AGRICULTURAL PRODUCTIVITY IN ASIA

MEASURES AND PERSPECTIVES 2019

The Asian Productivity Organization (APO) is an intergovernmental organization committed to improving productivity in the Asia-Pacific region. Established in 1961, the APO contributes to the sustainable socioeconomic development of the region through policy advisory services, acting as a think tank, and undertaking smart initiatives in the industry, agriculture, service, and public sectors. The APO is shaping the future of the region by assisting member economies in formulating national strategies for enhanced productivity and through a range of institutional capacity building efforts, including research and centers of excellence in member countries.

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Agricultural Productivity in Asia: Measures and Perspectives 2019

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FOREWORD

In Asian countries, agriculture employs approximately one-third of the labor force and contributes approximately 9% of total value added. However, the agriculture sector faces multiple, increasingly harsh challenges. The sector will need to double food, fiber, and fuel production in order to meet additional demands from a world population of more than nine billion in 2050. This output must come from the finite land and water available for agriculture. Degradation of natural resources and negative impacts of climate change make this task even more daunting. Increasing agricultural productivity through sustainable practices has therefore become an urgent imperative.

Increased agricultural productivity is also crucial in achieving national objectives of food security, rural poverty reduction, and inclusive economic growth. For many developing countries, agriculture contributes substantially to rural livelihoods, trade revenues, and food security. It is also the backbone of the food industry sector because it supplies the raw material requirements. Unfortunately, systems for monitoring productivity trends in many developing countries are inadequate. This translates into weak planning and programming systems, which often lead to inefficient allocation of scarce resources among sectors and even within the agriculture sector.

With expanding international trade in agrifood products, countries in the region need reliable databases on agricultural resources and their productivity so that governments can plan and pursue the appropriate policy mix and program support. This is essential for enhancing the competitiveness of agri-based enterprises and to help the private sector identify potential areas for investment in agriculture.

To produce a comprehensive report on agricultural performance and productivity trends in member economies, the APO commissioned a research team from the University of Queensland, Australia, under the leadership of Professor Christopher J. O'Donnell. This research addresses the current gaps and weaknesses in systems for monitoring agricultural productivity in member countries. It also paves the way for the establishment of a harmonized APO regional database on agricultural productivity indicators for benchmarking and monitoring trends which can be utilized in designing appropriate programs to support the needs of the sector in member countries.

The APO hopes that this publication will serve as an informative guide for government policymakers and national productivity organizations in identifying priorities among development goals and planning projects to address their specific needs.

Dr. AKP Mochtan
Secretary-General

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C.J. O'Donnell and A. Peyrache
Brisbane, December 2019

EXECUTIVE SUMMARY

This report is divided into six sections. Section 1 summarizes trends in employment and value added in world agriculture. Among other things, it reveals that the agriculture sector still employs approximately 30% of the world's labor force, and still accounts for approximately 4% of the world's GDP. This first section of the report also summarizes the current status of agricultural productivity measurement and analysis. The focus of the report is on changes in total factor productivity (TFP).

Section 2 provides a brief overview of the main concepts and methods used in this report to analyze TFP change. Proper measures of TFP change (i.e., ones that are consistent with measurement theory) can be decomposed into measures of environmental change, technical change, and efficiency change. Estimating these components involves estimating the position and shape of production frontiers. Common methods for estimating production frontiers include data envelopment analysis (DEA) and stochastic frontier analysis (SFA). DEA methods are underpinned by the assumption that all variables involved in the production process are observed and measured without error. This assumption is rarely, if ever, true. SFA methods do not require this assumption. Partly for this reason, SFA methods have been used to obtain the main results in this report.

Section 3 summarizes the data sources, data cleaning procedures, and basic estimation results. Most of the raw data were sourced from the Food and Agriculture Organization (FAO) Corporate Statistical Database (FAOSTAT) of the UN. The project team assembled annual data on four inputs (land, labor, fertilizers, and tractors) and three outputs (crops, livestock, and greenhouse gas emissions) for 91 countries for the 55 years from 1961 to 2015. The data were used to estimate a Cobb-Douglas stochastic production frontier. The estimated coefficients are all consistent with prior expectations. The average rate of technical progress is estimated to be 0.56% per annum. The estimated production frontier is found to exhibit slightly decreasing returns to scale. It is estimated that farmers in dry (respectively wet) tropical/subtropical climate zones operate in the least (respectively most) favorable production environments.

Section 4 reports estimates of average productivity and efficiency change in Africa, the Americas, Asia, and Europe. The focus is on measures of land, labor, capital, and TFP change. Among other things, it is estimated that average labor (respectively total factor) productivity in Asia was 2.507 (respectively 1.992) times higher in 2015 than it had been in 1961.

On the other hand, it is estimated that average capital productivity in Asia was 30.8% lower in 2015 than it had been in 1961. These results can be largely attributed to significant increases in capital.

Section 5 reports estimates of average productivity and efficiency change in a total of 23 countries, namely, Australia, China, France, Germany, the UK, the USA, and 17 APO member countries. Again, the focus is on changes in land, labor, capital, and TFP. Among other things, it is estimated that average labor productivity (respectively total factor productivity) in India, for example, was 1.931 (respectively 1.458) times higher in 2015 than it had been in 1961. On the other hand, it is estimated that average capital productivity in India was 97.3% lower in 2015 than it had been in 1961. It is estimated that, over the period 1961 to 2015, technical progress in world agriculture contributed to a 35.2% increase in Indian TFP, and lower technical efficiency in Indian agriculture contributed to an offsetting 7.8% fall in TFP.

Section 6 discusses some of the issues and challenges involved in monitoring agricultural productivity change in Asia. The main challenge is the collection of accurate data. The project team recommends that the APO works with appropriate statistical agencies in APO member countries to conduct a comprehensive farm-level survey across all countries on a regular basis.

CHAPTER 1
INTRODUCTION

This section summarizes trends in employment and value added in world agriculture. It also summarizes the current status of agricultural productivity measurement and analysis.

1.1 Trends in the Performance of the Agriculture Sector

The International Labour Organization (ILO) estimates that in 2000 the agriculture sector employed 39.6% of the world's labor force; by 2014, this percentage had fallen to 29.8%. Figure 1.1 reports a breakdown of this change by year and by region. This figure indicates that the agriculture sectors in Africa and Asia have always employed a much larger percentage of the labor force than the agriculture sectors in the Americas and Europe: in 2000 (respectively 2014), the agriculture sector in Africa employed 54.2% (respectively 51.2%) of that region's total labor force, the agriculture sector in Asia employed 49.7% (respectively 34.8%) of the total labor force, the agriculture sector in the Americas employed 10.8% (respectively 9.9%) of the total labor force, and the agriculture sector in Europe employed 14.8% (respectively 9.5%) of the total labor force. These regional differences in employment shares are generally associated with regional differences in national incomes: low agricultural employment shares are generally associated with higher national incomes. To illustrate, Table 1.1 reports a breakdown of employment shares in world and Asian agriculture in 2014 by national income category (and gender). This table reveals that in 2014 the agricultural sector in low (respectively high) income countries of the world employed 68.8% (respectively 3.2%) of the world's labor force; it also reveals that in 2014 the agricultural sector in low (respectively high) income Asian countries employed 65.3% (respectively 4.0%) of that region's labor force.

The Food and Agriculture Organization (FAO) estimates that in 1970 the agriculture sector accounted for 9.1% of world GDP; by 2014, this percentage had fallen to 4.3%. Figure 1.2 reports a breakdown of this change by year and by region. Again, this figure indicates that the agriculture sectors in Africa and Asia have for many years accounted for a much larger proportion of GDP than the agriculture sectors in the Americas and Europe: in 1970 (respectively 2014), the agriculture sector in Africa accounted for 21.2% (respectively 15.0%) of the region's GDP, the agriculture sector in Asia accounted for 21.1% (respectively 7.5%) of GDP, the agriculture sector in the Americas accounted for 3.6% (respectively 2.1%) of GDP, and the agriculture sector in Europe accounted for 9.3% (respectively 1.6%) of GDP.

1.2 Current Status of Agricultural Productivity Measurement

Agricultural productivity measurement typically involves the computation of partial and/or total factor productivity measures. A partial factor productivity (PFP) measure is a volume (i.e., quantity) measure of outputs divided by a volume measure of a subset of inputs. PFP measures that have been widely used in agriculture include output per hectare (i.e., land productivity), output per person (i.e., labor productivity), and output per unit of physical capital (i.e., capital productivity).

FIGURE 1.1

AGRICULTURAL EMPLOYMENT AS A PERCENTAGE OF THE TOTAL LABOR FORCE, 2000–2014

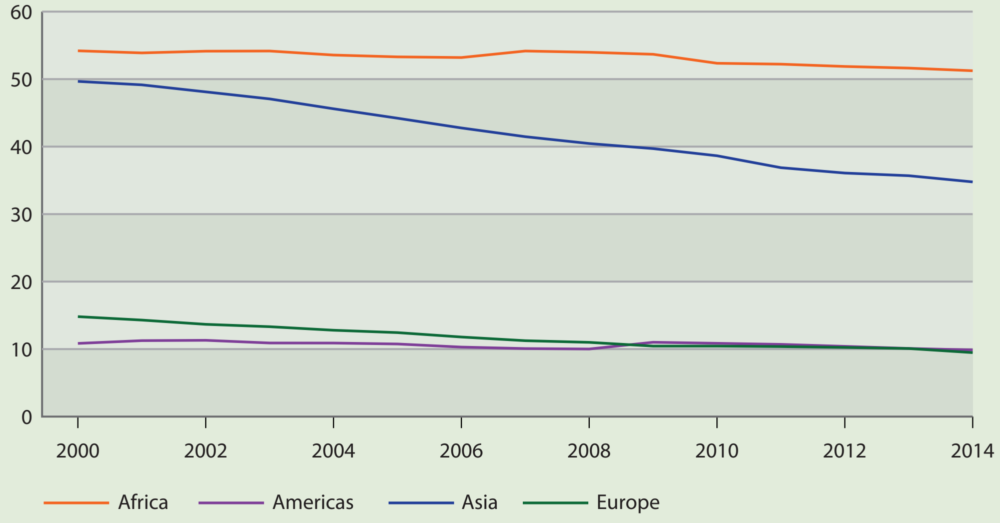


TABLE 1.1

AGRICULTURAL EMPLOYMENT AS A PERCENTAGE OF THE TOTAL LABOR FORCE, 2014

Region/Country	Total	Female	Male
World: Low income	68.8	66.2	71.8
World: Lower-middle income	41.0	38.3	46.8
World: Upper-middle income	24.3	22.6	26.5
World: High income	3.2	4.0	2.2
Asia and the Pacific: Low income	65.3	60.7	71.5
Asia and the Pacific: Lower-middle income	42.9	39.3	51.3
Asia and the Pacific: Upper-middle income	29.4	26.0	33.8
Asia and the Pacific: High income	4.0	4.4	3.5

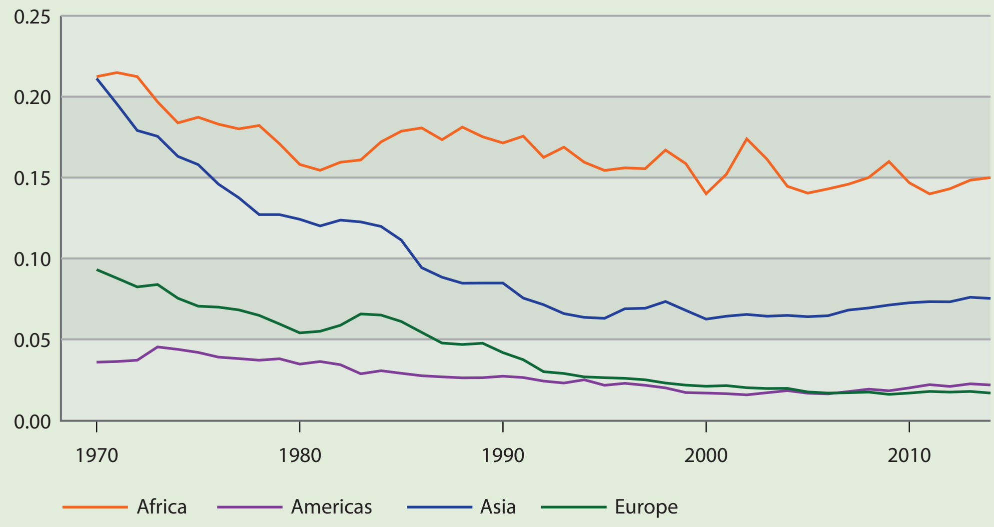
Kumbhakar [7], for example, used farm-level data to analyze labor productivity in India over the period 1980 to 1985; Holden, et al [6] used farm-plot-level data to analyze land productivity in Ethiopia over the period 1998 to 2006.

