these "subalterns".

In short, the results suggest that the fears for global agricultural production, as portrayed in the context of increasing anthropogenic pressures and climate change among other factors, need not only be couched in terms of the "tapering off" of production functions. Rather, it also warrants attention to seek ways of reversing or finding alternatives to what appears to be the falling capacity of land to return agricultural output, especially in high external input countries.

Last but not least, the study is by no means a panacea for the research challenge that it set out to meet. For sure, several important questions remain unresolved as outlined in the next section. Nonetheless, the study represents a significant furtherance of the research agenda that motivated it. It demonstrates that by making other models visible, as recommended by Escobar (1995), the eye of the economist engaged in quantitative international agricultural production studies can be healed of the coherence of reality that a singular theoretical framework dictates, thereby being made pluralistic. Such pluralism, Briggs and Sharp (2004) contend, constitutes a useful step that might uncover new challenges that offer solutions out of the development impasse.

REFERENCES

Andriansen, H.K. (2008). Understanding Pastoral Mobility: The Case of Senegalese Fulani. *The Geographical Journal* 174 (3), 207–222.

Angeles, L. (2007). Income Inequality and Colonialism. *European Economic Review* 51, 1155-1176.

Baltagi, B.H. (2005). *Econometric Analysis of Panel Data*. 3rd edition. John Wiley & Sons, West Sussex.

Bartels, B. (undated). Beyond "Fixed Versus Random Effects": A framework for improving substantive and statistical analysis of panel, time-series cross-sectional, and multilevel data. [On-line]. A revised version of a paper prepared for the Faculty Poster Session, Political Methodology Conference, Ann Arbor, MI, July 9-12, 2008. Department of Political Science, George Washington University, Washington, DC. Available from: http://home.gwu.edu/~bartels/cluster.pdf (Date accessed: 11/07/2012).

BBC (British Broadcasting Corporation). (16 December 2010). India's Micro-finance Suicide Epidemic. Available from: http://www.bbc.co.uk (Date accessed: 05/03/2011).

BBC (British Broadcasting Corporation). (24 January 2011). Report: Urgent Action Needed to Avert Global Hunger. Available from: http://www.bbc.co.uk (Date accessed: 05/03/2011).

BBC (British Broadcasting Corporation). (5 February 2011). State Multiculturalism Has Failed, Says David Cameron. Available from: http://www.bbc.co.uk (Date accessed: 05/03/2011).

Blaikie, P. (2000). Development, Post-, Anti-, and Populist: A Critical Review. *Environment and Planning A* 32, 1033-1050.

Beckford, C.L. (2002). Decision-Making and Innovation among Small-Scale Yam Farmers in Central Jamaica: A Dynamic, Pragmatic and Adaptive Process. *The Geographical Journal* 168 (3), 248-259.

Belsley, D.A., Kuh, E. and Welsch, R.E. (2004). *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. John Wiley & Sons, New Jersey.

Birch-Thomsen, T., Reenberg, A., Mertz, O., and Fog, B. (2010). Continuity and Change: Spatio-temporal Land Use Dynamics on Bellona Island, Solomon Islands. *Singapore Journal of Tropical Geography* 31 (1), 27–40.

Block, S.A. (1994). A New View of Agricultural Productivity in Sub-Saharan Africa. *American Journal of Agricultural Economics* 76 (3), 619-624.

Block, S. (2010). The Decline and Rise of Agricultural Productivity in Sub-Saharan Africa since 1961. National Bureau of Economic Research Working Paper No. 16481. Available from: http://www.nber.org/papers/w16481 (Date accessed: 11/11/2011).

Braun, N. (1998). On the role of public capital in production (PhD thesis). Department of Economics, University of Glasgow. Available from: http://theses.gla.ac.uk/1856/ (Date accessed: 28/08/2010).

Briggs, J. (2004). Agricultural Production in Eastern and Southern Africa: Issues and Challenges. In: D. Potts and T. Bowyer-Bower (editors). *Eastern and Southern Africa: Development Challenges in a Volatile Region*. Pearson Education, England.

Briggs, J. (2005). The use of indigenous knowledge in development: problems and challenges. *Progress in Development Studies* 5 (2), 99-114.

Briggs, J., Badri, M., and Mekki, A. M. (1999). Indigenous Knowledges and Vegetation Use among Bedouin in the Eastern Desert of Egypt. *Applied Geography* 19, 78-103.

Briggs, J., and Sharp, J. (2004). Indigenous knowledges and development: a postcolonial caution. *Third World Quarterly* 25 (4), 661-676.

Briggs, J., and Sharp, J. (2009). One Hundred Years Researching Egypt: From the Rule of Experts to Bedouin Voices? *Scottish Geographical Journal* 125 (3), 256-272.

Briggs, J. and Moyo, B. (2012). The Resilience of Indigenous Knowledge in Small-scale African Agriculture: Key Drivers. *Scottish Geographical Journal*, 1-17. doi: 10.1080/14702541.2012.694703.

Chambers, R. (2008). *Revolutions in Development Enquiry*. Earthscan, London.

Chirwa, E.W., and Zakeyo, C. (2006). Malawi. In: H. Thomas (editor). *Trade Reforms and Food Security: Country Case Studies and Synthesis*. FAO, Rome.

Craig, B.J., Pardey, P.G., and Roseboom, J. (1994). International Agricultural Productivity Patterns. CEFAP Working Paper No. WP94-1. University of Minnesota.

Craig, B.J., Pardey, P.G., and Roseboom, J. (1997). International Productivity Patterns: Accounting for Input Quality, Infrastructure, and Research. *American Journal of Agricultural Economics* 79, 1064–1076.

De Bondt, W., Muradoghu, G., Shefrin, H., and Staikorourad, S.K. (2008). Behavioral Finance: Quo Vadis? *Journal of Applied Finance* 19, 7-21.

Eriksen, C. (2007). Why do they burn the 'bush'? Fire, rural livelihoods, and conservation in Zambia. *The Geographical Journal* 173 (3), 242-256.

Escobar, A. (1995). *Encountering Development: The Making and Unmaking of the Third World*. Princeton University Press, Princeton.

Ethridge, D. (2004). *Research Methodology in Applied Economics*. Blackwell Publishing, Australia.

Fischer, G., van Velthuizen, H., Shah, M., and Nachtergaele, F. (2002). *Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results*. International Institute for Applied Systems Analysis, Laxenburg.

FAO (Food and Agriculture Organization of the United Nations). (2001). *The Economics of Soil Productivity in sub-Saharan Africa*. FAO, Rome.

FAO. (2011). *FAOSTAT Agricultural Data*. Available from: apps.fao.org (Date accessed: 14/01/2012).

GFU. (undated). Global Facilitation Unit for Underutilized Species website: http://www.underutilized-species.org (Date accessed: 13/01/2012).

Guan, Z., Kumbhakar, S.C., Myers, R.J., and Lansink, A.O. (2009). Measuring Excess Capital Capacity in Agricultural Production. *American Journal of Agricultural Economics* 91 (3), 765–776.

Gujarati, D.N. (2004). *Basic Econometrics*. 4th edition. The McGraw−Hill Companies, New Delhi.

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica* 46, 1251-71.

Hayami, Y., and Ruttan, V. W. (1971). *Agricultural Development: An International Perspective*. Baltimore: John Hopkins University Press.

Hill, P. (1966). A Plea for Indigenous Economics: The West African Example. *Economic Development and Cultural Change* 15 (1), 10-20.

Howitt, R., Havnen, O., and Veland, S. (2012). Natural and Unnatural Disasters: Responding with Respect for Indigenous Rights and Knowledges. *Geographical Research* 50 (1), 47-59.

Howitt, R., and Suchet, S. (2004). Rethinking the building blocks: management and indigenous epistemologies. University of Macquarie, Australia.

Jerven, M. (2009). The Relativity of Poverty and Income: How Reliable Are African Economic Statistics? *African Affairs* 109/434, 77-96.

Kazungu, K. (2009). Trade Liberalization and the Structure of Production in Tanzania (PhD thesis). Department of Economics, University of Glasgow. Available from: http://theses.gla.ac.uk/625/01/2009KhatibuPhD.pdf (Date accessed: 28/08/2010).

Kindred, D., Sylvester-Bradley, R., Garstang, J., Weightman, R., and Kilpatrick, J.. (2008). *Anticipated and Potential Improvements in Land Productivity and Increased Agricultural Inputs with Intensification*. A study commissioned by AEA Technology as part of the The Gallagher Biofuels Review for Renewable Fuels Agency, Department for Transport.

Kozanayi, W., and Frost, P. (2002). Marketing of Mopane Worm in Southern Zimbabwe. University of Zimbabwe, Harare. Available from: www.dfid.gov.uk/r4d/.../R7822_-_Mopane_Worm_Marketing.pdf (Date accessed: 13/01/2012).

Krätli, S. (2008). What Do Breeders Breed? On Pastoralists, Cattle and Unpredictability. *Journal of Agriculture and Environment for International Development* 102 (1/2), 123-139.

Lanning, G., and Mueller, M. (1979). *Africa Undermined: Mining Companies and the Underdevelopment of Africa*. Penguin Books, Harmondsworth.

Lee, D. J., and Zepeda, L. (2001). Agricultural Productivity and Natural Resource Depletion. In: L. Zepeda (editor). *Agricultural Investment and Productivity in Developing Countries*. FAO, Rome.

Lewis, K.A., and Tzilivakis, J. (1998). Evaluating a Technique Used to Measure Environmental Performance within Agriculture – Case Studies. *Eco-Management and Auditing* 5, 126-135.

Mertz, O., Bruun, T.B., Fog, B., Rasmussen, K., and Agergaard, J. (2010). Sustainable Land Use in Tikopia: Food Production and Consumption in Isolated Land Use Systems. *Singapore Journal of Tropical Geography* 31 (1), 10–26.