A total factor productivity (TFP) measure is a volume measure of outputs divided by a volume measure of all inputs. TFP measures that have been widely used in agriculture include the Fisher, Törnqvist, Malmquist, Hicks-Moorsteen (HM), Elteto-Koves-Szulc (EKS) and Caves-Christensen-Diewert (CCD) TFP indices. Mullen [10], for example, used farm-level data and the Fisher TFP index to measure agricultural productivity change in Australia over the period 1954 to 2004; Coelli and Rao [2] used FAO data and the Malmquist index to measure agricultural productivity changes in 93 countries over the period 1980 to 2000; and Hadley, et al [5] used farm-level data and the HM index to measure agricultural productivity changes in England and Wales over the period 2000 to 2004.

Unfortunately, except in restrictive special cases (e.g., there is only one output and only one input), the TFP indices described above do not satisfy basic axioms from index theory. For example, the

FIGURE 1.2

AGRICULTURAL GDP AS A PERCENTAGE OF TOTAL GDP, 1970–2014



Fisher, Törnqvist, Malmquist, and HM TFP indices do not satisfy a transitivity axiom. This axiom says that if we compare the productivity of farmer A and farmer C indirectly through farmer B, then we must get the same index number as when we compare the productivity of farmers A and C directly. TFP indices that have good axiomatic properties include the Lowe and Geometric Young (GY) TFP indices. Both of these indices have been used in agriculture. O'Donnell [11], for example, uses United States Department of Agriculture (USDA) data and the Lowe index to measure agricultural productivity change in 48 states over the period 1960 to 2004; more recently, O'Donnell [12] uses USDA data and the GY index to measure agricultural productivity change in 11 states over the period 1960 to 1989.

1.3 Current Explanations for Agricultural Productivity Change

Measures of productivity change are measures of output change divided by measures of input change. Economists have many different models that can be used to explain output change and input change (and therefore productivity change). For example, it is common for business economists to assume that firms are price takers in output and input markets, and that businessmen choose outputs and inputs in order to maximize profits. In such cases, profit-maximizing output and input quantities will depend, inter alia, on relative output and input prices (i.e., the terms of trade) and characteristics of the 'production possibilities set' (i.e., the set of output-input combinations that are technically possible).

As another example, it is common for agricultural economists to assume that firms are price takers in output and input markets, and that farmers choose inputs to maximize expected profits in the face of uncertainty about output prices and characteristics of the production environment (e.g., rainfall). In these cases, expected revenue-maximizing inputs (and, ultimately, realized outputs) will change with input prices, expectations about output prices, environmental variables, and characteristics of the production possibilities set. Much more complex models of firm behavior are available. In most, if not all, of these models, output and/or input change (and therefore productivity change) depends, inter alia, on characteristics of the production possibilities set. Different explanations for output and input change (and therefore productivity change) generally involve different assumptions about this set. For example, Kumbhakar [7] assumes that the boundary of the production possibilities set (i.e., the production frontier) can be represented by a translog function; Coelli and Rao [2] assume that the production frontier exhibits constant returns to scale (CRS).

In practice, observed outputs and inputs may differ from optimal outputs and inputs because firm managers do not have enough knowledge and/or skills to solve complex maximization problems (i.e., they are boundedly rational). The failure to solve optimization problems is known as inefficiency (e.g., the difference between observed profit and maximum possible profit is known as profit inefficiency). Different explanations for output and input change (and therefore productivity change) allow for different types of inefficiency. For example, Coelli and Rao [2] allow for output-oriented technical inefficiency (i.e., the failure to produce maximum output from given inputs).

CHAPTER 2

PRODUCTIVITY CONCEPTS AND ANALYTICAL METHODS

This section provides a brief overview of the main concepts and methods used in this project to analyze a total factor productivity (TFP) change. It draws heavily on O'Donnell [12, 13].

2.1 Production Technologies

In O'Donnell [12, 13], the term 'production technology' (or simply technology) refers to a technique, method or system for transforming inputs into outputs (e.g., a technique for planting and growing rice). For practical purposes, O'Donnell [12, 13] finds it convenient to think of a technology as a book of instructions, or recipe. The set of technologies that exist in any given period is called a technology set. If we think of a technology as a book of instructions, then we can think of a technology set as a library.

Common Assumptions

It is possible to measure TFP change without knowing anything about technologies, (i.e., we can calculate changes in output-input ratios without knowing anything about how the inputs are used to produce the outputs). However, we generally need to make some assumptions about technologies in order to explain productivity change. It is common to assume the following:

- A1: It is possible to produce zero output.
- A2: There is a limit to what can be produced using a finite amount of inputs.
- A3: A positive amount of at least one input is needed in order to produce a positive amount of any output.
- A4: The set of outputs that can be produced using given inputs contains all the points on its boundary.
- A5: The set of inputs that can produce given outputs contains all the points on its boundary.
- A6: If given inputs can be used to produce particular outputs, then they can also be used to produce fewer outputs (outputs are strongly disposable).
- A7: If given outputs can be produced using particular inputs, then they can also be produced using more inputs (inputs are strongly disposable).

- A8: If a given output-input combination is possible in a particular production environment, then it is also possible in a better production environment (environmental variables are strongly disposable).

- A9: If two input-output combinations are possible, then any linear combination of those input-output combinations is also possible (production possibilities sets are convex).

This project is underpinned by assumptions A2 and A6 to A8. If these assumptions are true, then technologies can be represented using various sets and functions. In this project, the focus is on output sets and output distance functions.

Output Sets

An output set is a set containing all outputs that can be produced using given inputs. A period-and-environment-specific output set is a set containing all outputs that can be produced using given inputs in a given period in a given production environment. For a precise definition, let $x = (x_1, . . . , x_M)'$, $q = (q_1, . . . , q_N)'$ and $z = (z_1, . . . , z_J)'$ denote vectors of inputs, outputs, and environmental variables, respectively. Mathematically, the set of outputs that can be produced using inputs x in period t (i.e., using the period-t technology set) in an environment characterized by z is [13]:

$$P^t(x, z) = \{q: x \text{ can produce } q \text{ in period } t \text{ in environment } z\}. \qquad (2.1)$$

The boundary of this set is a period-and-environment-specific frontier. A large part of productivity and efficiency analysis is concerned with estimating how the position and shape of this frontier changes over time. An example of an output set is the following:

$$P^t(x,z) = \left\{ q : \sum_{n=1}^{N} \gamma_n q_n \le A(t) \prod_{j=1}^{J} z_j^{\delta_j} \prod_{m=1}^{M} x_m^{\beta_m} \right\} \qquad (2.2)$$

where $A(t) > 0$ is a measure of how the production frontier changes over time; $(\beta_1, . . . ,\beta_M)' \geq 0$ is a vector of output elasticities; $(\gamma_1, . . . , \gamma_N)' \geq 0$ is a vector of parameters that sum to one; and $\sum_m \beta_m = r$ is the elasticity of scale. The elasticity of scaple measures the percent increase in the output vector associated with a one percent increase in the input vector, holding all other variables fixed. The production frontier is said to exhibit decreasing returns to scale (DRS), constant returns to scale (CRS) or increasing returns to scale (IRS) as the elasticity of scale is less than, equal to, or greater than one respectively.

Output Distance Functions

An output distance function (ODF) gives the reciprocal of the largest factor by which it is possible to scale up a given output vector when using a given input vector. For example, if it is technically possible for a firm to use its inputs to produce five times as much of every output, then the ODF takes the value $\rho = 1/5 = 0.2$. A period-and-environment-specific ODF gives the reciprocal of the largest factor by which it is possible to scale up a given output vector when using a given input vector in a given period in a given production environment. Mathematically, the reciprocal of the largest factor by which it is possible to scale up the output vector q when using inputs x in period t in an environment characterized by z is [13]:

$$D_O^t(x,q,z) = \inf\{\rho > 0 : q/\rho \in P^t(x,z)\}. \qquad (2.3)$$

ODFs are nonnegative and linearly homogeneous in outputs. If outputs are strongly disposable, then they are also nondecreasing in outputs. If assumptions A2 and A6 to A8 are true, then output sets and ODFs are equivalent representations of technologies. If the output set is given by (2.2), for example, then the ODF is:

$$D_O^t(x,q,z) = \left(A(t) \prod_{j=1}^{J} z_j^{\delta_j} \prod_{m=1}^{M} x_m^{\beta_m} \right)^{-1} \left(\sum_{n=1}^{N} \gamma_n q_n \right) \qquad (2.4)$$

where $A(t) > 0$, $(\beta_1, \ldots, \beta_M)' \geq 0, (\gamma_1, \ldots, \gamma_N)' \geq 0$ and $\sum_n \gamma_n = 1$.

2.2 Managerial Behavior

The existence of different sets and functions has no implications for managerial behavior. The existence of the ODF, for example, does not mean that managers will attempt to scale up their output vectors until they reach the production frontier. Rather, they will tend to behave differently depending on what they value, and on what they can and cannot choose. This project focuses on managers who seek to maximize output and/or TFP. It is convenient at this point to introduce firm and time subscripts into the notation and, for example, let $x_{it} = (x_{1it}, \ldots, x_{Mit})'$ and $q_{it} = (q_{1it}, \ldots, q_{Nit})'$ denote the outputs and inputs of firm i in period t.

Output Maximization

If a firm manager places nonnegative values on outputs (not necessarily market values) and all other variables involved in the production process have been predetermined, then he/she will generally aim to maximize a measure of total output. If there is more than one output, then the precise form of the output maximization problem will depend on how easily the manager can choose the output mix. If the manager of firm i can only choose output vectors that are scalar multiples of $q_{it} \geq 0$, then his/her period t output-maximization problem is [13]:

$$\max_q \{Q(q) : q \propto q_{it}, D_O^t(x_{it}, q, z_{it}) \leq 1\} \qquad (2.5)$$

where $Q(.)$ is a nonnegative, nondecreasing, linearly homogeneous, scalar-valued aggregator function satisfying $Q(q_{it}) > 0$. The output vector that solves this problem is $\bar{q}_{it} \equiv q_{it} / D_O^t(x_{it}, q_{it}, z_{it})$. This vector lies on the production frontier. The associated aggregate output is $Q(\bar{q}_{it}) = Q(q_{it}) / D_O^t(x_{it}, q_{it}, z_{it})$.

TFP Maximization

If a firm manager places nonnegative values on outputs and inputs and all environmental variables have been predetermined, then he/she may aim to maximize a measure of TFP.

TFP is a volume (i.e., quantity) measure of total output divided by a volume measure of total input. If the manager of firm i can choose outputs and inputs freely, then his/her period-t TFP-maximization problem can be written as [13]:

$$\max_{x \geq 0, q \geq 0} \{Q(q) / X(x) : D^t{}_O(x, q, z_{it}) \leq 1\} \qquad (2.6)$$

where $Q(.)$ and $X(.)$ are nonnegative, nondecreasing, linearly homogeneous, scalar-valued aggregator functions with parameters (or weights) that represent the values the firm manager places on outputs and inputs. There may be several pairs of output and input vectors that solve this problem. Let q_{it}^* and x_{it}^* denote one such pair. This output-input combination lies on the production frontier. The associated maximum TFP is $TFP^t(z_{it}) = Q(q_{it}^*) / X(x_{it}^*) = \mathrm{Q}$

2.3 Measures of Efficiency

Measures of efficiency can be viewed as measures of how well firm managers have solved different optimization problems. This project focuses on output-oriented measures of technical, scale and mix efficiency. These measures take values that lie between zero (indicating totally inefficient) and one (indicating fully efficient).

Output-oriented Technical Efficiency

The output-oriented technical efficiency (OTE) of manager i in period t can be viewed as a measure of how well he/she has solved the problem represented by equation (2.5). Mathematically, the OTE of manager i in period t is:

$$OTE^t(x_{it}, q_{it}, z_{it}) = Q(q_{it})/Q(\bar{q}_{it}) \qquad (2.7)$$

where $Q(q_{it})$ is the aggregate output of the firm and $Q(\bar{q}_{it}) = Q(q_{it})/D_O^t(x_{it}, q_{it}, z_{it})$ is the maximum aggregate output that is possible when using x_{it} to produce a scalar multiple of $q_{it} \geq 0$ in period t in an environment characterized by z_{it}. An equivalent definition is $OTE^t(x_{it}, q_{it}, z_{it}) = D_O^t(x_{it}, q_{it}, z_{it})$. These definitions can be found in O'Donnell [13]. However, the concept can be traced back at least as far as Farrell [4]. A manager may be technically inefficient because he/she did not choose the right technology (i.e., did not choose the right book from the library) and/or did not use the chosen technology properly (i.e., did not follow instructions).