Mhango, J., and Dick, J. (2011). Analysis of Fertiliser Subsidy Programs and Ecosystem Services in Malawi. *Renewable Agriculture and Food Systems* 26 (3), 200-207.

Mkandawire, A.C. (1998). *Living My Destiny: A Medical and Historical Narrative*. Popular Publications, Limbe.

Moyo, B.H.Z. (2008). The Use and Role of Indigenous Knowledge in Small-scale Agricultural Systems in Africa: The Case of Farmers in Northern Malawi (PhD thesis). Department of Geographical and Earth Sciences, University of Glasgow. Available from: http://theses.gla.ac.uk/2022/ (Date accessed: 15/03/2011).

Moyo, B.H.Z. (2009). Indigenous Knowledge-Based Farming Practices: A Setting for the Contestation of Modernity, Development and Progress. *Scottish Geographical Journal* 125 (3-4), 353-360.

Moyo, B. (2010). *Incorporating Indigenous Knowledge into Agricultural Systems in Malawi: The Case of Farmers in Northern Malawi*. LAP LAMBERT Academic Publishing GmbH & Co. KG, Germany.

Moyo, B.H.Z. (5 January 2011). Unpublished Lecture Notes on Agriculture and Environment. Natural Resources Management Department, Bunda College of Agriculture, University of Malawi.

Mwale, M., Bhebhe, E., Chimonyo, M., and Tinyiko, E.H. (2005). Use of Herbal Plants in Poultry Health Management in the Mushagashe Small-scale Commercial Farming Area in Zimbabwe. *Intern J Appl Res Vet Med* 3 (2), 163-170.

Nation Newspaper. (21 February 2011). Development Aid and Conditionalities.

Nissanke, M.K. (2001). Financing Enterprise Development in sub-Saharan Africa. *Cambridge Journal of Economics* 25 (3), 343-367.

Patel, T. (2002). Indigenous Fertility Control. In: V. Desai and R.B. Potter (editors). *The Companion to Development Studies.* Arnold, London.

Redclift, M. (1995). *Sustainable Development: Exploring the contradictions*. Routledge, London and New York.

Rigby, D., and Caceres, D. (1997). The Sustainability of Agricultural Systems. Rural Resources/Rural Livelihoods Working Paper No. 10. Institute for Development Policy and Management, University of Manchester.

Riseth, J.A. (2007). An Indigenous Perspective on National Parks and Sami Reindeer Management in Norway. *The Geographical Research* 45 (2), 177-185.

Rizzi, J.W. (2008). Behavioral Basis of the Financial Crisis. *Journal of Applied Finance* 18 (2), 84-96.

Robinson, J. (2003). Postcolonialising Geography: Tactics and Pitfalls. *Singapore Journal of Tropical Geography* 24 (3), 273-289.

Rodney, W. (1972). *How Europe underdeveloped Africa*. Bogle-L'Ouverture Publications, London.

Sharma, M., and Zeller, M. (2000). Informal Markets: What Lessons Can We Learn From Them? International Food Policy Research Institute Policy Brief No. 8. In: M. Sharma (editor). *microFINANCE: A Pathway From Poverty*.

StataCorp LP. (2009a). Stata Base Reference Manual: Release 11. Stata Press, Texas.

StataCorp LP. (2009b). Stata User's Guide: Release 11. Stata Press, Texas.

Sullivan, S., and Homewood, K. (2004). Natural Resources: Use, Access, Tenure and Management. In: D. Potts and T. Bowyer-Bower (editors). *Eastern and Southern Africa: Development Challenges in a Volatile Region*. Pearson Education, England.

Tellis, W. (1997). Introduction to Case Study. *The Qualitative Report* 3 (2). Available from: http://www.nova.edu/ssss/QR/QR3-2/tellis1.html (Date accessed: 05/02/2010).

Tembo, F. (2003). Multiple identities, representations and categorisations: experiences in the study of people's life-worlds in rural Malawi. *Singapore Journal of Tropical Geography* 24 (2), 229-241.

Tietenberg, T. (2006). *Environmental and Natural Resource Economics*. 7th edition. Pearson Education, Addison Wesley.

Tijani, A.A., and Omodiagbe, K.F. (2006). Profitability of Indigenous Pest Control Methods: The Case of Cocoa Farmers in Osun State, Nigeria. *Uniswa Research Journal of Agriculture, Science and Technology* 9 (2), 140-148.

Toms, R. (2003). Worming your way to a sustainable harvest. [On-line]. *Spore 108*. Available from: spore.cta.int/images/stories/pdf/old/spore108.pdf (Date accessed: 15/01/2012).

Toms, R.B., Thagwana, M.P., and Lithole, K.D. (2003). The Mopane Worm – Indigenous Knowledge in the Classroom. [On-line]. Science in Africa (On-line Science Magazine). Available from: http://www.scienceinafrica.co.za/2003/june/mopane.htm (Date accessed: 15/01/2012).

United Nations. (2007). *Fighting climate change: human solidarity in a divided world.* Human Development Report 2007/2008. Palgrave Macmillan, Hampshire/New York.

United Nations. (2010). *The Real Wealth of Nations: Pathways to Human Development*. Human Development Report 2010. 20th Anniversary Edition. Palgrave Macmillan, Hampshire/New York.

Wiebe, K.D., Meredith, J.S., and Schimmelpfennig, D.E.. (2001). Agricultural Productivity for Sustainable Food Security in sub-Saharan Africa. In: L. Zepeda (editor). *Agricultural Investment and Productivity in Developing Countries.* FAO, Rome.

Wilmott, P. (2000). The Use, Misuse and Abuse of Mathematics in Finance. *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 358 (1765), 63-73. Available from: http://www.jstor.org/stable/2666776. (Date accessed: 20/08/2008).

WCED (World Commission on Environment and Development). (1987). *Our Common Future*. WCED Report. Oxford University Press, Oxford.

Wooldridge, J.M. (1999). *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, MA.

Velazco, J. (2001). Agricultural Production in Peru (1950-1995): Sources of Growth. In: L. Zepeda (editor). *Agricultural Investment and Productivity in Developing Countries.* FAO, Rome.

Vollrath, D. (2007). Land Distribution and International Agricultural Productivity. *American Journal of Agricultural Economics* 89 (1), 202–216. Available from: ajae.oxfordjournals.org (Date accessed: 15/02/ 2011).

Young, C. and Banda, H.K. (editors). (2008). *Our African Way of Life*. Central Africana Limited, Blantyre, Malawi.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association* 57 (298), 348-368.

Zepeda, L. (2001). Agricultural Investment, Production Capacity and Productivity. In: L. Zepeda (editor). *Agricultural Investment and Productivity in Developing Countries.* FAO, Rome.

Zerfu, D. (2002). The Macroeconomic Impact of HIV/AIDS in Ethiopia. Department of Economics, Addis Ababa University.

APPENDIX A

DATA FOR REGRESSION OUTLIER IDENTIFICATION AND AGRICULTURAL PRODUCTS AGGREGATION

Table A-1 Countries and years excluded from the sample for 1981-2005 panel data regression based on wheat unit output aggregation

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Botswana	1984	1989	1994	1999	2004
Gambia	1981	1986	1991	1996	2001
Jordan	1984	1989	1994	1999	2004
Lesotho	1981	1986	1991	1996	2001
Lesotho	1982	1987	1992	1997	2002
Lesotho	1983	1988	1993	1998	2003
Lesotho	1984	1989	1994	1999	2004
Lesotho	1985	1990	1995	2000	2005
Mauritius	1982	1987	1992	1997	2002
New Caledonia	1981	1986	1991	1996	2001
New Caledonia	1982	1987	1992	1997	2002
New Caledonia	1983	1988	1993	1998	2003
New Caledonia	1984	1989	1994	1999	2004
New Caledonia	1985	1990	1995	2000	2005
Nigeria	1982	1987	1992	1997	2002
Nigeria	1983	1988	1993	1998	2003
Nigeria	1984	1989	1994	1999	2004
Nigeria	1985	1990	1995	2000	2005
United Arab Emirates	1984	1989	1994	1999	2004
United Arab Emirates	1985	1990	1995	2000	2005
Zimbabwe	1982	1987	1992	1997	2002

Table A-2 Countries and years excluded from the sample for 1981-2005 panel data regression based on tonnage output aggregation

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Albania	1981	1986	1991	1996	2001
Botswana	1984	1989	1994	1999	2004
Cape Verde	1983	1988	1993	1998	2003
Cuba	1981	1986	1991	1996	2001
Cyprus	1982	1987	1992	1997	2002
Cyprus	1983	1988	1993	1998	2003
Fiji	1981	1986	1991	1996	2001
Guyana	1981	1986	1991	1996	2001
Guyana	1982	1987	1992	1997	2002
Guyana	1983	1988	1993	1998	2003
Guyana	1984	1989	1994	1999	2004
Guyana	1985	1990	1995	2000	2005
Lesotho	1981	1986	1991	1996	2001
Lesotho	1982	1987	1992	1997	2002
Lesotho	1983	1988	1993	1998	2003
Lesotho	1984	1989	1994	1999	2004
Lesotho	1985	1990	1995	2000	2005
Libya	1983	1988	1993	1998	2003
Mauritius	1981	1986	1991	1996	2001
Mauritius	1982	1987	1992	1997	2002
Mauritius	1983	1988	1993	1998	2003
Mauritius	1984	1989	1994	1999	2004
Mauritius	1985	1990	1995	2000	2005
New Caledonia	1981	1986	1991	1996	2001
New Caledonia	1982	1987	1992	1997	2002
New Caledonia	1983	1988	1993	1998	2003
New Caledonia	1984	1989	1994	1999	2004
New Caledonia	1985	1990	1995	2000	2005
Portugal	1981	1986	1991	1996	2001
Saint Kitts and Nevis	1982	1987	1992	1997	2002
Saint Kitts and Nevis	1984	1989	1994	1999	2004
Seychelles	1985	1990	1995	2000	2005
Swaziland	1981	1986	1991	1996	2001
Swaziland	1982	1987	1992	1997	2002
Swaziland	1983	1988	1993	1998	2003
Swaziland	1984	1989	1994	1999	2004
Swaziland	1985	1990	1995	2000	2005
United Arab Emirates	1984	1989	1994	1999	2004
United Arab Emirates	1985	1990	1995	2000	2005
Uruguay	1983	1988	1993	1998	2003
Uruguay	1985	1990	1995	2000	2005
Zimbabwe	1982	1987	1992	1997	2002

Table A-3 Countries and years excluded from the sample for 1981-2005 panel data regression based on FAO's (2011) international dollar output aggregation

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Angola	1985	1990	1995	2000	2005
Argentina	1985	1990	1995	2000	2005
Australia	1983	1988	1993	1998	2003
Botswana	1981	1986	1991	1996	2001
Chile	1983	1988	1993	1998	2003
Côte d'Ivoire	1981	1986	1991	1996	2001
Côte d'Ivoire	1982	1987	1992	1997	2002
Côte d'Ivoire	1983	1988	1993	1998	2003
Côte d'Ivoire	1984	1989	1994	1999	2004
Côte d'Ivoire	1985	1990	1995	2000	2005
Fiji	1981	1986	1991	1996	2001
Fiji	1983	1988	1993	1998	2003
Gambia	1981	1986	1991	1996	2001
Gambia	1982	1987	1992	1997	2002
Gambia	1983	1988	1993	1998	2003
Gambia	1985	1990	1995	2000	2005
Guyana	1981	1986	1991	1996	2001
Honduras	1982	1987	1992	1997	2002
Israel	1984	1989	1994	1999	2004
Israel	1985	1990	1995	2000	2005
Lao People's Democratic Republic	1983	1988	1993	1998	2003
Lesotho	1981	1986	1991	1996	2001
Lesotho	1982	1987	1992	1997	2002
Lesotho	1983	1988	1993	1998	2003
Lesotho	1984	1989	1994	1999	2004
Lesotho	1985	1990	1995	2000	2005
Mauritius	1982	1987	1992	1997	2002
Mozambique	1982	1987	1992	1997	2002
Mozambique	1984	1989	1994	1999	2004
Mozambique	1985	1990	1995	2000	2005
Myanmar	1984	1989	1994	1999	2004
New Caledonia	1981	1986	1991	1996	2001
New Caledonia	1982	1987	1992	1997	2002
New Caledonia	1983	1988	1993	1998	2003
New Caledonia	1984	1989	1994	1999	2004
New Caledonia	1985	1990	1995	2000	2005

(continued)

Table A-3 Countries and years excluded from the sample for 1981-2005 panel data regression based on FAO's (2011) international dollar output aggregation (continued)

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Nigeria	1981	1986	1991	1996	2001
Nigeria	1982	1987	1992	1997	2002
Nigeria	1983	1988	1993	1998	2003
Nigeria	1984	1989	1994	1999	2004
Nigeria	1985	1990	1995	2000	2005
Samoa	1982	1987	1992	1997	2002
Senegal	1982	1987	1992	1997	2002
Seychelles	1985	1990	1995	2000	2005
United Arab Emirates	1984	1989	1994	1999	2004
United Arab Emirates	1985	1990	1995	2000	2005
Yemen	1982	1987	1992	1997	2002
Yemen	1984	1989	1994	1999	2004
Yemen	1985	1990	1995	2000	2005
Zambia	1982	1987	1992	1997	2002
Zimbabwe	1981	1986	1991	1996	2001
Zimbabwe	1982	1987	1992	1997	2002
Zimbabwe	1983	1988	1993	1998	2003
Zimbabwe	1984	1989	1994	1999	2004
Zimbabwe	1985	1990	1995	2000	2005

Table A-4 Countries and years excluded from the sample for 1961-2005 panel data regression based on wheat unit output aggregation

Country	1961-65	1966-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05
Botswana	1961	1966	1971	1976	1981	1986	1991	1996	2001
Botswana	1962	1967	1972	1977	1982	1987	1992	1997	2002
Botswana	1963	1968	1973	1978	1983	1988	1993	1998	2003
Botswana	1964	1969	1974	1979	1984	1989	1994	1999	2004
Botswana	1965	1970	1975	1980	1985	1990	1995	2000	2005
Cape Verde	1963	1968	1973	1978	1983	1988	1993	1998	2003
Cape Verde	1964	1969	1974	1979	1984	1989	1994	1999	2004
Democratic Republic of the Congo	1961	1966	1971	1976	1981	1986	1991	1996	2001
Democratic Republic of the Congo	1962	1967	1972	1977	1982	1987	1992	1997	2002
Democratic Republic of the Congo	1963	1968	1973	1978	1983	1988	1993	1998	2003
Democratic Republic of the Congo	1964	1969	1974	1979	1984	1989	1994	1999	2004
Democratic Republic of the Congo	1965	1970	1975	1980	1985	1990	1995	2000	2005
Gambia	1961	1966	1971	1976	1981	1986	1991	1996	2001
Ghana	1961	1966	1971	1976	1981	1986	1991	1996	2001
Ghana	1962	1967	1972	1977	1982	1987	1992	1997	2002
Lesotho	1961	1966	1971	1976	1981	1986	1991	1996	2001
Lesotho	1962	1967	1972	1977	1982	1987	1992	1997	2002
Lesotho	1963	1968	1973	1978	1983	1988	1993	1998	2003
Mauritania	1961	1966	1971	1976	1981	1986	1991	1996	2001
Mauritania	1962	1967	1972	1977	1982	1987	1992	1997	2002
Mauritania	1963	1968	1973	1978	1983	1988	1993	1998	2003
Mauritania	1964	1969	1974	1979	1984	1989	1994	1999	2004
Mauritania	1965	1970	1975	1980	1985	1990	1995	2000	2005
Mongolia	1963	1968	1973	1978	1983	1988	1993	1998	2003

(continued)

Table A-4 Countries and years excluded from the sample for 1961-2005 panel data regression based on wheat unit output aggregation (continued)

Country	1961-65	1966-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05
Namibia	1961	1966	1971	1976	1981	1986	1991	1996	2001
Namibia	1962	1967	1972	1977	1982	1987	1992	1997	2002
Namibia	1963	1968	1973	1978	1983	1988	1993	1998	2003
Namibia	1964	1969	1974	1979	1984	1989	1994	1999	2004
Namibia	1965	1970	1975	1980	1985	1990	1995	2000	2005
New Caledonia	1965	1970	1975	1980	1985	1990	1995	2000	2005
Nigeria	1961	1966	1971	1976	1981	1986	1991	1996	2001
Nigeria	1962	1967	1972	1977	1982	1987	1992	1997	2002
Nigeria	1963	1968	1973	1978	1983	1988	1993	1998	2003
Nigeria	1964	1969	1974	1979	1984	1989	1994	1999	2004
Nigeria	1965	1970	1975	1980	1985	1990	1995	2000	2005
Sweden	1961	1966	1971	1976	1981	1986	1991	1996	2001
Sweden	1962	1967	1972	1977	1982	1987	1992	1997	2002
Sweden	1963	1968	1973	1978	1983	1988	1993	1998	2003

Table A-5 Crop products and their wheat relative prices or weights for aggregation: wheat relative prices per metric tonne

FAO Code	Item	Weight	FAO Code	Item	Weight
800	Agave Fibres Nes	6.847	108	Cereals, nes	2.940
221	Almonds, with shell	12.554	531	Cherries	11.687
711	Anise, badian, fennel, corian.	6.124	220	Chestnuts	10.867
515	Apples	2.912	191	Chick peas	2.948
526	Apricots	5.184	459	Chicory roots	4.287
226	Arecanuts	3.010	689	Chillies and peppers, dry	7.824
366	Artichokes	4.769	401	Chillies and peppers, green	5.468
367	Asparagus	15.163	693	Cinnamon (canella)	10.277
572	Avocados	6.345	512	Citrus fruit, nes	3.051
203	Bambara beans	4.650	698	Cloves	21.893
486	Bananas	1.626	661	Cocoa beans	10.232
44	Barley	0.894	249	Coconuts	1.344
176	Beans, dry	3.009	656	Coffee, green	13.061
414	Beans, green	4.795	813	Coir	1.401
558	Berries Nes	9.091	195	Cow peas, dry	3.099
552	Blueberries	10.371	554	Cranberries	9.776
216	Brazil nuts, with shell	6.834	397	Cucumbers and gherkins	3.488
181	Broad beans, horse beans, dry	1.789	550	Currants	6.956
89	Buckwheat	1.559	577	Dates	3.531
358	Cabbages and other brassicas	2.330	399	Eggplants (aubergines)	3.761
101	Canary seed	2.298	821	Fibre Crops Nes	2.198
461	Carobs	3.241	569	Figs	7.726
426	Carrots and turnips	1.914	773	Flax fibre and tow	9.439
217	Cashew nuts, with shell	4.228	94	Fonio	0.941
591	Cashewapple	0.000	619	Fruit Fresh Nes	3.484
125	Cassava	3.861	603	Fruit, tropical fresh nes	3.139
265	Castor oil seed	1.981	406	Garlic	4.635
393	Cauliflowers and broccoli	3.299	720	Ginger	4.513

(continued)

Table A-5 Crop products and their wheat relative prices or weights for aggregation: wheat relative prices per metric tonne (continued)