Technical, Scale and Mix Efficiency

The technical, scale and mix efficiency (TSME) of manager i in period t can be viewed as a measure of how well he/she has solved the problem represented by equation (2.6). Mathematically, the TSME of manager i in period t is:

$$TSME^t(x_{it}, q_{it}, z_{it}) = TFP(x_{it}, q_{it})/TFP^t(z_{it}) \qquad (2.8)$$

where $TFP(x_{it}, q_{it}) = Q(q_{it})/X(x_{it})$ is the observed TFP of the firm and $TFP^t(z_{it}) = Q(q_{it}^*)/X(x_{it}^*)$ is the maximum TFP that is possible in period t in an environment characterized by z_{it}. Again, this definition can be found in O'Donnell [13]. Importantly, the TSME of a firm can be broken into output-oriented measures of technical efficiency and scale and mix efficiency. The technical efficiency component is the measure of OTE defined by equation 2.7. The associated output-oriented scale and mix efficiency (OSME) of manager i in period t is [13]:

$$OSME^t(x_{it}, q_{it}, z_{it}) = TFP^t(x_{it}, \bar{q}_{it})/TFP^t(z_{it}) \qquad (2.9)$$

where $TFP(x_{it}, \bar{q}_{it}) = Q(\bar{q}_{it})/X(x_{it})$ is the maximum TFP possible when using x_{it} to produce a scalar multiple of $q_{it} \geq 0$ in period t in an environment characterized by z_{it}. Equivalently, $OSME^t(x_{it}, q_{it}, z_{it}) = TSME^t(x_{it}, q_{it}, z_{it})/OTE^t(x_{it}, q_{it}, z_{it})$. Thus, OSME can be viewed as the component of TSME that remains after accounting for OTE. This concept can be traced back at least as far as O'Donnell [11].

2.4 Index Numbers

An index is a measure of change in a variable (or group of variables) over time and/or space. A TFP index is an output index divided by an input index. This project is concerned with output and input indices that are proper in the sense that they satisfy the axioms listed in O'Donnell [12, 13].

Output Indices

In O'Donnell [12, 13], an output quantity index that compares q_{it} with q_{ks} using the latter as the reference (or base) vector is defined as any variable of the form

$$QI\,(q_{ks}, q_{it}) = Q(q_{it})/Q(q_{ks}) \qquad (2.10)$$

where Q (.) is any nonnegative, nondecreasing, linearly homogeneous, scalar-valued aggregator function. Output indices that are constructed in this way are proper in the sense that they satisfy the index number axioms listed in O'Donnell [12,13]. One of these axioms is transitivity. Transitivity says that if we compare the outputs of farmer A and farmer C indirectly through farmer B, then we must get the same index number as when we compare the outputs of farmers A and C directly. Any nonnegative, nondecreasing, linearly homogeneous, scalar-valued aggregator function can be used for purposes of constructing a proper output index. This project constructs an additive index. Additive indices are constructed using aggregator functions of the form $Q\,(q_{it}) \propto a'q_{it}$ where a is any nonnegative vector of weights. The class of additive output indices includes the Lowe output index of O'Donnell [11].

Input Indices

In O'Donnell [12, 13], an input quantity index that compares x_{it} with x_{ks} using the latter as the reference vector is defined as any variable of the form

$$XI\,(x_{ks}, x_{it}) = X\,(x_{it})/X\,(x_{ks}) \qquad (2.11)$$

where X (.) is a nonnegative, nondecreasing, linearly homogeneous, scalar-valued aggregator function. Again, all input indices that are constructed in this way are proper in the sense that satisfy the index number axioms listed in O'Donnell [12, 13]. Again, this project constructs an additive index. Additive input indices are constructed using aggregator functions of the form $X\,(x_{it}) \propto b'\,x_{it}$ where b is any nonnegative vector of weights. The class of additive input indices includes the Lowe input index of O'Donnell [11].

TFP Indices

In O'Donnell [12, 13], an index that compares the TFP of firm i in period t with the TFP of firm k in period s is any variable of the form

$$TFPI\,(x_{ks}, q_{ks}, x_{it}, q_{it}) = QI\,(q_{ks}, q_{it})/XI\,(x_{ks}, x_{it}) \qquad (2.12)$$

where QI (.) is any proper output index and XI (.) is any proper input index. In O'Donnell [12, 13], a TFP index is said to be "proper" if and only if it can be written in this form. The class of proper TFP indices includes the Lowe TFP index of O'Donnell [11] and the geometric Young (GY) TFP index of O'Donnell [12].

2.5 Data Envelopment Analysis

Productivity analysis involves estimating production frontiers. Data envelopment analysis (DEA) methods for estimating production frontiers can be traced back at least as far as Farrell [4]. The most common DEA models are underpinned by the following assumptions [13]:

- **DEA1:** Production possibilities sets can be represented by distance, revenue, cost or profit functions.

- **DEA2:** All relevant quantities, prices and/or environmental variables are observed and measured without error.

- **DEA3:** Production frontiers are piecewise (or locally) linear.

- **DEA4:** Outputs, inputs and environmental variables are strongly disposable.

- **DEA5:** Production possibilities sets are convex.

Under these assumptions, most measures of efficiency can be estimated by solving linear programs (LPs).

Estimating OTE

Estimating the measure of OTE defined by equation (2.7) involves estimating the ODF. If assumptions DEA1 to DEA3 are true, then the ODF is $D_O^{it}(x_{it}, q_{it}, z_{it}) = \gamma_{it}' q_{it} / (\alpha_{it} + \delta_{it}' z_{it} + \beta_{it}' x_{it})$ where $\gamma_{it}, \alpha_{it}, \delta_{it}$ and are unknown parameters to be estimated. Estimating these parameters involves maximizing $\gamma_{it}' q_{it} / (\alpha_{it} + \delta_{it}' z_{it} + \beta_{it}' x_{it})$ subject to constraints that ensure that assumptions DEA4 and DEA5 are satisfied. Assumption DEA4 will be satisfied if and only if $\gamma_{it} \geq 0$, $\delta_{it} \geq 0$ and $\beta_{it} \geq 0$. If there are I firms in the dataset, then assumption DEA5 will be satisfied if and only if $\gamma_{it}' q_{hr} \leq \alpha_{it} + \delta_{it}' z_{hr} + \beta_{it}' x_{hr}$ for all $h \leq I$ and $r \geq t$. For identification purposes, it is common to set $\gamma_{it}' q_{it} = 1$. With all these constraints, the estimation problem becomes the following:

$$\min_{\alpha_{it}, \delta_{it}, \beta_{it}, \gamma_{it}} \{\alpha_{it} + \delta_{it}' z_{it} + \beta_{it}' x_{it} : \gamma_{it} \geq 0, \delta_{it} \geq, \beta_{it} \geq 0,$$
$$\gamma_{it}' q_{hr} \leq \alpha_{it} + \delta_{it}' z_{it} + \beta_{it}' x_{hr} \text{ for all } h \leq I$$
$$\text{and } r \leq t, \gamma_{it}' q_{it} = 1\}. \quad (2.13)$$

This is a standard LP. The value of the objective function at the optimum is an estimate of the reciprocal of $OTE^t(x_{it}, q_{it}, z_{it})$. The problem represented by equation (2.13) can be found in O'Donnell, et al [14].

Equation (2.13) is a primal LP. Every primal LP has a dual form with the property that if the primal and its dual both have feasible solutions, then the optimized values of the two objective functions are equal. The dual form of equation (2.13) is the following:

$$\max_{\mu, \lambda_{11}, \ldots, \lambda_{It}} \{\mu : \mu q_{it} \leq \sum_{h=1}^{I} \sum_{r=1}^{t} \lambda_{hr} q_{hr},$$
$$\sum_{h=1}^{I} \sum_{r=1}^{t} \lambda_{hr} z_{hr} \leq z_{it}, \sum_{h=1}^{I} \sum_{r=1}^{t} \lambda_{hr} x_{hr} \leq x_{it},$$
$$\sum_{h=1}^{I} \sum_{r=1}^{t} \lambda_{hr} = 1, (\lambda_{11}, \ldots, \lambda_{It})' \geq 0\}. \quad (2.14)$$

Again, this is a standard LP. The value of the objective function at the optimum is an estimate of the reciprocal of $OTE^t(x_{it}, q_{it}, z_{it})$. The problem represented by equation (2.14) can be found in O'Donnell, et al [14].

Equation (2.14) is suitable for estimating OTE when environmental variables are cardinal variables. In these cases, period-and-environment-specific frontiers should be estimated using observations on firms that operated in *any* environment. In this project, the only environmental variable is a nominal variable. In these cases, period-and-environment-specific frontiers should be estimated using observations on firms that operated in specific environments. Thus, in this project, the dual LP is the following:

$$\max_{\mu,\lambda_{11},\ldots,\lambda_{It}} \{\mu : \mu q_{it} \leq \sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} q_{hr},$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} z_{hr} \leq z_{it}, \sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} x_{hr} \leq x_{it},$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} = 1, (\lambda_{11},\ldots,\lambda_{It})' \geq 0\} \quad (2.15)$$

where $d_{hrit} = I(z_{hr} = z_{it})$ is a dummy variable that takes the value 1 if, in period r, firm h operated in an environment characterized by z_{it}. This dummy variable effectively deletes from the sample any observations on firms that did not operate in the same environment as firm i in period t. Again, this is a standard LP. The value of the objective function at the optimum is an estimate of the reciprocal of $OTE^t(x_{it}, q_{it}, z_{it})$.

Estimating TSME

Estimating the measure of TSME defined by equation (2.8) involves estimating the maximum TFP that is possible in a given period in a given production environment. If the environmental variable is a nominal variable, then the estimation problem can be written as:

$$\max_{q,x,\lambda_{11},\ldots,\lambda_{It}} \{Q(q)/X(x) : q \leq \sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} q_{hr},$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} z_{hr} \leq z_{it}, \sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} x_{hr} \leq x,$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\lambda_{hr} d_{hrit} = 1, (\lambda_{11},\ldots,\lambda_{It})' \geq 0\}. \quad (2.16)$$

This is a fractional program. The value of the objective function at the optimum is an estimate of $TFP^t(z_{it})$. The problem can be rewritten as:

$$\max_{\bar{q},\bar{x},\theta_{11},\ldots,\theta_{It}} \{Q(\bar{q}) : \bar{q} \leq \sum_{h=1}^{I}\sum_{r=1}^{t}\theta_{hr} d_{hrit} q_{hr}, \ X(\bar{x}) = 1,$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\theta_{hr} d_{hrit} z_{hr} \leq \kappa z_{it}, \sum_{h=1}^{I}\sum_{r=1}^{t}\theta_{hr} \theta_{hrit} x_{hr} \leq \bar{x},$$
$$\sum_{h=1}^{I}\sum_{r=1}^{t}\theta_{hr} d_{hrit} = \kappa, (\theta_{11},\ldots,\theta_{It})' \geq 0\}. \quad (2.17)$$

The value of the objective function at the optimum is still an estimate of $TFP^t(z_{it})$. The value of κ at the optimum is an estimate of $1/X\left(x_{it}^*\right)$ The values of $\bar{q}$ and $\bar{x}$ at the optimum are estimates of $q_{it}^*/X\left(x_{it}^*\right)$ and $x_{it}^*/X\left(x_{it}^*\right)$ If the aggregator functions are linear functions, as they are in this project, then equation (2.17) is an LP.

Decomposing TFP Change

DEA methods can be used to decompose any proper TFP index into a measure of environment and technical change and a measure of technical, scale and mix efficiency change. Mathematically,

$$TFPI(x_{ks}, q_{ks}, x_{it}, q_{it}) = \left[\frac{TFP^t(z_{it})}{TFP^s(z_{ks})}\right]\left[\frac{TSME^t(x_{it}, q_{it}, z_{it})}{TSME^s(x_{ks}, q_{ks}, z_{ks})}\right] \quad (2.18)$$

where $TFP^t(z_{it})$ is the maximum TFP that is possible in period t in an environment characterized by z_{it}, and $TSME^t(x_{it}, q_{it}, z_{it})$ is the measure of TSME defined by equation (2.8). The first ratio on the right-hand side is an environment and technology index (ETI). The second ratio is a technical, scale and mix efficiency index (TSMEI). The two ratios on the right-hand side of equation 2.18 can be broken into smaller components. First, the ETI can be broken into separate measures of environmental change and technical change. Mathematically,

$$\frac{TFP^t(z_{it})}{TFP^s(z_{ks})} = \left[\frac{TFP^t(z_{it})\,TFP^s(z_{it})}{TFP^t(z_{ks})TFP^s(z_{ks})}\right]^{1/2}\left[\frac{TFP^t(z_{it})\,TFP^t(z_{ks})}{TFP^s(z_{it})TFP^s(z_{ks})}\right]^{1/2}. \qquad (2.19)$$

The first ratio on the right-hand side is an environment index (EI). The second ratio is a technology index (TI). Next, the TSMEI in equation (2.18) can be broken into separate measures of technical efficiency change and scale and mix efficiency change. Mathematically,

$$\frac{TSME^t(x_{it}, q_{it}, z_{it})}{TSME^s(x_{ks}, q_{ks}, z_{ks})} = \left[\frac{OSME^t(x_{it}, q_{it}, z_{it})}{OSME^s(x_{ks}, q_{ks}, z_{ks})}\right]\left[\frac{OTE^t(x_{it}, q_{it}, z_{it})}{OTE^s(x_{ks}, q_{ks}, z_{ks})}\right]. \qquad (2.20)$$

The first ratio on the right-hand side is an output-oriented scale and mix efficiency index (OSMEI). The second ratio is an output-oriented technical efficiency index (OTEI). In summary, DEA methods can be used to decompose any TFP index into the product of an environment index, a technology index, an output-oriented scale and mix efficiency index, and an output-oriented technical efficiency index, i.e., TFPI = EI × TI × OSMEI × OTEI.

2.6 Stochastic Frontier Analysis

Stochastic frontier analysis (SFA) methods for estimating production frontiers can be traced back to Aigner, et al [1] and Meeusen and van den Broeck [9]. Stochastic frontier models (SFMs) allow for the possibility that some variables involved in the production process are unobserved or measured with error. They also allow for the fact that the functional forms of relevant distance, revenue, cost and/or profit functions are generally unknown. SFMs merely assume that these functions exist.

Output-oriented Models

If the ODF exists, then it is linearly homogeneous in outputs. This means we can write $D_O^t(x_{it}, q_{it}, z_{it}) = q_{1it} D_O^t\left(x_{it}, q_{it}^*, z_{it}\right)$ where $q_{it}^* \equiv q_{it}/q_{1it}$ is a vector of normalized outputs. Equivalently,

$$\ln q_{1it} = -\ln D_O^t(x_{it}, q_{it}^*, z_{it}) - u_{it} \qquad (2.21)$$

where $u_{it} \equiv -\ln OTE^t(x_{it}, q_{it}, z_{it}) \geq 0$ is an output-oriented technical inefficiency effect. If the functional form of the ODF is unknown, then (2.21) can be rewritten as

$$\ln q_{1it} = f^t(x_{it}, q_{it}^*, z_{it}) + v_{it} - u_{it} \qquad (2.22)$$

where $f^t(.)$ is an arbitrary approximating function chosen by the researcher and $v_{it} \equiv -\ln D_O^t(x_{it}, q_{it}^*, z_{it}) - f^t(x_{it}, q_{it}^*, z_{it})$ is an unobserved variable that accounts for functional form errors and other sources of statistical noise. The exact nature of the noise component depends on both the SFM and the unknown ODF. For example, suppose the SFM is

$$\ln q_{1it} = \sum_{j=1}^{J} \alpha_j d_{jit} + \lambda t + \sum_{m=1}^{M} \beta_m \ln x_{mit} - \sum_{n=1}^{N} \xi_n \ln q_{nit}^{*} + v_{it} - u_{it} \qquad (2.23)$$

where d_{jit} is a dummy variable that takes the value 1 if firm i operated in environment j in period t (and 0 otherwise) and $\Sigma_n \xi_n = 1$. If the ODF is given by (2.4), for example, then the noise component in this model is

$$v_{it} = [\ln A(t) - \lambda t] + \left[\sum_{j=1}^{J} \delta_j \ln z_{jit} - \sum_{j=1}^{J} \alpha_j d_{jit} \right] + \left[\sum_{n=1}^{N} \xi_n \ln q_{nit}^{*} - \ln \left(\sum_{n=1}^{N} \gamma_n q_{nit}^{*} \right) \right] \qquad (2.24)$$

The first term on the right-hand side can be viewed as functional form error. The second term can be viewed as a measurement error. The last term is a functional form error.

Maximum Likelihood Estimation

Two of the most common assumptions found in the stochastic frontier literature are:

- **ML1:** u_{it} is an independent $N^{+}(0, \sigma_u^2)$ random variable.
- **ML2:** v_{it} is an independent $N(0, \sigma_v^2)$ random variable.

Here, the term 'independent' means, inter alia, that v_{it} and u_{it} are not correlated with the other explanatory variables or with each other. Assumption ML1 says that u_{it} is a half-normal random variable obtained by truncating the $N(0, \sigma_u^2)$ distribution from below at zero. If ML1 and ML2 are true, then ML estimators for the unknown parameters are consistent.

Decomposing TFP Change

SFA methods can be used to decompose any proper TFP index into a measure of technical efficiency change, a measure of the change in statistical noise, and a combined measure of environmental change, technical change and scale and mix efficiency change. Mathematically,

$$TEPI(x_{ks}, q_{ks}, x_{it}, q_{it}) = \left[\frac{Q(q_{it})}{Q(q_{ks})} \frac{q_{1ks}}{q_{1it}} \frac{\exp[f^{t}(x_{it}, q_{it}^{*}, z_{it})]}{\exp[f^{s}(x_{ks}, q_{ks}^{*}, z_{ks})]} \frac{X(x_{ks})}{X(x_{it})} \right] \times \left[\frac{\exp(-u_{it})}{\exp(-u_{ks})} \right] \left[\frac{\exp(v_{it})}{\exp(v_{ks})} \right] \qquad (2.25)$$

The first term on the right-hand side is an output-oriented environment, technology and scale and mix efficiency index (OETSMEI). The second term is an output-oriented technical efficiency index (OTEI). The final term is a statistical noise index (SNI).

Depending on the precise form of the SFM, finer output-oriented decompositions of proper TFP indices may be available. For example, if the SFM is given by (2.23), then the OETSMEI in (2.25) can be decomposed further into separate measures of environmental change, technical change, and scale and mix efficiency change. Mathematically,

$$\frac{Q(q_{it})}{Q(q_{ks})}\frac{q_{1ks}}{q_{1it}}\frac{\exp[f^{t}(x_{it},q_{it}^{*},z_{it})]}{\exp[f^{s}(x_{ks},q_{ks}^{*},z_{ks})]}\frac{X(x_{ks})}{X(x_{it})}=\left[\frac{\exp\left(\Sigma_{j}\alpha_{j}d_{jit}\right)}{\exp\left(\Sigma_{j}\alpha_{j}d_{jks}\right)}\right]$$

$$\times\left[\frac{\exp(\lambda t)}{\exp(\lambda s)}\right]\times\left[\frac{Q(q_{it})}{Q(q_{ks})}\prod_{n=1}^{N}\left(\frac{q_{nks}}{q_{nit}}\right)^{\xi n}\frac{X(x_{ks})}{X(x_{it})}\prod_{m=1}^{M}\left(\frac{x_{mit}}{x_{mks}}\right)^{\beta m}\right]. \qquad (2.26)$$

The first term on the right-hand side is an environment index (EI). The second term is a technology index (TI). The final term is an output-oriented scale and mix efficiency index (OSMEI). If there is only one output, then the output components in the OSMEI vanish. If there is only one input and $\Sigma_m \beta_m = 1$, then the input components vanish. In summary, depending on the form of the SFM, SFA methods can be used to decompose any TFP index into the product of an environment index, a technology index, an output-oriented scale and mix efficiency index, an output-oriented technical efficiency index, and a statistical noise index, i.e., TFPI = EI × TI × OSMEI × OTEI × SNI.

CHAPTER 3

DATA AND ESTIMATION

This section summarizes the data sources, data cleaning procedures and basic estimation results. The ML estimates reported later in this section are used to derive the detailed estimates of TFP and efficiency change reported in Sections 4 and 5 .

3.1 Data

The research team sourced output, input, and agricultural GDP data from the FAOSTAT service of the FAO. These data cover the agricultural sectors of I = 91 countries for the T = 55 years from 1961 to 2015. The team obtained employment share data from the ILOSTAT service of the ILO; these data only cover the period 2000 to 2014.

The agricultural sector includes divisions 1–5 of the International Standard Industrial Classification (ISIC, revision 3) and includes cultivation of crops, livestock production, forestry, hunting, and fishing. This subsection discusses the countries, the variables and the data cleaning procedures.

Countries

All countries were classified into one of four climate zones (wet temperate, dry temperate, wet tropical/subtropical, and dry tropical/subtropical) and one of four geographical regions (Africa, the Americas, Asia, and Europe). Table 3.1 lists all ninety-one countries and their climate zones and regional classifications. The countries listed in this table include 17 APO member countries, namely Bangladesh, Cambodia, India, Indonesia, Islamic Republic of Iran, Japan, the Republic of Korea, Lao PDR, Malaysia, Mongolia, Nepal, Pakistan, the Philippines, the Republic of China, Sri Lanka, Thailand, and Vietnam (rows corresponding to these countries are marked with an asterisk *). Data for three APO member countries, Fiji, Hong Kong, and Singapore were unavailable or otherwise considered unreliable.

Variables

The research team attempted to measure all the outputs and inputs involved in agricultural production in each of the countries. Wherever possible, variables were disaggregated to a level where all items within any output or input category could be regarded as reasonably homogeneous, e.g., total agricultural output was disaggregated into crop output and livestock output. The research team was careful to distinguish between measures of volume (or quantity), price, and value. The research team assembled data on $N = 3$ outputs (crops, livestock, and greenhouse gas emissions) and $M = 4$ inputs (land, labor, fertilizers, and tractors). All of these variables were normalized to have unit means.

Other inputs such as seeds, pesticides, and machinery other than tractors were unobserved and therefore omitted. This is one source of statistical noise. Characteristics of production environments (e.g., rainfall and temperature) were also unobserved and accounted for by climate dummy variables. This is another source of statistical noise. Descriptive statistics for all variables are reported in Table 3.2. The mean values of the dummy variables give the proportions of observations classified by each climate zone. Thus, for example, 12.1% of countries/observations were in the wet temperate zone.

TABLE 3.1

COUNTRIES, CLIMATES, AND REGIONS

ID	Country	Climate	Region
74	Afghanistan	Dry tropical/subtropical	Asia
75	Algeria	Dry tropical/subtropical	Africa
76	Angola	Dry tropical/subtropical	Africa
12	Argentina	Dry temperate	Americas
13	Australia	Dry temperate	Asia
1	Austria	Wet temperate	Europe
39*	Bangladesh	Wet tropical/subtropical	Asia
14	Belgium-Luxembourg	Dry temperate	Europe
40	Bolivia	Wet tropical/subtropical	Americas
77	Botswana	Dry tropical/subtropical	Africa
41	Brazil	Wet tropical/subtropical	Americas
15	Bulgaria	Dry temperate	Europe
43*	Cambodia	Wet tropical/subtropical	Asia
44	Cameroon	Wet tropical/subtropical	Africa
16	Canada	Dry temperate	Americas
78	Chad	Dry tropical/subtropical	Africa
2	Chile	Wet temperate	Americas
17	PR China	Dry temperate	Asia
69*	ROC	Wet tropical/subtropical	Asia
45	Colombia	Wet tropical/subtropical	Americas
48	Congo	Wet tropical/subtropical	Africa
46	Costa Rica	Wet tropical/subtropical	Americas
42	Cote d'Ivoire	Wet tropical/subtropical	Africa
47	Cuba	Wet tropical/subtropical	Americas
19	Denmark	Dry temperate	Europe
49	Ecuador	Wet tropical/subtropical	Americas
79	Egypt	Dry tropical/subtropical	Africa
50	El Salvador	Wet tropical/subtropical	Americas
20	Finland	Dry temperate	Europe
21	France	Dry temperate	Europe
22	Germany	Dry temperate	Europe
51	Ghana	Wet tropical/subtropical	Africa
23	Greece	Dry temperate	Europe
52	Guatemala	Wet tropical/subtropical	Americas
53	Guinea	Wet tropical/subtropical	Africa
54	Honduras	Wet tropical/subtropical	Americas
24	Hungary	Dry temperate	Europe
80*	India	Dry tropical/subtropical	Asia
55*	Indonesia	Wet tropical/subtropical	Asia
81*	IR Iran	Dry tropical/subtropical	Asia
82	Iraq	Dry tropical/subtropical	Asia
3	Ireland	Wet temperate	Europe
25	Israel	Dry temperate	Asia
26	Italy	Dry temperate	Europe
4*	Japan	Wet temperate	Asia