FAO Code	Item	Weight	FAO Code	Item	Weight
549	Gooseberries	5.467	103	Mixed grain	2.788
507	Grapefruit (inc. pomelos)	2.585	449	Mushrooms and truffles	17.273
560	Grapes	4.912	292	Mustard seed	2.426
242	Groundnuts, with shell	4.476	836	Natural rubber	7.270
839	Gums Natural	12.798	702	Nutmeg, mace and cardamoms	24.038
225	Hazelnuts, with shell	9.744	234	Nuts, nes	15.733
777	Hemp Tow Waste	5.182	75	Oats	0.849
336	Hempseed	4.024	254	Oil palm fruit	0.000
677	Hops	34.509	339	Oilseeds, Nes	4.000
780	Jute	2.073	430	Okra	3.182
778	Kapok Fibre	3.474	260	Olives	7.343
311	Kapokseed in Shell	3.059	402	Onions (inc. shallots), green	2.391
263	Karite Nuts (Sheanuts)	1.602	403	Onions, dry	1.495
592	Kiwi fruit	9.940	490	Oranges	2.416
224	Kolanuts	1.690	782	Other Bastfibres	2.497
420	Leguminous vegetables, nes	3.472	568	Other melons (inc.cantaloupes)	2.591
497	Lemons and limes	2.893	600	Papayas	4.084
201	Lentils	2.858	534	Peaches and nectarines	4.799
372	Lettuce and chicory	4.774	521	Pears	3.479
333	Linseed	1.879	187	Peas, dry	1.828
210	Lupins	1.388	417	Peas, green	3.582
56	Maize	0.852	687	Pepper (Piper spp.)	14.424
446	Maize, green	4.377	748	Peppermint	15.589
571	Mangoes, mangosteens, guavas	3.822	587	Persimmons	6.224
809	Manila Fibre (Abaca)	4.778	197	Pigeon peas	3.068
671	Maté	5.439	574	Pineapples	2.021
299	Melonseed	3.385	223	Pistachios	23.751
79	Millet	1.237	489	Plantains	1.460

(continued)

Table A-5 Crop products and their wheat relative prices or weights for aggregation: wheat relative prices per metric tonne (continued)

FAO Code	Item	Weight	FAO Code	Item	Weight
536	Plums and sloes	4.209	156	Sugar cane	0.895
68	Popcorn	0.000	161	Sugar crops, nes	6.508
296	Poppy seed	6.470	267	Sunflower seed	2.253
116	Potatoes	1.241	122	Sweet potatoes	1.850
211	Pulses, nes	2.219	495	Tangerines, mandarins, clem.	3.448
394	Pumpkins, squash and gourds	3.246	136	Taro (cocoyam)	3.288
754	Pyrethrum, Dried	16.663	667	Tea	12.951
523	Quinces	2.852	826	Tobacco, unmanufactured	18.344
92	Quinoa	6.217	388	Tomatoes	4.212
788	Ramie	15.761	97	Triticale	1.469
270	Rapeseed	1.934	275	Tung Nuts	0.000
547	Raspberries	9.769	692	Vanilla	228.155
27	Rice, paddy	1.650	463	Vegetables fresh nes	3.237
149	Roots and Tubers, nes	3.135	205	Vetches	1.281
71	Rye	0.821	222	Walnuts, with shell	10.845
280	Safflower seed	2.210	567	Watermelons	1.535
328	Seed cotton	0.000	15	Wheat	1.000
289	Sesame seed	4.568	137	Yams	3.628
789	Sisal	3.112	135	Yautia (cocoyam)	2.306
83	Sorghum	0.749			
530	Sour cherries	4.708			
236	Soybeans	1.574			
723	Spices, nes	11.173			
373	Spinach	3.385			
541	Stone fruit, nes	3.882			
544	Strawberries	10.228			
423	String beans	5.050			
157	Sugar beet	0.308			

Table A-6 Livestock products and their wheat relative prices or weights for aggregation: wheat relative prices per metric tonne

FAO Code	Item	Weight
1183	Beeswax	21.650
1089	Bird meat, nes	41.509
957	Buffalo Hide	5.024
947	Buffalo meat	8.037
951	Buffalo milk, whole, fresh	1.989
1127	Camel meat	14.837
1130	Camel milk, whole, fresh	2.116
919	Cattle Hides	9.632
867	Cattle meat	16.122
1058	Chicken meat	8.059
882	Cow milk, whole, fresh	2.306
1069	Duck meat	14.070
1163	Game meat	25.833
1017	Goat meat	13.836
1020	Goat milk, whole, fresh	1.928
1025	Goatskins	15.483
1073	Goose and guinea fowl meat	17.521
1100	Hair of Horses	24.107
1062	Hen eggs, in shell	7.319
1182	Honey, natural	8.106
1097	Horse meat	13.231
1166	Meat nes	17.950
1108	Meat of Asses	5.010
1111	Meat of Mules	4.219
1151	Meat of Other Rod	2.893
1158	Meat of Camelids	7.314
1167	Offals, Nes	8.009
1091	Other bird eggs, in shell	23.781
1035	Pig meat	13.333
1141	Rabbit meat	16.673
977	Sheep meat	13.492
982	Sheep milk, whole, fresh	1.229
995	Sheepskins	11.723
1185	Silk-worm cocoons, reelable	128.786
999	Skins With Wool Sheep	11.723
1080	Turkey meat	11.769
987	Wool, greasy	17.872

Table A-7 Feed products and their wheat relative prices or weights for aggregation: wheat relative prices per metric tonne

FAO Code	Item	Weight	FAO Code	Item	Weight
2617	Apples	2.912	2570	Oilcrops, Other	4.000
2615	Bananas	1.626	2598	Oilseed Cakes, Other	0.739
2513	Barley	0.894	2580	Olive Oil	14.545
2546	Beans	3.009	2602	Onions	1.495
2731	Bovine Meat	16.122	2611	Oranges, Mandarines	2.416
2600	Brans	0.643	2577	Palm Oil	2.959
2740	Butter, Ghee	14.543	2595	Palmkernel Cake	0.620
2532	Cassava	3.861	2576	Palmkernel Oil	3.573
2520	Cereals, Other	2.940	2562	Palmkernels	1.623
2741	Cheese	19.505	2547	Peas	1.828
2633	Cocoa Beans	10.232	2616	Plantains	1.460
2578	Coconut Oil	3.707	2531	Potatoes	1.241
2560	Coconuts - Incl Copra	1.344	2734	Poultry Meat	8.936
2596	Copra Cake	0.671	2549	Pulses, Other	2.219
2661	Cotton Lint	8.782	2593	Rape and Mustard Cake	0.866
2559	Cottonseed	1.078	2574	Rape and Mustard Oil	3.783
2594	Cottonseed Cake	0.826	2558	Rape and Mustardseed	1.949
2575	Cottonseed Oil	3.792	2805	Rice (Milled Equivalent)	1.650
2619	Dates	3.531	2534	Roots, Other	3.135
2744	Eggs	7.319	2515	Rye	0.821
2737	Fats, Animals, Raw	3.175	2561	Sesameseed	4.568
2625	Fruits, Other	3.484	2597	Sesameseed Cake	1.119
2613	Grapefruit	2.585	2579	Sesameseed Oil	12.687
2620	Grapes	4.912	2664	Soft-Fibres, Other	2.198
2591	Groundnut Cake	1.045	2518	Sorghum	0.749
2572	Groundnut Oil	5.522	2590	Soyabean Cake	1.363
2820	Groundnuts (in Shell Eq)	4.476	2571	Soyabean Oil	3.558
2556	Groundnuts (Shelled Eq)	4.476	2555	Soyabeans	1.574
2745	Honey	8.106	2537	Sugar Beet	0.308
2514	Maize	0.852	2536	Sugar Cane	0.895
2749	Meat Meal	1.687	2827	Sugar, Raw Equivalent	2.094
2735	Meat, Other	17.950	2557	Sunflowerseed	2.253
2848	Milk - Excluding Butter	2.306	2592	Sunflowerseed Cake	0.755
2739	Milk, Skimmed	9.266	2573	Sunflowerseed Oil	4.014
2738	Milk, Whole	2.518	2533	Sweet Potatoes	1.850
2517	Millet	1.237	2635	Tea	12.951
2544	Molasses	0.397	2601	Tomatoes	4.212
2732	Mutton & Goat Meat	13.492	2605	Vegetables, Other	3.237
2516	Oats	0.849	2511	Wheat	1.000
2736	Offals, Edible	7.205	2742	Whey	3.768
2586	Oilcrops Oil, Other	4.712	2535	Yams	3.628

Table A-8 Cow equivalent units for aggregating livestock

FAO Code	Livestock	Cow equivalent of a single animal
1171	Animals Live Nes	0.000
1107	Asses	1.000
1181	Beehives	0.000
946	Buffaloes	1.250
1126	Camels	1.389
866	Cattle	1.000
1057	Chickens	0.013
1068	Ducks	0.013
1072	Geese and guinea fowls	0.013
1016	Goats	0.125
1096	Horses	1.250
1110	Mules	1.250
1157	Other Camelids	0.000
1150	Other Rodents	0.000
1034	Pigs	0.250
976	Sheep	0.125
1079	Turkeys	0.013

APPENDIX B

COLLINEARITY DIAGNOSTICS

Table B-1 Condition indices and variance-decomposition proportions for 1981-1985 regression data with 599-observation cross-sections (corresponding to Table 4.7).