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ID	Country	Climate	Region
83	Kenya	Dry tropical/subtropical	Africa
8*	ROK	Wet temperate	Asia
56*	Lao PDR	Wet tropical/subtropical	Asia
84	Libya	Dry tropical/subtropical	Africa
57	Madagascar	Wet tropical/subtropical	Africa
58	Malawi	Wet tropical/subtropical	Africa
59*	Malaysia	Wet tropical/subtropical	Asia
85	Mali	Dry tropical/subtropical	Africa
86	Mexico	Dry tropical/subtropical	Americas
27*	Mongolia	Dry temperate	Asia
87	Morocco	Dry tropical/subtropical	Africa
88	Mozambique	Dry tropical/subtropical	Africa
60	Myanmar	Wet tropical/subtropical	Asia
5*	Nepal	Wet temperate	Asia
28	Netherlands	Dry temperate	Europe
6	New Zealand	Wet temperate	Asia
61	Nicaragua	Wet tropical/subtropical	Americas
62	Nigeria	Wet tropical/subtropical	Africa
18	North Korea	Dry temperate	Asia
7	Norway	Wet temperate	Europe
29*	Pakistan	Dry temperate	Asia
63	Panama	Wet tropical/subtropical	Americas
64	Papua New Guinea	Wet tropical/subtropical	Asia
65	Paraguay	Wet tropical/subtropical	Americas
66	Peru	Wet tropical/subtropical	Americas
67*	Philippines	Wet tropical/subtropical	Asia
30	Poland	Dry temperate	Europe
31	Portugal	Dry temperate	Europe
89	South Africa	Dry tropical/subtropical	Africa
32	Spain	Dry temperate	Europe
68*	Sri Lanka	Wet tropical/subtropical	Asia
33	Sweden	Dry temperate	Europe
9	Switzerland	Wet temperate	Europe
34	Syria	Dry temperate	Asia
37	Tanzania	Dry temperate	Africa
70*	Thailand	Wet tropical/subtropical	Asia
35	Tunisia	Dry temperate	Africa
36	Turkey	Dry temperate	Asia
71	Uganda	Wet tropical/subtropical	Africa
10	UK	Wet temperate	Europe
38	USA	Dry temperate	Americas
11	Uruguay	Wet temperate	Americas
72	Venezuela	Wet tropical/subtropical	Americas
73*	Vietnam	Wet tropical/subtropical	Asia
90	Zambia	Dry tropical/subtropical	Africa
91	Zimbabwe	Dry tropical/subtropical	Africa

* APO member country

Data Cleaning

Data on the output and input quantity variables listed in Table 3.2 were downloaded from FAOSTAT. Tractor data from the FAO were incomplete, i.e., there were many missing values. A more complete dataset was constructed using additional tractor data provided by national experts and contained in a report prepared for the APO in 2013. The tractor data contained in the APO 2013 report only ranged from 1980 to 2009. The series needed to be extrapolated in order to correct any missing values and construct a complete time series. This is another source of statistical noise.

Two separate data series for the consumption of fertilizers were available on the FAO website. One series ranged from 1961 to 2002 and the other from 2002 to 2012. Econometric methods were used to test the consistency of the two series for each country. Consistent fertilizer series were consolidated into a single fertilizer series. Otherwise, the more recent data series was used. This is another source of statistical noise.

TABLE 3.2

DESCRIPTIVE STATISTICS FOR SELECTED VARIABLES

Variable		Mean	Std. Dev.	Minimum	Maximum
q_1	Crops	1	2.954	0.002	45.294
q_2	Livestock	1	2.770	0.006	37.959
q_3	Emissions	1	2.242	0.008	18.338
d_1	Wet temperate	0.121	0.326	0	1
d_2	Dry temperate	0.297	0.457	0	1
d_3	Wet tropical/subtropical	0.385	0.487	0	1
d_4	Dry tropical/subtropical	0.198	0.398	0	1
x_1	Land	1	2.141	0.013	13.255
x_2	Labor	1	3.625	0.006	30.490
x_3	Fertilizers	1	3.553	4.3E-05	52.039
x_4	Tractors	1	2.802	2.2E-05	24.613

Cleaning the dataset involved inspecting minima, maxima, scatterplots, and histograms of variables; ratios of variables; residuals obtained from simple regression models; and efficiency estimates obtained from simple DEA models. Records were removed or corrected if any input or output variables took negative values or if essential inputs (e.g., land) took zero values. The number of missing values in the dataset was very low. The research team interpolated missing values using long-term growth rates of the relevant variables. This is another source of statistical noise.

3.2 Estimation

The research team used both DEA and SFA methods to estimate various measures of efficiency. SFA methods were also used to measure TFP change. This section summarizes the main results. The main drawback of DEA methods is that they do not account for measurement errors and other sources of statistical noise. For this reason, the research team used SFA methods to generate the results reported in Sections 4 and 5.

DEA

DEA estimates of TSME, OSME, and OTE for selected countries in selected years are reported in Table 3.3. The interpretation of the estimates is straightforward. For example, the estimates reported in the first row indicate that Afghanistan was only 33.2% efficient in 1961, and that this was entirely due to output-oriented scale and mix inefficiency, i.e., TSME = OSME × OTE = 0.332 × 1 = 0.332. The summary statistics reported at the bottom of Table 3.3 reveal that this pattern of inefficiency was repeated in most countries in most years.

TABLE 3.3

DEA EFFICIENCY ESTIMATES

Country	Year	TSME	OSME	OTE
Afghanistan	1961	0.332	0.332	1.000
Algeria	1961	0.391	0.424	0.921
Angola	1961	0.155	0.155	1.000
Argentina	1961	0.327	0.327	1.000
Australia	1961	0.060	0.060	1.000
Venezuela	1961	0.223	0.229	0.971
Vietnam	1961	0.304	0.304	1.000
Zambia	1961	0.138	0.300	0.461
Zimbabwe	1961	0.372	0.372	1.000
Afghanistan	2015	0.163	0.163	1.000
Algeria	2015	0.488	0.601	0.812
Angola	2015	0.290	0.290	1.000
Argentina	2015	0.511	0.511	1.000
Australia	2015	0.118	0.118	1.000
Venezuela	2015	0.421	0.421	1.000
Vietnam	2015	0.460	0.460	1.000
Zambia	2015	0.176	0.176	1.000
Zimbabwe	2015	0.171	0.298	0.576
Minimum		0.006	0.007	0.317
1st Quartile		0.269	0.318	0.876
Median		0.399	0.448	1.000
Mean		0.427	0.468	0.912
3rd Quartile		0.555	0.604	1.000
Maximum		1.000	1.000	1.000

SFA

ML estimates of the unknown parameters in equation (2.23) are reported in Table 3.4. These estimates are consistent with prior expectations. The relative magnitudes of the estimated intercept parameters are estimates of relative environmental conditions. The lowest (estimated) intercept is −0.0731 for countries in the dry tropics/subtropics (e.g., Afghanistan, Algeria, and Egypt), and the highest intercept is 0.5824 for countries in the wet tropics/subtropics (e.g., Indonesia and Lao PDR). This indicates that farmers in the dry tropics/subtropics operate in the least favorable production environment, and that farmers in the wet tropics/subtropics operate in the most favorable production environment. The coefficient of the time trend indicates that world agriculture has experienced technical progress at an average annual rate of 0.56%. The coefficients of the log-inputs sum to 0.961, indicating that the production frontier exhibits slightly decreasing returns to scale. The coefficients of the log-normalized outputs indicate that the shadow revenue shares of livestock, crops and greenhouse gas emissions are 0.5103, 0.1084, and 0.3813 respectively. Finally, the estimate of $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ reported in Table 3.4 is significantly different from zero at the 1% level. This indicates that there is technical inefficiency in this dataset. Estimates of OTE for selected countries in selected years are reported in Table 3.5.

TABLE 3.4

ML PARAMETER ESTIMATES

Parameter	Variable	Estimate	St. Err.	*p*-value
α_1	Wet temperate	0.5171	0.0313	< 0.0001
α_2	Dry temperate	0.5311	0.0316	< 0.0001
α_3	Wet tropical/subtropical	0.5824	0.0295	< 0.0001
α_4	Dry tropical/subtropical	-0.0731	0.0314	0.0201
λ	Time	0.0056	0.0004	< 0.0001
β_1	Land	0.2507	0.0057	< 0.0001
β_2	Labor	0.4123	0.0069	< 0.0001
β_3	Fertilizers	0.1770	0.0050	< 0.0001
β_4	Tractors	0.1215	0.0055	< 0.0001
ξ_2	Normalized crops	0.1084	0.0132	< 0.0001
ξ_3	Normalized emissions	0.3813	0.0111	< 0.0001
$\sigma^2 = \sigma_v^2 + \sigma_\upsilon^2$		0.2301	0.0149	< 0.0001
$\gamma = \sigma_\upsilon^2 /(\sigma_v^2 + \sigma_\upsilon^2)$		0.4226	0.0692	< 0.0001

TFP

The TFP index used in this project is an additive index. Additive TFP index numbers can be computed using any nonnegative measures of relative value as weights. The ML estimates of ξ_1 and ξ_2 in (2.23) are both positive. These estimates are therefore used as output weights. The estimate of ξ_3 is also positive. However, greenhouse gas emissions are viewed as an undesirable output (equivalently, production of greenhouse gas emissions is regarded as an unproductive activity) and so this output is given a weight of zero. Thus, the output aggregator function used to compute the TFP index in this project is $Q(q_{it}) = 0.5103q_{1it} + 0.1084q_{2it}$. On the input side, the ML estimates of

$\beta_1,\ldots,\beta_4$ reported in Table 3.3 are all positive. These estimates are therefore used as input weights. Thus, the input aggregator function used in this project is $X(x_{it}) = 0.2507x_{1it} + 0.4123x_{2it} + 0.1770x_{3it} + 0.1215x_{4it}$.

DEA and SFA methods were both used to decompose the TFP index into various measures of environment change, technical change, and efficiency change. The DEA results were generally similar to the SFA results. This is illustrated in Figure 3.1, with the panels in this figure comparing TFP and efficiency in Vietnam over the sample period with TFP and efficiency in Australia in 1961. For some countries in Africa and Asia, where the data often appeared to contain large measurement errors, the DEA results sometimes differed from the SFA results. This is illustrated in Figure 3.2, with the panels in this figure comparing TFP and efficiency in Mongolia over the sample period with TFP and efficiency in Australia in 1961. The rest of this report focuses on the SFA results. SFA results should generally be preferred over DEA results in the presence of measurement errors and other sources of statistical noise.

TABLE 3.5

SFA EFFICIENCY ESTIMATES

Country	Year	OTE
Afghanistan	1961	0.906
Algeria	1961	0.710
Angola	1961	0.816
Argentina	1961	0.904
Australia	1961	0.803
Venezuela	1961	0.803
Vietnam	1961	0.844
Zambia	1961	0.677
Zimbabwe	1961	0.768
Afghanistan	2015	0.796
Algeria	2015	0.800
Angola	2015	0.866
Argentina	2015	0.902
Australia	2015	0.863
Venezuela	2015	0.828
Vietnam	2015	0.803
Zambia	2015	0.794
Zimbabwe	2015	0.718
Minimum		0.343
1st Quartile		0.764
Median		0.804
Mean		0.793
3rd Quartile		0.834
Maximum		0.918

FIGURE 3.1

COMPONENTS OF TFP CHANGE IN VIETNAM (CF. AUSTRALIA IN 1961)