Condition index	Constant	Int Dummy	HI Dummy	Ln Land	Ln Fertilizer	Ln Tractors	Ln Labour	Ln Livestock	Ln Land (Int)	Ln Fertilizer (Int)
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.36	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
17.15	0.00	0.03	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.01
21.44	0.01	0.00	0.00	0.00	0.30	0.04	0.00	0.00	0.00	0.01
25.31	0.00	0.03	0.01	0.00	0.25	0.02	0.01	0.00	0.00	0.00
31.91	0.00	0.07	0.02	0.00	0.08	0.00	0.00	0.00	0.00	0.04
41.28	0.03	0.00	0.01	0.00	0.01	0.36	0.01	0.01	0.00	0.03
50.41	0.03	0.01	0.05	0.12	0.00	0.00	0.05	0.01	0.00	0.01
53.85	0.01	0.05	0.00	0.00	0.03	0.06	0.00	0.01	0.01	0.73
68.26	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.06	0.03	0.00
76.39	0.00	0.00	0.01	0.02	0.03	0.01	0.00	0.01	0.00	0.01
81.92	0.02	0.01	0.01	0.18	0.01	0.04	0.01	0.26	0.16	0.07
101.61	0.17	0.20	0.03	0.21	0.03	0.32	0.01	0.06	0.10	0.01
125.57	0.18	0.32	0.00	0.13	0.05	0.03	0.19	0.04	0.41	0.00
140.43	0.51	0.27	0.74	0.02	0.16	0.05	0.52	0.02	0.07	0.06
179.36	0.00	0.00	0.08	0.30	0.01	0.05	0.18	0.53	0.21	0.01

Variance-decomposition proportions are those of the regression coefficients of the variables listed in the first row (Belsley *et al.*, 2004).
HI and Int denote high external input and intermediate countries, respectively.
Columns may not add to unity due to rounding error.

(continued)

Table B-1 Condition indices and variance-decomposition proportions for 1981-1985 regression data with 599-observation cross-sections (corresponding to Table 4.7). (continued)

Condition index	Ln Tractors (Int)	Ln Labour (Int)	Ln Livestock (Int)	Ln Land (HI)	Ln Fertilizer (HI)	Ln Tractors (HI)	Ln Labour (HI)	Ln Livestock (HI)	P Dummy	N Dummy
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.21
3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.16
4.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.52
12.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
17.15	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
21.44	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
25.31	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.00
31.91	0.04	0.04	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.01
41.28	0.01	0.04	0.00	0.01	0.00	0.03	0.04	0.00	0.00	0.00
50.41	0.11	0.00	0.01	0.02	0.01	0.11	0.01	0.00	0.00	0.00
53.85	0.07	0.04	0.02	0.00	0.01	0.01	0.02	0.00	0.01	0.01
68.26	0.20	0.11	0.06	0.17	0.01	0.09	0.08	0.00	0.00	0.01
76.39	0.00	0.01	0.00	0.02	0.92	0.22	0.01	0.01	0.03	0.00
81.92	0.06	0.00	0.02	0.01	0.01	0.14	0.04	0.02	0.01	0.00
101.61	0.31	0.08	0.17	0.22	0.00	0.22	0.02	0.00	0.02	0.00
125.57	0.11	0.06	0.28	0.00	0.00	0.07	0.30	0.11	0.00	0.00
140.43	0.03	0.44	0.07	0.12	0.02	0.03	0.16	0.20	0.04	0.04
179.36	0.03	0.17	0.37	0.41	0.00	0.00	0.26	0.66	0.00	0.02

Table B-2 Condition indices and variance-decomposition proportions for 1986-1990 regression data with 599-observation cross-sections (corresponding to Table 4.7).

Condition index	Constant	HI Dummy	Ln Land	Ln Fertilizer	Ln Tractors	Ln Labour	Ln Livestock	Ln Land (Int)	Ln Fertilizer (Int)	Ln Tractors (Int)
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.36	0.02	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
19.41	0.00	0.03	0.00	0.03	0.02	0.01	0.00	0.00	0.00	0.02
21.63	0.02	0.00	0.00	0.32	0.03	0.00	0.00	0.00	0.02	0.01
28.15	0.01	0.03	0.00	0.10	0.01	0.01	0.00	0.00	0.00	0.03
39.52	0.02	0.00	0.02	0.09	0.14	0.01	0.00	0.00	0.33	0.02
41.46	0.09	0.04	0.00	0.26	0.19	0.01	0.00	0.00	0.17	0.08
49.37	0.08	0.06	0.11	0.00	0.00	0.05	0.00	0.00	0.14	0.04
63.63	0.02	0.04	0.00	0.00	0.06	0.08	0.01	0.01	0.01	0.32
68.75	0.39	0.07	0.01	0.04	0.20	0.06	0.06	0.07	0.18	0.00
78.47	0.08	0.00	0.14	0.00	0.01	0.00	0.18	0.07	0.02	0.04
84.38	0.09	0.00	0.04	0.08	0.01	0.00	0.16	0.06	0.05	0.03
108.65	0.02	0.02	0.31	0.00	0.23	0.38	0.02	0.26	0.02	0.28
128.51	0.16	0.55	0.07	0.04	0.05	0.12	0.04	0.31	0.04	0.09
172.31	0.01	0.11	0.29	0.02	0.04	0.27	0.53	0.20	0.02	0.03

Variance-decomposition proportions are those of the regression coefficients of the variables listed in the first row (Belsley *et al.*, 2004).
HI and Int denote high external input and intermediate countries, respectively.
Columns may not add to unity due to rounding error.

(continued)

Table B-2 Condition indices and variance-decomposition proportions for 1986-1990 regression data with 599-observation cross-sections (corresponding to Table 4.7). (continued)

Condition index	Ln Labour (Int)	Ln Livestock (Int)	Ln Land (HI)	Ln Fertilizer (HI)	Ln Tractors (HI)	Ln Labour (HI)	Ln Livestock (HI)	P Dummy	N Dummy
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.22
3.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.24
4.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.48
12.36	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
19.41	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.63	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
28.15	0.01	0.00	0.00	0.00	0.04	0.07	0.00	0.01	0.01
39.52	0.04	0.00	0.01	0.00	0.01	0.02	0.00	0.00	0.01
41.46	0.03	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00
49.37	0.02	0.01	0.03	0.00	0.12	0.01	0.00	0.01	0.00
63.63	0.11	0.11	0.06	0.00	0.00	0.14	0.00	0.01	0.00
68.75	0.01	0.00	0.12	0.00	0.28	0.01	0.00	0.06	0.01
78.47	0.02	0.02	0.03	0.36	0.01	0.00	0.03	0.01	0.00
84.38	0.00	0.00	0.02	0.61	0.24	0.10	0.00	0.00	0.00
108.65	0.31	0.03	0.21	0.01	0.20	0.29	0.00	0.00	0.00
128.51	0.19	0.38	0.10	0.00	0.08	0.00	0.32	0.01	0.02
172.31	0.24	0.43	0.40	0.01	0.00	0.34	0.65	0.00	0.01

Table B-3 Condition indices and variance-decomposition proportions for 1991-1995 regression data with 599-observation cross-sections (corresponding to Table 4.7).

Condition index	Constant	HI Dummy	Ln Land	Ln Fertilizer	Ln Tractors	Ln Labour	Ln Livestock	Ln Land (Int)	Ln Fertilizer (Int)	Ln Tractors (Int)
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.43	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
19.35	0.00	0.03	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.02
20.64	0.01	0.00	0.00	0.28	0.04	0.00	0.00	0.00	0.01	0.02
28.96	0.01	0.03	0.00	0.06	0.01	0.01	0.00	0.00	0.00	0.02
37.22	0.00	0.00	0.03	0.12	0.08	0.00	0.00	0.00	0.38	0.04
40.94	0.06	0.04	0.00	0.16	0.25	0.02	0.00	0.00	0.13	0.07
48.95	0.09	0.07	0.12	0.01	0.00	0.03	0.00	0.00	0.17	0.04
60.46	0.01	0.03	0.00	0.00	0.05	0.07	0.01	0.02	0.00	0.32
68.68	0.21	0.07	0.03	0.03	0.21	0.06	0.01	0.14	0.23	0.00
72.04	0.01	0.01	0.02	0.03	0.01	0.00	0.02	0.00	0.01	0.01
81.06	0.32	0.00	0.09	0.14	0.00	0.00	0.39	0.08	0.02	0.07
106.36	0.01	0.01	0.42	0.01	0.27	0.34	0.00	0.33	0.02	0.29
123.19	0.24	0.58	0.04	0.07	0.03	0.20	0.02	0.25	0.01	0.07
163.26	0.00	0.13	0.25	0.00	0.03	0.25	0.54	0.17	0.01	0.02

Variance-decomposition proportions are those of the regression coefficients of the variables listed in the first row (Belsley *et al.*, 2004).
HI and Int denote high external input and intermediate countries, respectively.
Columns may not add to unity due to rounding error.

(continued)

Table B-3 Condition indices and variance-decomposition proportions for 1991-1995 regression data with 599-observation cross-sections (corresponding to Table 4.7). (continued)

Condition index	Ln Labour (Int)	Ln Livestock (Int)	Ln Land (HI)	Ln Fertilizer (HI)	Ln Tractors (HI)	Ln Labour (HI)	Ln Livestock (HI)	P Dummy	N Dummy
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.23
3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.20
4.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.48
12.43	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
19.35	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
20.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
28.96	0.01	0.00	0.00	0.00	0.04	0.10	0.00	0.02	0.01
37.22	0.03	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.02
40.94	0.03	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00
48.95	0.04	0.01	0.03	0.00	0.15	0.01	0.00	0.02	0.00
60.46	0.09	0.12	0.06	0.00	0.00	0.14	0.00	0.00	0.01
68.68	0.00	0.01	0.14	0.00	0.32	0.01	0.00	0.07	0.00
72.04	0.01	0.01	0.05	0.89	0.14	0.01	0.01	0.01	0.01
81.06	0.00	0.01	0.02	0.06	0.04	0.07	0.03	0.01	0.00
106.36	0.25	0.01	0.21	0.00	0.23	0.30	0.00	0.00	0.00
123.19	0.27	0.43	0.09	0.03	0.05	0.01	0.29	0.01	0.01
163.26	0.24	0.40	0.36	0.00	0.00	0.33	0.67	0.00	0.01

Table B-4 Condition indices and variance-decomposition proportions for 1996-2000 regression data with 599-observation cross-sections (corresponding to Table 4.7).