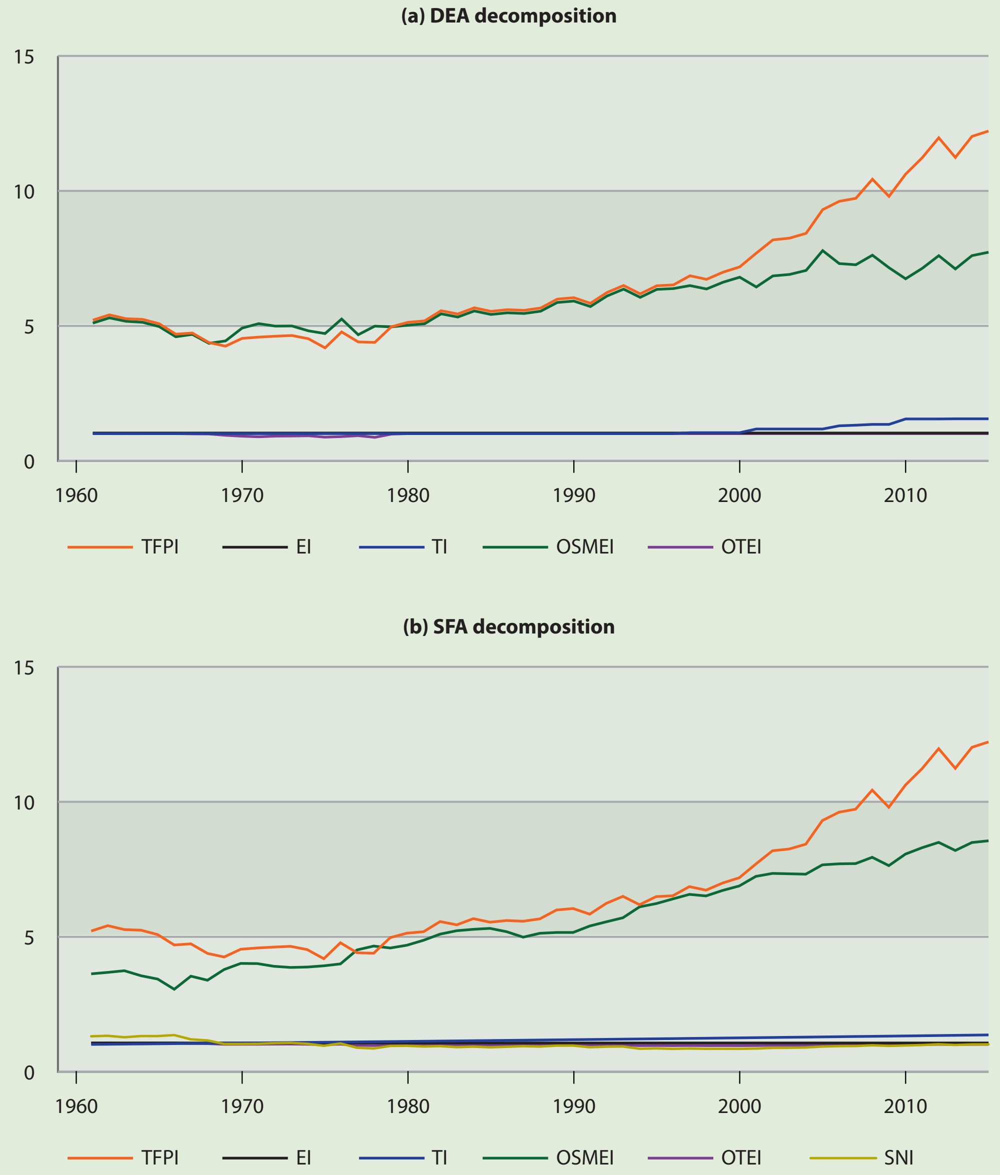
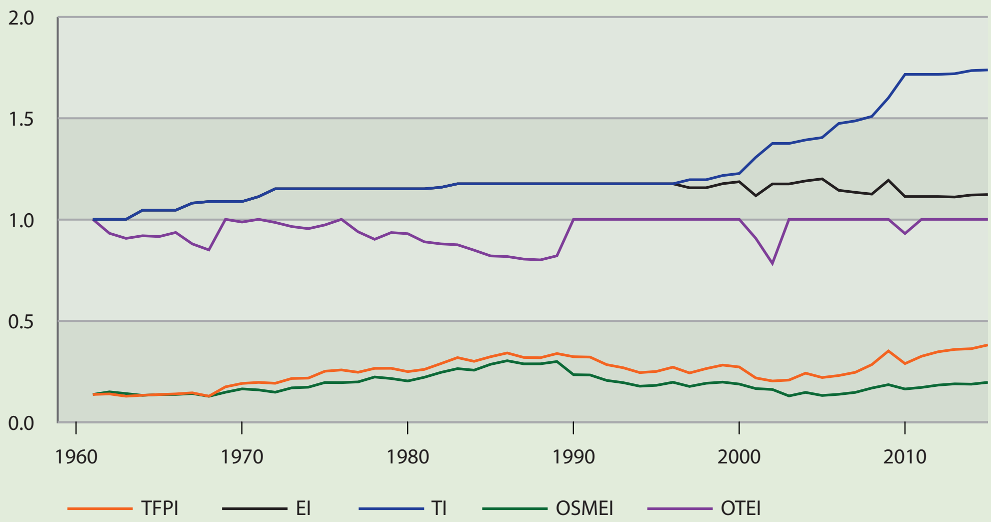


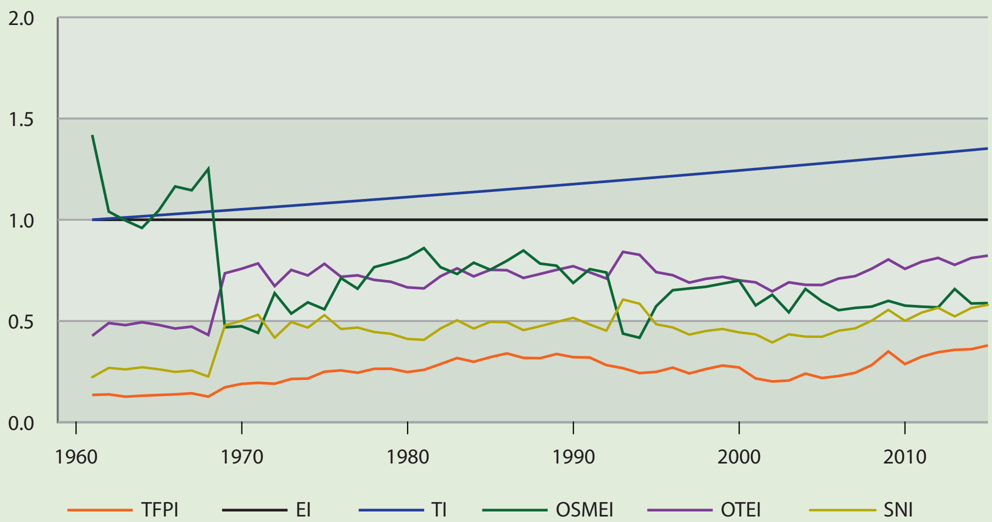
FIGURE 3.2

COMPONENTS OF TFP CHANGE IN MONGOLIA (CF. AUSTRALIA IN 1961)

(a) DEA decomposition



(b) SFA decomposition



CHAPTER 4
PRODUCTIVITY CHANGE BY REGION

This section reports estimates of average productivity and efficiency changes in Africa, the Americas, Asia, and Europe. The focus is on measures of land, labor, capital, and total factor productivity (TFP) change. The measure of TFP change is the additive TFP index discussed in Section 3.2. The averages reported in this section are calculated as unweighted geometric averages of the country-specific results.

4.1 Africa

Figure 4.1 reports average changes in productivity in Africa from 1961 to 2015. The index numbers used to construct this figure are reported in Table 4.1. Panel (a) in Figure 4.1 indicates that average land productivity increased steadily, and much faster than labor productivity, over the sample period. In 2015, average land (respectively labor) productivity was 3.685 (respectively 1.734) times higher than it had been in 1961. Panel (a) also indicates that average capital productivity fell in the first half of the sample period before recovering slightly in the second half. In 1984 (respectively 2015), average capital productivity was 67.6% (respectively 30.8%) lower than it had been in 1961. Panel (b) in Figure 4.1 indicates that average TFP was 2.414 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$\begin{aligned} \text{TFPI} &= \text{EI} \times \text{TI} \times \text{OSMEI} \times \text{OTEI} \times \text{SNI} \\ &= 1 \times 1.352 \times 1.810 \times 1.004 \times 0.983 \\ &= 2.414 \end{aligned}$$

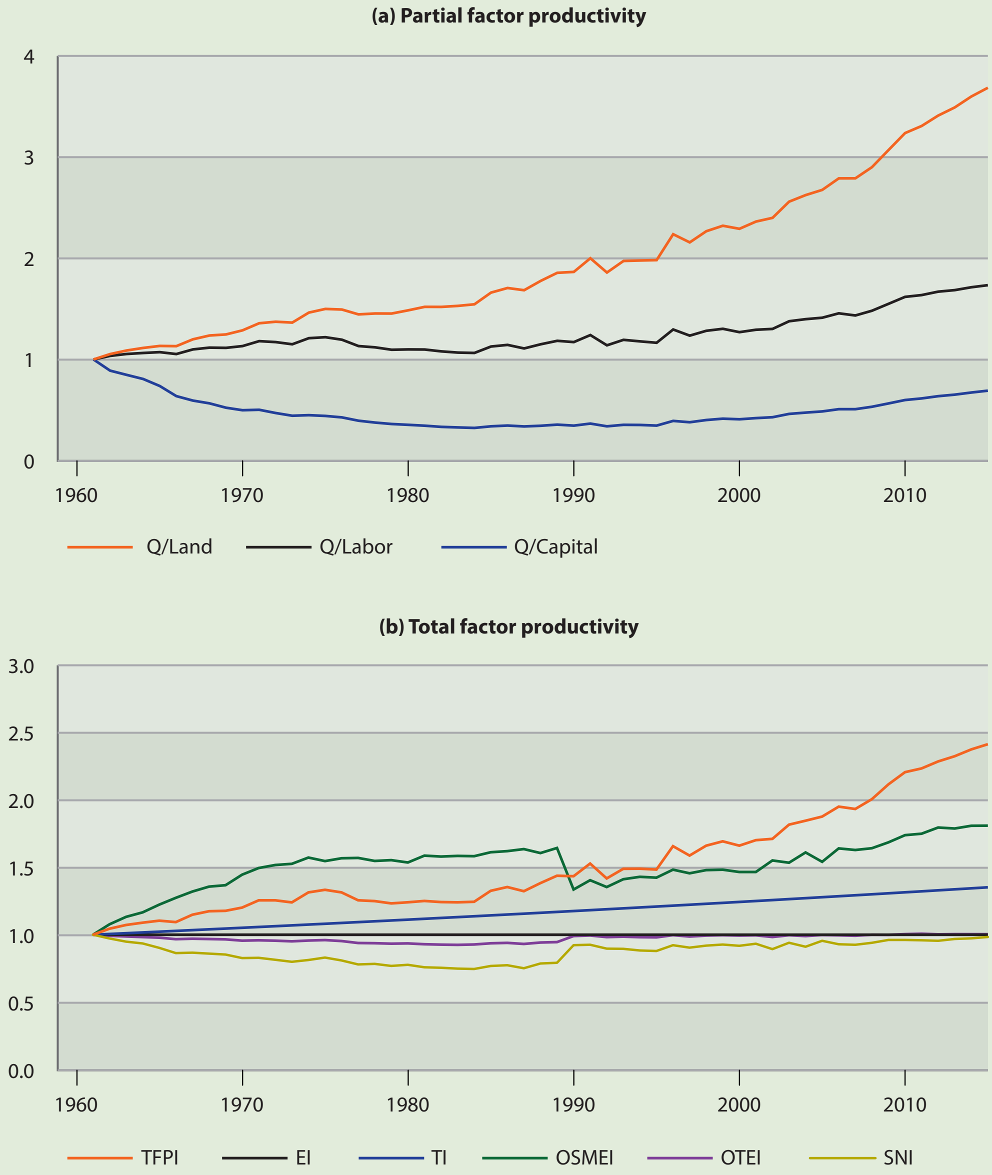
This decomposition indicates that, on average, (i) changes in the production environment (the EI component) had no impact on measured TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to an 81% increase in TFP; (iv) changes in technical efficiency (the OTEI component) had a negligible impact on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) also had a negligible impact on TFP.

4.2 The Americas

Figure 4.2 reports average changes in productivity in the Americas from 1961 to 2015. The index numbers used to construct this figure are reported in Table 4.2. Panel (a) in Figure 4.2 indicates that average land and labor productivity increased steadily and at almost exactly the same rate over the sample period. In 2015, average land (respectively labor) productivity was 3.290 (respectively 3.281) times higher than it had been in 1961. Panel (a) also indicates that average capital productivity fell in the first half of the sample period before fully recovering in the second half. In 1987 (respectively 2015), average capital productivity was 41.8% lower (respectively 5.3% higher) than it had been in 1961. Panel (b) in Figure 4.2 indicates that average TFP was 2.217 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

FIGURE 4.1

AVERAGE PRODUCTIVITY CHANGE IN AFRICA (CF. AFRICA IN 1961)



$$\begin{aligned} TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\ &= 1 \times 1.352 \times 1.597 \times 1.000 \times 1.027 \\ &= 2.217 \end{aligned}$$

This decomposition indicates that, on average, (i) changes in the production environment (the EI component) had no impact on measured TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 59.7% increase in TFP; (iv) changes in technical efficiency (the OTEI component) had no impact on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) had a negligible impact on TFP.