Condition index	Constant	HI Dummy	Ln Land	Ln Fertilizer	Ln Tractors	Ln Labour	Ln Livestock	Ln Land (Int)	Ln Fertilizer (Int)	Ln Tractors (Int)
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.56	0.02	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
19.48	0.00	0.02	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.05
21.33	0.02	0.00	0.00	0.46	0.02	0.00	0.00	0.00	0.01	0.01
29.29	0.03	0.02	0.00	0.04	0.01	0.03	0.00	0.00	0.00	0.02
37.44	0.00	0.00	0.05	0.09	0.17	0.01	0.00	0.01	0.16	0.03
39.62	0.09	0.08	0.01	0.16	0.18	0.01	0.00	0.00	0.14	0.15
50.48	0.11	0.05	0.09	0.00	0.00	0.02	0.00	0.00	0.32	0.00
59.23	0.01	0.02	0.00	0.01	0.07	0.09	0.00	0.04	0.04	0.38
64.7	0.09	0.01	0.02	0.04	0.09	0.04	0.00	0.09	0.10	0.00
69.17	0.08	0.06	0.00	0.03	0.15	0.02	0.01	0.04	0.19	0.02
76.27	0.27	0.01	0.08	0.10	0.00	0.00	0.33	0.08	0.01	0.05
100.22	0.00	0.00	0.42	0.00	0.23	0.29	0.00	0.39	0.03	0.26
114.79	0.28	0.60	0.00	0.03	0.01	0.24	0.00	0.12	0.00	0.02
159.53	0.00	0.10	0.33	0.03	0.03	0.26	0.65	0.21	0.00	0.02

Variance-decomposition proportions are those of the regression coefficients of the variables listed in the first row (Belsley *et al.*, 2004).
HI and Int denote high external input and intermediate countries, respectively.
Columns may not add to unity due to rounding error.

(continued)

Table B-4 Condition indices and variance-decomposition proportions for 1996-2000 regression data with 599-observation cross-sections (corresponding to Table 4.7). (continued)

Condition index	Ln Labour (Int)	Ln Livestock (Int)	Ln Land (HI)	Ln Fertilizer (HI)	Ln Tractors (HI)	Ln Labour (HI)	Ln Livestock (HI)	P Dummy	N Dummy
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.26
3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.23
4.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.43
12.56	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
19.48	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.33	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
29.29	0.01	0.00	0.00	0.00	0.04	0.14	0.00	0.01	0.01
37.44	0.05	0.00	0.02	0.00	0.00	0.02	0.00	0.02	0.03
39.62	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01
50.48	0.08	0.00	0.03	0.00	0.21	0.01	0.00	0.04	0.00
59.23	0.05	0.11	0.04	0.00	0.00	0.18	0.00	0.00	0.00
64.7	0.00	0.01	0.21	0.35	0.08	0.03	0.00	0.01	0.00
69.17	0.00	0.00	0.00	0.60	0.42	0.00	0.00	0.07	0.01
76.27	0.01	0.03	0.04	0.00	0.01	0.02	0.05	0.00	0.00
100.22	0.17	0.00	0.16	0.00	0.22	0.30	0.04	0.00	0.00
114.79	0.33	0.40	0.15	0.02	0.02	0.05	0.29	0.02	0.01
159.53	0.25	0.45	0.33	0.01	0.00	0.25	0.61	0.01	0.00

Table B-5 Condition indices and variance-decomposition proportions for 2001-2005 regression data with 599-observation cross-sections (corresponding to Table 4.7).

Condition index	Constant	HI Dummy	Ln Land	Ln Fertilizer	Ln Tractors	Ln Labour	Ln Livestock	Ln Land (Int)	Ln Fertilizer (Int)	Ln Tractors (Int)
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.51	0.02	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
19.17	0.00	0.02	0.00	0.01	0.03	0.01	0.00	0.00	0.00	0.05
22.62	0.02	0.00	0.00	0.37	0.03	0.00	0.00	0.00	0.02	0.02
28.97	0.03	0.02	0.00	0.02	0.01	0.03	0.00	0.00	0.00	0.03
36.05	0.02	0.01	0.04	0.05	0.28	0.01	0.00	0.01	0.06	0.00
40.91	0.08	0.07	0.03	0.22	0.09	0.00	0.00	0.00	0.25	0.24
47.21	0.16	0.06	0.10	0.00	0.01	0.00	0.00	0.01	0.37	0.00
56.51	0.02	0.02	0.00	0.01	0.07	0.08	0.00	0.07	0.11	0.36
60.74	0.04	0.00	0.01	0.07	0.03	0.05	0.00	0.06	0.00	0.00
64.89	0.07	0.04	0.00	0.03	0.22	0.03	0.01	0.04	0.13	0.05
76.74	0.32	0.01	0.10	0.11	0.00	0.00	0.30	0.06	0.01	0.01
96.69	0.00	0.00	0.44	0.02	0.16	0.30	0.01	0.41	0.04	0.20
113.64	0.23	0.58	0.01	0.00	0.02	0.20	0.01	0.16	0.00	0.02
162.84	0.01	0.15	0.29	0.07	0.02	0.29	0.67	0.17	0.00	0.01

Variance-decomposition proportions are those of the regression coefficients of the variables listed in the first row (Belsley *et al.*, 2004).
HI and Int denote high external input and intermediate countries, respectively.
Columns may not add to unity due to rounding error.

(continued)

Table B-5 Condition indices and variance-decomposition proportions for 2001-2005 regression data with 599-observation cross-sections (corresponding to Table 4.7). (continued)

Condition index	**Ln Labour (Int)**	**Ln Livestock (Int)**	**Ln Land (HI)**	**Ln Fertilizer (HI)**	**Ln Tractors (HI)**	**Ln Labour (HI)**	**Ln Livestock (HI)**	P Dummy	N Dummy
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.19
3.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.34
4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.41
12.51	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
19.17	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.62	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
28.97	0.01	0.00	0.00	0.00	0.03	0.16	0.00	0.01	0.00
36.05	0.07	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.03
40.91	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00
47.21	0.06	0.00	0.01	0.00	0.11	0.02	0.00	0.04	0.01
56.51	0.05	0.09	0.04	0.00	0.00	0.16	0.00	0.00	0.00
60.74	0.00	0.01	0.16	0.53	0.04	0.05	0.01	0.00	0.00
64.89	0.00	0.00	0.02	0.39	0.59	0.00	0.00	0.05	0.00
76.74	0.03	0.05	0.03	0.01	0.02	0.03	0.05	0.01	0.00
96.69	0.17	0.00	0.22	0.01	0.16	0.27	0.01	0.00	0.00
113.64	0.32	0.42	0.15	0.01	0.03	0.03	0.27	0.02	0.00
162.84	0.26	0.42	0.33	0.02	0.00	0.29	0.65	0.03	0.00

Table B-6 Panel Data LSDV Estimation under SUR, 1981-2005 (543-observation cross-sections): Dependent Variable is the natural logarithms of aggregate output in wheat units

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land	-0.0759	0.0000	-0.0545	0.0020	-0.0104	0.5430	0.0217	0.2250	-0.0270	0.1150
	(0.0172)		(0.0176)		(0.0171)		(0.0179)		(0.0172)	
Ln Fertilizer	0.0079	0.0840	0.0136	0.0070	0.0272	0.0000	0.0240	0.0000	0.0128	0.0190
	(0.0046)		(0.0051)		(0.0046)		(0.0045)		(0.0055)	
Ln Tractors	0.1386	0.0000	0.1339	0.0000	0.1214	0.0000	0.0974	0.0000	0.0935	0.0000
	(0.0116)		(0.0121)		(0.0119)		(0.0119)		(0.0110)	
Ln Labour	0.6880	0.0000	0.6710	0.0000	0.6722	0.0000	0.6598	0.0000	0.6729	0.0000
	(0.0154)		(0.0142)		(0.0141)		(0.0142)		(0.0139)	
Ln Livestock	0.1554	0.0000	0.1419	0.0000	0.1113	0.0000	0.1060	0.0000	0.1707	0.0000
	(0.0160)		(0.0168)		(0.0167)		(0.0177)		(0.0180)	
Ln Land (Int)	0.2359	0.0000	0.2247	0.0000	0.1527	0.0000	0.2308	0.0000	0.2858	0.0000
	(0.0348)		(0.0359)		(0.0339)		(0.0333)		(0.0322)	
Ln Fertilizer (Int)	0.0427	0.0050	0.0345	0.0110	0.0518	0.0000	0.0361	0.0060	0.0310	0.0210
	(0.0151)		(0.0136)		(0.0124)		(0.0132)		(0.0134)	
Ln Tractors (Int)	-0.0592	0.0130	-0.0484	0.0370	-0.0391	0.0700	-0.0682	0.0010	-0.0532	0.0050
	(0.0237)		(0.0232)		(0.0216)		(0.0207)		(0.0189)	
Ln Labour (Int)	-0.4604	0.0000	-0.4322	0.0000	-0.4523	0.0000	-0.4249	0.0000	-0.4016	0.0000
	(0.0218)		(0.0209)		(0.0205)		(0.0212)		(0.0204)	
Ln Livestock (Int)	0.2488	0.0000	0.2630	0.0000	0.3215	0.0000	0.2794	0.0000	0.2137	0.0000
	(0.0303)		(0.0300)		(0.0294)		(0.0310)		(0.0303)	

Standard errors are given in parentheses. HI and Int denote high external input and intermediate countries, respectively. N/A denotes coefficients restricted to zero due to their statistical insignificance.