TABLE 4.1

AVERAGE PRODUCTIVITY CHANGE IN AFRICA (CF. AFRICA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.053	1.035	0.890	1.045	1	1.006	1.077	0.992	0.972
1963	1.089	1.054	0.848	1.072	1	1.011	1.133	0.987	0.949
1964	1.114	1.064	0.807	1.090	1	1.017	1.166	0.983	0.935
1965	1.134	1.072	0.738	1.104	1	1.023	1.223	0.978	0.902
1966	1.132	1.053	0.638	1.094	1	1.028	1.274	0.967	0.864
1967	1.199	1.099	0.594	1.148	1	1.034	1.321	0.970	0.867
1968	1.237	1.117	0.566	1.174	1	1.040	1.357	0.968	0.860
1969	1.247	1.115	0.523	1.177	1	1.046	1.368	0.966	0.853
1970	1.288	1.132	0.499	1.201	1	1.052	1.446	0.956	0.827
1971	1.358	1.181	0.503	1.255	1	1.057	1.495	0.958	0.828
1972	1.373	1.172	0.471	1.255	1	1.063	1.518	0.956	0.814
1973	1.364	1.150	0.444	1.240	1	1.069	1.526	0.951	0.799
1974	1.463	1.210	0.449	1.314	1	1.075	1.573	0.957	0.812
1975	1.500	1.220	0.442	1.333	1	1.081	1.547	0.960	0.830
1976	1.493	1.195	0.427	1.314	1	1.087	1.568	0.953	0.809
1977	1.445	1.132	0.395	1.255	1	1.093	1.570	0.938	0.779
1978	1.454	1.120	0.376	1.250	1	1.100	1.548	0.937	0.784
1979	1.454	1.096	0.362	1.233	1	1.106	1.554	0.934	0.768
1980	1.486	1.099	0.354	1.241	1	1.112	1.536	0.935	0.777
1981	1.520	1.098	0.345	1.251	1	1.118	1.587	0.929	0.758
1982	1.520	1.080	0.334	1.242	1	1.124	1.580	0.926	0.755
1983	1.530	1.068	0.328	1.240	1	1.131	1.585	0.925	0.748
1984	1.545	1.065	0.324	1.245	1	1.137	1.583	0.927	0.746
1985	1.661	1.128	0.339	1.326	1	1.143	1.612	0.936	0.768
1986	1.706	1.144	0.347	1.354	1	1.150	1.621	0.939	0.773
1987	1.684	1.109	0.338	1.323	1	1.156	1.636	0.931	0.751
1988	1.777	1.150	0.345	1.383	1	1.163	1.606	0.942	0.786
1989	1.856	1.184	0.356	1.438	1	1.169	1.644	0.945	0.792
1990	1.865	1.172	0.346	1.434	1	1.176	1.335	0.990	0.922
1991	2.000	1.241	0.366	1.528	1	1.182	1.405	0.994	0.926
1992	1.859	1.140	0.339	1.418	1	1.189	1.354	0.982	0.897
1993	1.974	1.194	0.354	1.489	1	1.196	1.412	0.985	0.895
1994	1.978	1.179	0.353	1.490	1	1.202	1.430	0.982	0.883
1995	1.982	1.165	0.346	1.483	1	1.209	1.424	0.980	0.879
1996	2.238	1.296	0.393	1.657	1	1.216	1.483	0.997	0.922
1997	2.157	1.235	0.379	1.587	1	1.223	1.456	0.987	0.904
1998	2.267	1.283	0.401	1.661	1	1.229	1.479	0.993	0.919
1999	2.322	1.303	0.415	1.693	1	1.236	1.483	0.996	0.927
2000	2.291	1.270	0.409	1.661	1	1.243	1.466	0.993	0.918
2001	2.363	1.294	0.420	1.702	1	1.250	1.466	0.995	0.933
2002	2.399	1.302	0.429	1.712	1	1.257	1.551	0.983	0.893
2003	2.560	1.378	0.462	1.817	1	1.264	1.534	0.996	0.940
2004	2.625	1.399	0.475	1.846	1	1.271	1.611	0.990	0.911
2005	2.676	1.413	0.486	1.877	1	1.278	1.541	0.998	0.955
2006	2.790	1.456	0.509	1.951	1	1.286	1.641	0.995	0.929
2007	2.790	1.435	0.509	1.933	1	1.293	1.629	0.992	0.925

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Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
2008	2.900	1.482	0.533	2.006	1	1.300	1.642	1.000	0.940
2009	3.069	1.550	0.565	2.116	1	1.307	1.686	0.999	0.961
2010	3.237	1.619	0.599	2.207	1	1.315	1.739	1.004	0.961
2011	3.307	1.637	0.615	2.234	1	1.322	1.750	1.007	0.959
2012	3.410	1.670	0.637	2.286	1	1.329	1.796	1.003	0.955
2013	3.491	1.685	0.652	2.325	1	1.337	1.788	1.004	0.968
2014	3.599	1.714	0.673	2.376	1	1.344	1.809	1.004	0.973
2015	3.685	1.734	0.692	2.414	1	1.352	1.810	1.004	0.983

FIGURE 4.2

AVERAGE PRODUCTIVITY CHANGE IN THE AMERICAS (CF. THE AMERICAS IN 1961)

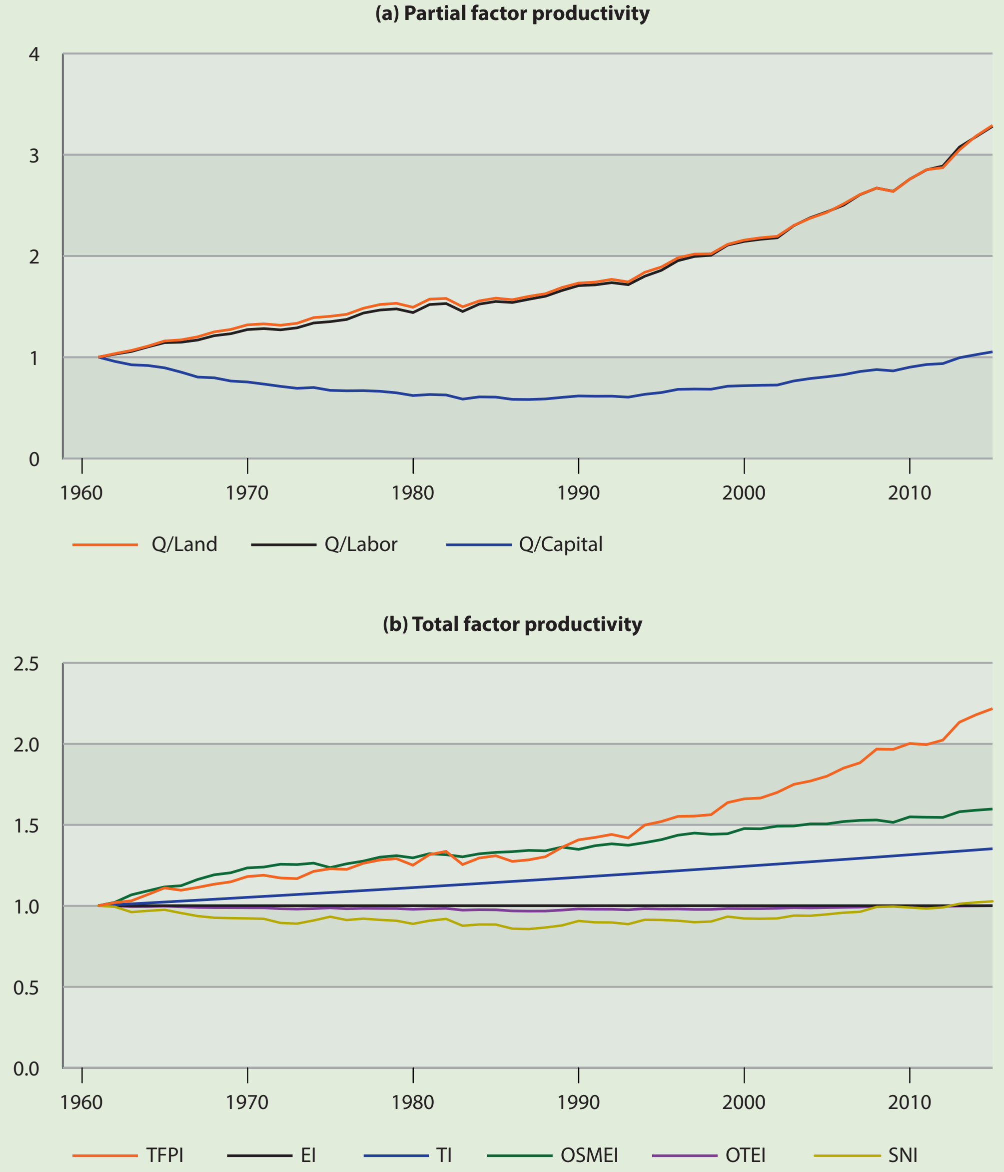

TABLE 4.2

AVERAGE PRODUCTIVITY CHANGE IN THE AMERICAS (CF. THE AMERICAS IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.035	1.030	0.958	1.019	1	1.006	1.021	0.999	0.993
1963	1.067	1.056	0.925	1.030	1	1.011	1.067	0.994	0.961
1964	1.109	1.102	0.917	1.069	1	1.017	1.092	0.994	0.968
1965	1.160	1.144	0.895	1.110	1	1.023	1.116	0.997	0.975
1966	1.171	1.148	0.852	1.096	1	1.028	1.124	0.993	0.955
1967	1.201	1.169	0.803	1.113	1	1.034	1.162	0.989	0.936
1968	1.250	1.212	0.796	1.133	1	1.040	1.191	0.988	0.926
1969	1.274	1.232	0.764	1.147	1	1.046	1.204	0.988	0.923
1970	1.320	1.273	0.755	1.180	1	1.052	1.233	0.987	0.922
1971	1.329	1.282	0.734	1.188	1	1.057	1.239	0.987	0.919
1972	1.315	1.270	0.711	1.171	1	1.063	1.256	0.982	0.893
1973	1.335	1.290	0.692	1.167	1	1.069	1.254	0.979	0.889
1974	1.391	1.338	0.700	1.212	1	1.075	1.263	0.982	0.909
1975	1.404	1.351	0.672	1.228	1	1.081	1.235	0.987	0.932
1976	1.424	1.373	0.668	1.224	1	1.087	1.259	0.981	0.912
1977	1.483	1.436	0.669	1.262	1	1.093	1.275	0.984	0.920
1978	1.520	1.466	0.663	1.282	1	1.100	1.300	0.983	0.913
1979	1.532	1.477	0.647	1.291	1	1.106	1.309	0.983	0.907
1980	1.493	1.440	0.621	1.250	1	1.112	1.296	0.978	0.888
1981	1.573	1.520	0.631	1.315	1	1.118	1.321	0.981	0.907
1982	1.580	1.530	0.626	1.336	1	1.124	1.315	0.984	0.918
1983	1.498	1.451	0.586	1.254	1	1.131	1.302	0.973	0.876
1984	1.556	1.524	0.607	1.295	1	1.137	1.321	0.975	0.884
1985	1.583	1.550	0.605	1.309	1	1.143	1.329	0.975	0.884
1986	1.567	1.540	0.583	1.274	1	1.150	1.334	0.968	0.858
1987	1.601	1.572	0.582	1.283	1	1.156	1.342	0.967	0.856
1988	1.627	1.602	0.587	1.303	1	1.163	1.339	0.967	0.865
1989	1.689	1.659	0.603	1.360	1	1.169	1.362	0.973	0.878
1990	1.732	1.707	0.617	1.407	1	1.176	1.348	0.980	0.906
1991	1.742	1.714	0.614	1.422	1	1.182	1.370	0.978	0.897
1992	1.769	1.736	0.614	1.440	1	1.189	1.382	0.978	0.896
1993	1.743	1.716	0.605	1.418	1	1.196	1.374	0.975	0.886
1994	1.839	1.800	0.633	1.498	1	1.202	1.390	0.982	0.913
1995	1.891	1.858	0.650	1.520	1	1.209	1.408	0.979	0.912
1996	1.982	1.953	0.682	1.551	1	1.216	1.435	0.980	0.907

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Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1997	2.018	1.995	0.685	1.554	1	1.223	1.449	0.977	0.898
1998	2.021	2.007	0.683	1.562	1	1.229	1.441	0.977	0.902
1999	2.115	2.107	0.713	1.637	1	1.236	1.445	0.983	0.933
2000	2.157	2.144	0.718	1.660	1	1.243	1.477	0.982	0.921
2001	2.180	2.165	0.722	1.665	1	1.250	1.475	0.982	0.919
2002	2.194	2.179	0.725	1.700	1	1.257	1.492	0.984	0.921
2003	2.302	2.299	0.765	1.749	1	1.264	1.492	0.987	0.939
2004	2.373	2.378	0.789	1.770	1	1.271	1.505	0.986	0.938
2005	2.431	2.436	0.807	1.800	1	1.278	1.505	0.988	0.947
2006	2.514	2.502	0.827	1.850	1	1.286	1.520	0.990	0.957
2007	2.608	2.606	0.859	1.883	1	1.293	1.527	0.991	0.962
2008	2.671	2.671	0.877	1.967	1	1.300	1.529	0.997	0.992
2009	2.637	2.639	0.864	1.966	1	1.307	1.515	0.998	0.995
2010	2.758	2.759	0.901	2.002	1	1.315	1.549	0.995	0.989
2011	2.852	2.850	0.927	1.995	1	1.322	1.547	0.993	0.982
2012	2.872	2.888	0.937	2.023	1	1.329	1.545	0.995	0.989
2013	3.048	3.075	0.994	2.134	1	1.337	1.581	0.998	1.012
2014	3.184	3.178	1.024	2.179	1	1.344	1.590	0.999	1.021
2015	3.290	3.281	1.053	2.217	1	1.352	1.597	1.000	1.027