(continued)

Table B-6 Panel Data LSDV Estimation under SUR, 1981-2005 (543-observation cross-sections): Dependent Variable is the natural logarithms of aggregate output in wheat units (continued)

	1981-85		1986-90		1991-95		1996-00		2001-05	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Ln Land (HI)	0.5423	0.0000	0.4157	0.0000	0.3963	0.0000	0.3963	0.0000	0.4136	0.0000
	(0.0344)		(0.0341)		(0.0321)		(0.0329)		(0.0331)	
Ln Fertilizer (HI)	0.0633	0.0020	0.1324	0.0000	0.0960	0.0000	0.0387	0.0360	0.0585	0.0000
	(0.0200)		(0.0221)		(0.0184)		(0.0185)		(0.0166)	
Ln Tractors (HI)	-0.1076	0.0000	-0.1265	0.0000	-0.0951	0.0000	-0.0355	0.1060	-0.0052	0.8080
	(0.0208)		(0.0215)		(0.0208)		(0.0220)		(0.0214)	
Ln Labour (HI)	-0.5192	0.0000	-0.5385	0.0000	-0.5185	0.0000	-0.5149	0.0000	-0.5219	0.0000
	(0.0215)		(0.0212)		(0.0201)		(0.0196)		(0.0190)	
Ln Livestock (HI)	-0.0511	0.1980	0.0640	0.1010	0.0726	0.0460	0.0866	0.0130	0.0266	0.4570
	(0.0398)		(0.0390)		(0.0363)		(0.0349)		(0.0357)	
Int Dummy	0.4888	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.1700)		(0.0000)		(0.0000)		(0.0000)		(0.0000)	
HI Dummy	3.3410	0.0000	2.5871	0.0000	2.6225	0.0000	2.5658	0.0000	2.7975	0.0000
	(0.2347)		(0.2102)		(0.2040)		(0.2104)		(0.2102)	
P Dummy	0.5039	0.0000	0.4254	0.0000	0.4363	0.0000	0.4651	0.0000	0.5051	0.0000
	(0.0225)		(0.0227)		(0.0223)		(0.0243)		(0.0249)	
N Dummy	-0.4850	0.0000	-0.4294	0.0000	-0.3769	0.0000	-0.4179	0.0000	-0.4358	0.0000
	(0.0235)		(0.0245)		(0.0233)		(0.0250)		(0.0261)	
Constant	3.7245	0.0000	3.9113	0.0000	3.8066	0.0000	3.9290	0.0000	3.5017	0.0000
	(0.1566)		(0.1214)		(0.1247)		(0.1272)		(0.1224)	
Observations	543		543		543		543		543	
"R-squared"	0.9842		0.9831		0.9830		0.9819		0.9837	
χ^2 statistic	43557	0.0000	40413	0.0000	41460	0.0000	38308	0.0000	40749	
B-P test statistic	2122.665	0.0000								

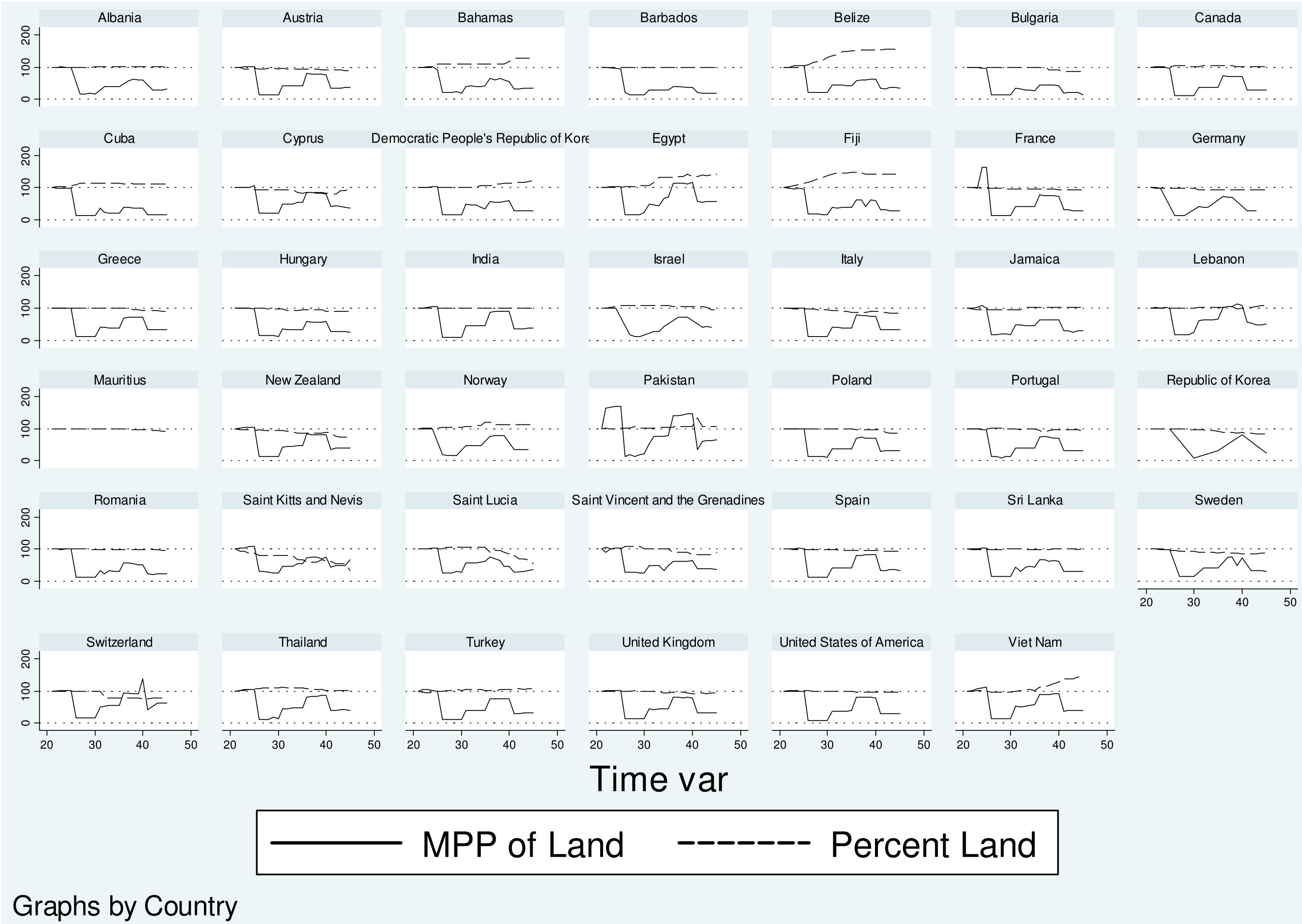

Figure B-1 Growth paths of MPP of land, and land in high external input countries under wheat unit output aggregation, 1981-05 (543-observation cross-sections data)

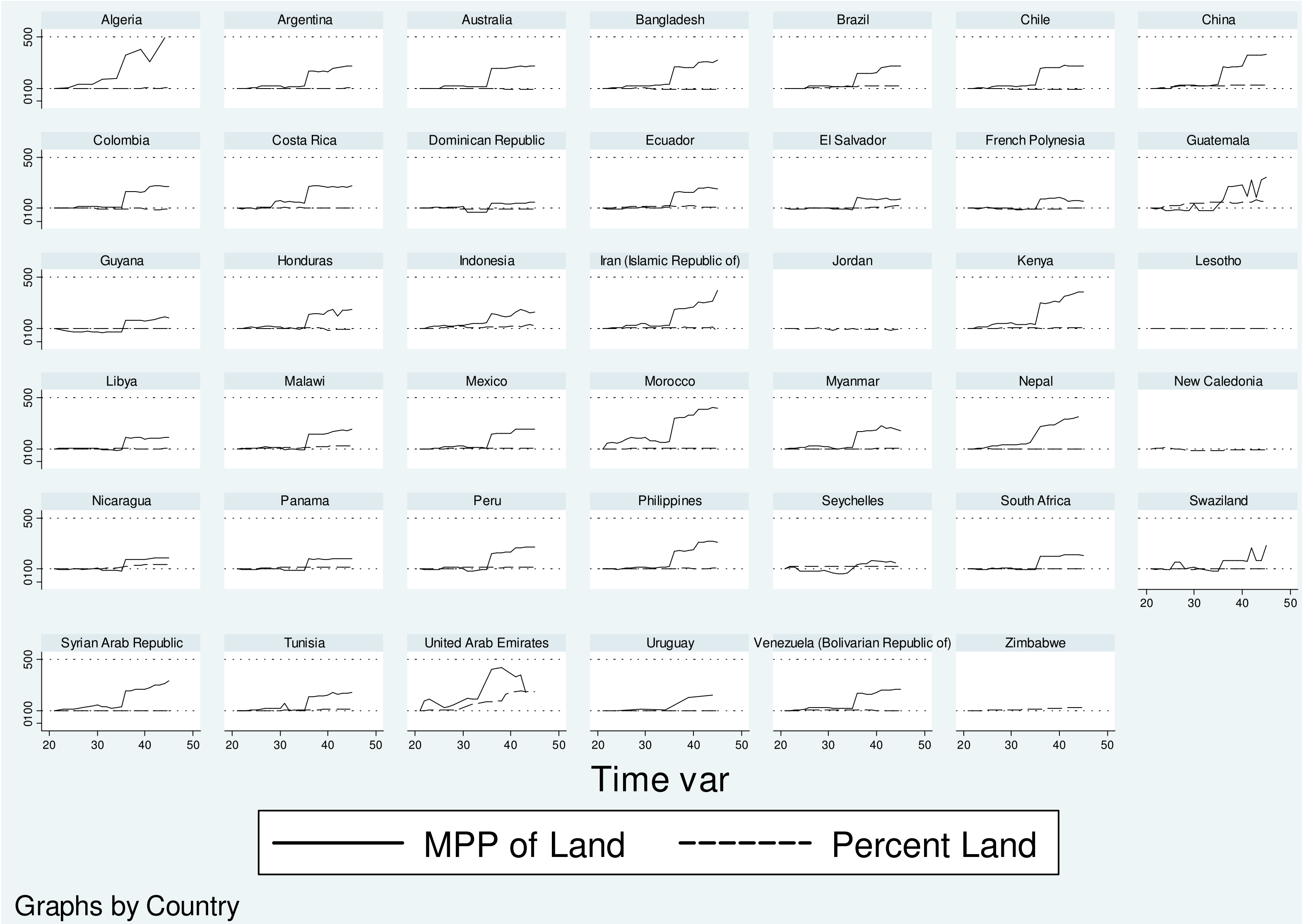

Figure B-2 Growth paths of MPP of land, and land in intermediate countries under wheat unit output aggregation, 1981-05 (543-observation cross-sections data)

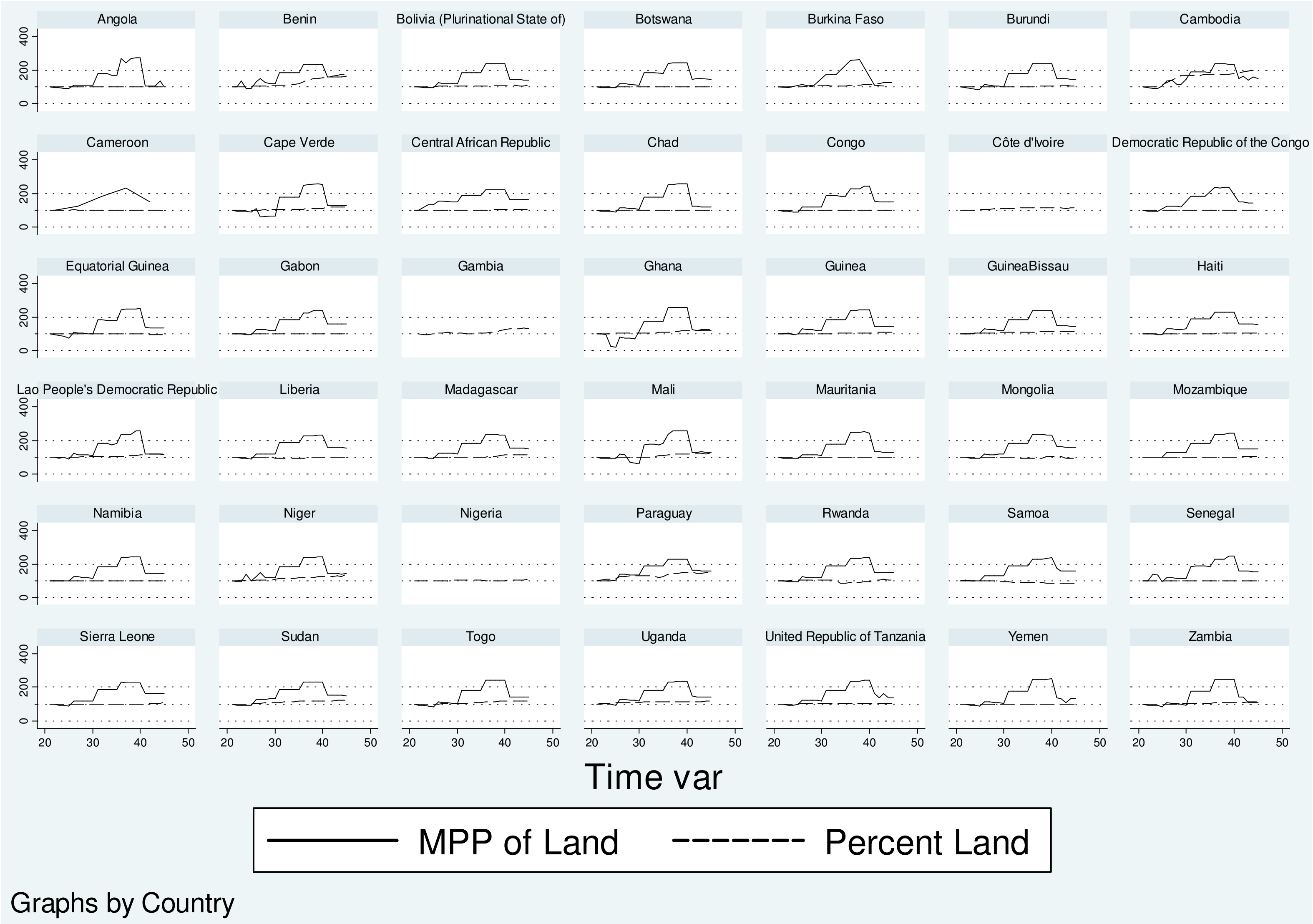

Figure B-3 Growth paths of MPP of land, and land in low external input countries under wheat unit output aggregation, 1981-05 (543-observation cross-sections data)

Table B-7 Countries and years excluded from the sample for 1981-2005 panel data regression based on wheat unit output aggregation (543-observation cross-sections data).

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Albania	1981	1986	1991	1996	2001
Algeria	1982	1987	1992	1997	2002
Algeria	1983	1988	1993	1998	2003
Algeria	1985	1990	1995	2000	2005
Barbados	1983	1988	1993	1998	2003
Botswana	1984	1989	1994	1999	2004
Burkina Faso	1982	1987	1992	1997	2002
Burkina Faso	1984	1989	1994	1999	2004
Burkina Faso	1985	1990	1995	2000	2005
Cameroon	1981	1986	1991	1996	2001
Cameroon	1983	1988	1993	1998	2003
Cameroon	1984	1989	1994	1999	2004
Cameroon	1985	1990	1995	2000	2005
Cape Verde	1983	1988	1993	1998	2003
Central African Republic	1983	1988	1993	1998	2003
Côte d'Ivoire	1981	1986	1991	1996	2001
Côte d'Ivoire	1982	1987	1992	1997	2002
Côte d'Ivoire	1983	1988	1993	1998	2003
Côte d'Ivoire	1984	1989	1994	1999	2004
Côte d'Ivoire	1985	1990	1995	2000	2005
Democratic Republic of the Congo	1985	1990	1995	2000	2005
Gambia	1981	1986	1991	1996	2001
Gambia	1982	1987	1992	1997	2002
Gambia	1983	1988	1993	1998	2003
Gambia	1984	1989	1994	1999	2004
Gambia	1985	1990	1995	2000	2005
Germany	1984	1989	1994	1999	2004
Germany	1985	1990	1995	2000	2005
Israel	1981	1986	1991	1996	2001
Israel	1985	1990	1995	2000	2005
Jordan	1981	1986	1991	1996	2001
Jordan	1982	1987	1992	1997	2002
Jordan	1983	1988	1993	1998	2003
Jordan	1984	1989	1994	1999	2004
Jordan	1985	1990	1995	2000	2005
Lesotho	1981	1986	1991	1996	2001
Lesotho	1982	1987	1992	1997	2002
Lesotho	1983	1988	1993	1998	2003
Lesotho	1984	1989	1994	1999	2004
Lesotho	1985	1990	1995	2000	2005
Mauritius	1981	1986	1991	1996	2001

(continued)

Table B-7 Countries and years excluded from the sample for 1981-2005 panel data regression based on wheat unit output aggregation (543-observation cross-sections data). (continued)

Country	1981-85	1986-90	1991-95	1996-00	2001-05
Mauritius	1982	1987	1992	1997	2002
Mauritius	1983	1988	1993	1998	2003
Mauritius	1984	1989	1994	1999	2004
Mauritius	1985	1990	1995	2000	2005
Nepal	1985	1990	1995	2000	2005
New Caledonia	1981	1986	1991	1996	2001
New Caledonia	1982	1987	1992	1997	2002
New Caledonia	1983	1988	1993	1998	2003
New Caledonia	1984	1989	1994	1999	2004
New Caledonia	1985	1990	1995	2000	2005
Nicaragua	1983	1988	1993	1998	2003
Nigeria	1981	1986	1991	1996	2001
Nigeria	1982	1987	1992	1997	2002
Nigeria	1983	1988	1993	1998	2003
Nigeria	1984	1989	1994	1999	2004
Nigeria	1985	1990	1995	2000	2005
Norway	1985	1990	1995	2000	2005
Republic of Korea	1981	1986	1991	1996	2001
Republic of Korea	1982	1987	1992	1997	2002
Republic of Korea	1983	1988	1993	1998	2003
Republic of Korea	1984	1989	1994	1999	2004
Saint Lucia	1982	1987	1992	1997	2002
Seychelles	1985	1990	1995	2000	2005
Sweden	1981	1986	1991	1996	2001
Switzerland	1982	1987	1992	1997	2002
United Arab Emirates	1984	1989	1994	1999	2004
United Arab Emirates	1985	1990	1995	2000	2005
Uruguay	1981	1986	1991	1996	2001
Uruguay	1982	1987	1992	1997	2002
Uruguay	1983	1988	1993	1998	2003
Uruguay	1985	1990	1995	2000	2005
Zimbabwe	1981	1986	1991	1996	2001
Zimbabwe	1982	1987	1992	1997	2002
Zimbabwe	1983	1988	1993	1998	2003
Zimbabwe	1984	1989	1994	1999	2004
Zimbabwe	1985	1990	1995	2000	2005