4.3 Asia

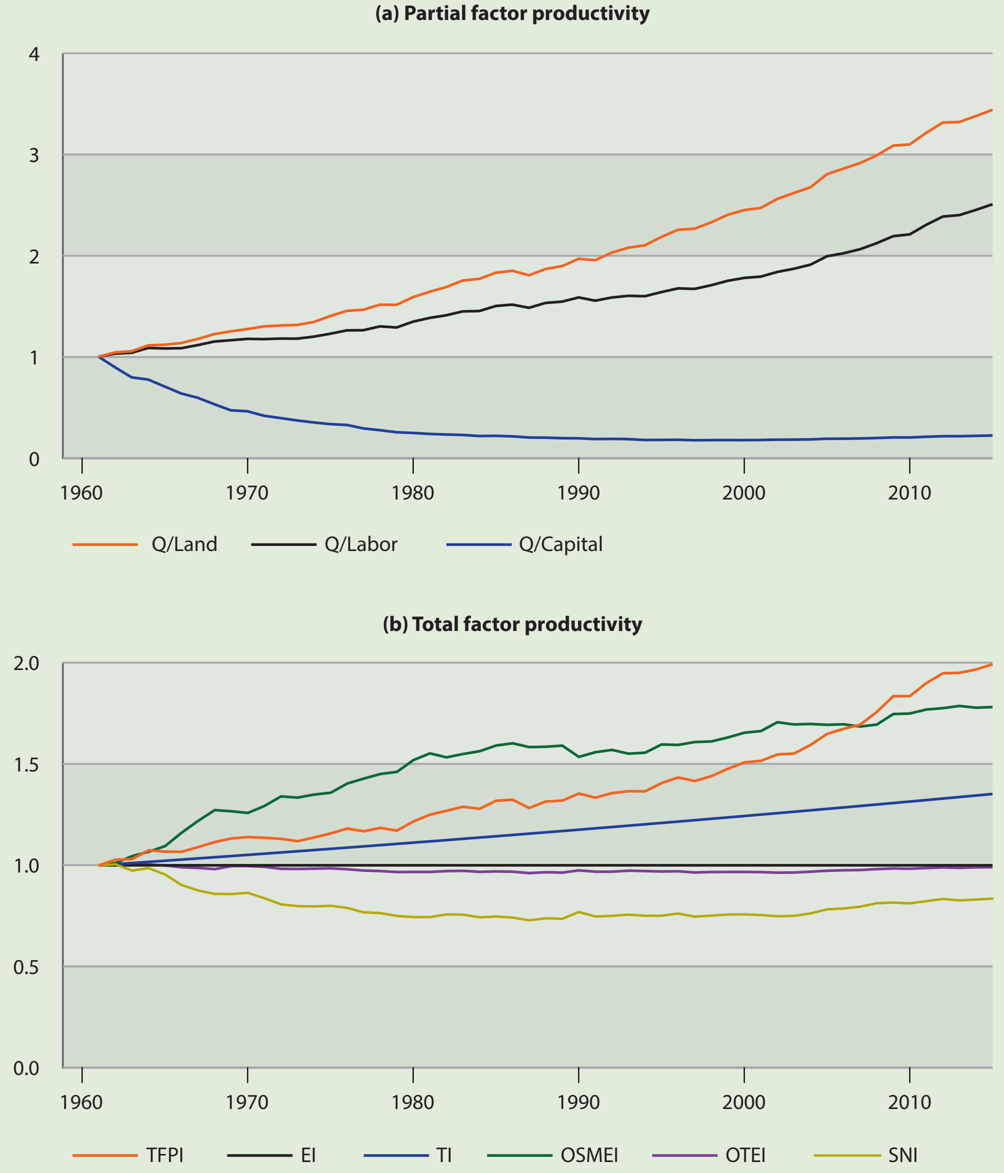
Figure 4.3 reports average changes in measured productivity in Asia from 1961 to 2015. The index numbers used to construct this figure are reported in Table 4.3. Panel (a) in Figure 4.3 indicates that average land productivity increased steadily, and somewhat faster than labor productivity, over the sample period. In 2015, the measure of average land (respectively labor) productivity was 3.442 (respectively 2.507) times higher than it had been in 1961. Panel (a) also indicates that average capital productivity fell in the first half of the sample period and remained relatively low. In 2015, the measure of average capital productivity was 77.9% lower than it had been in 1961. Panel (b) in Figure 4.3 indicates that average TFP was almost twice as high in 2015 as it had been in 1961. The breakdown of this increase is as follows:

$$\begin{aligned} TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\ &= 1 \times 1.352 \times 1.781 \times 0.991 \times 0.835 \\ &= 1.992 \end{aligned}$$

This decomposition indicates that, on average, (i) changes in the production environment (the EI component) had no impact on measured TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 78.1% increase in TFP; (iv) changes in technical efficiency (the OTEI component) had a negligible impact on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) led to a 16.5% fall in measured TFP.

FIGURE 4.3

AVERAGE PRODUCTIVITY CHANGE IN ASIA (CF. ASIA IN 1961))



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AVERAGE PRODUCTIVITY CHANGE IN ASIA (CF. ASIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.042	1.029	0.895	1.028	1	1.006	1.011	1.006	1.005
1963	1.054	1.038	0.795	1.030	1	1.011	1.045	1.001	0.974
1964	1.112	1.086	0.774	1.074	1	1.017	1.067	1.005	0.986
1965	1.118	1.081	0.704	1.067	1	1.023	1.095	0.999	0.954
1966	1.135	1.084	0.635	1.067	1	1.028	1.161	0.990	0.902
1967	1.176	1.115	0.594	1.090	1	1.034	1.220	0.987	0.876

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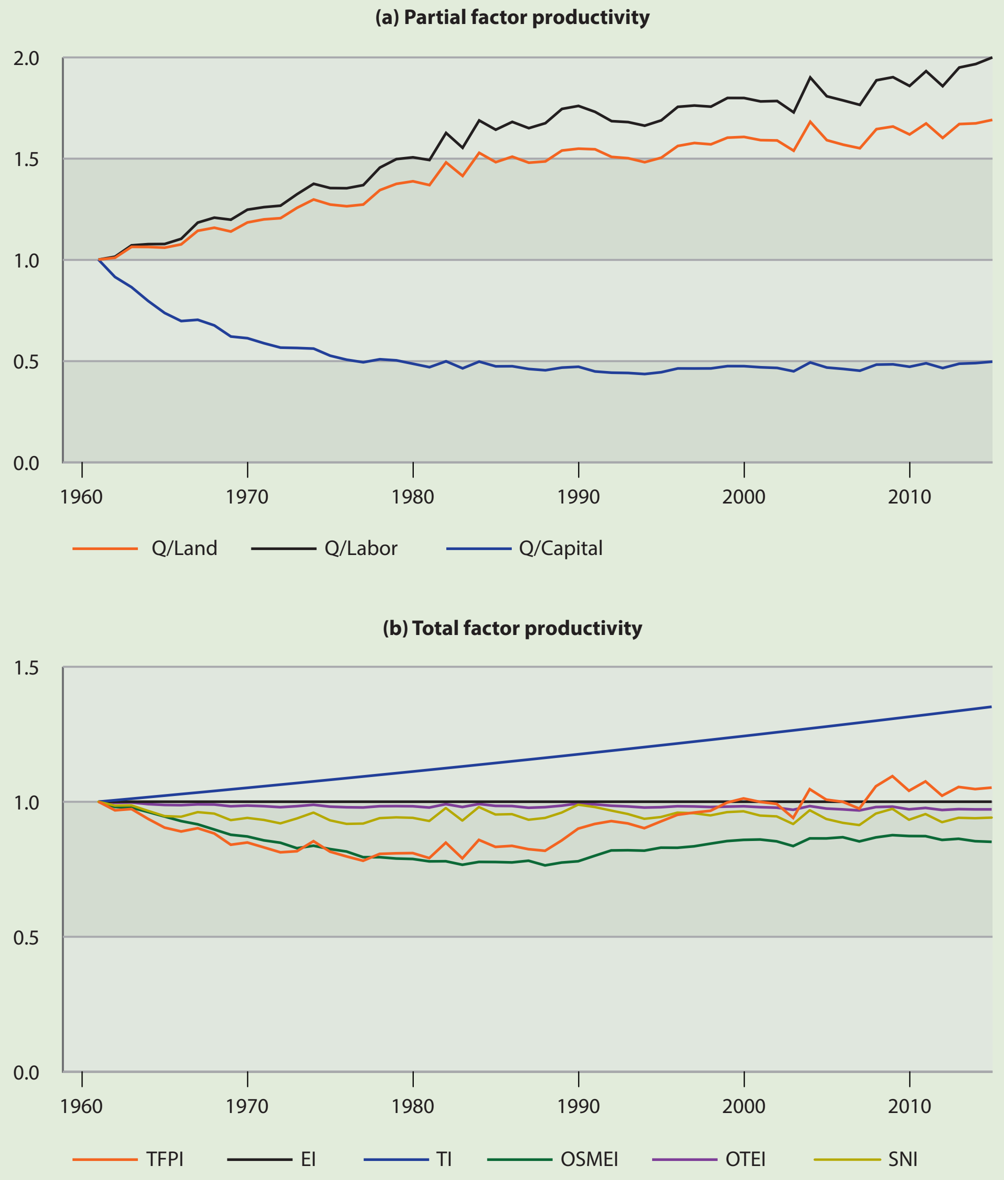
Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1968	1.224	1.150	0.529	1.115	1	1.040	1.272	0.981	0.859
1969	1.251	1.163	0.470	1.132	1	1.046	1.267	0.996	0.858
1970	1.273	1.176	0.460	1.139	1	1.052	1.258	0.996	0.864
1971	1.300	1.174	0.415	1.136	1	1.057	1.293	0.992	0.837
1972	1.309	1.179	0.393	1.130	1	1.063	1.340	0.983	0.807
1973	1.314	1.178	0.369	1.119	1	1.069	1.334	0.982	0.799
1974	1.343	1.198	0.350	1.137	1	1.075	1.349	0.983	0.797
1975	1.402	1.227	0.333	1.157	1	1.081	1.358	0.985	0.800
1976	1.453	1.260	0.325	1.181	1	1.087	1.403	0.980	0.790
1977	1.464	1.262	0.290	1.168	1	1.093	1.428	0.974	0.768
1978	1.515	1.300	0.273	1.185	1	1.100	1.451	0.972	0.764
1979	1.513	1.289	0.252	1.171	1	1.106	1.461	0.967	0.750
1980	1.589	1.346	0.246	1.216	1	1.112	1.519	0.967	0.744
1981	1.641	1.383	0.236	1.250	1	1.118	1.552	0.967	0.745
1982	1.688	1.409	0.230	1.269	1	1.124	1.533	0.971	0.758
1983	1.753	1.448	0.226	1.289	1	1.131	1.549	0.973	0.756
1984	1.770	1.451	0.215	1.279	1	1.137	1.563	0.968	0.743
1985	1.830	1.501	0.217	1.319	1	1.143	1.591	0.970	0.748
1986	1.849	1.515	0.212	1.323	1	1.150	1.602	0.968	0.742
1987	1.805	1.483	0.201	1.283	1	1.156	1.583	0.962	0.729
1988	1.867	1.532	0.199	1.315	1	1.163	1.585	0.966	0.739
1989	1.895	1.544	0.194	1.319	1	1.169	1.591	0.964	0.736
1990	1.968	1.586	0.193	1.354	1	1.176	1.535	0.975	0.769
1991	1.954	1.554	0.185	1.334	1	1.182	1.558	0.968	0.747
1992	2.029	1.585	0.187	1.356	1	1.189	1.569	0.968	0.750
1993	2.078	1.602	0.185	1.366	1	1.196	1.551	0.973	0.757
1994	2.101	1.598	0.176	1.365	1	1.202	1.556	0.972	0.751
1995	2.184	1.639	0.177	1.406	1	1.209	1.596	0.969	0.751
1996	2.255	1.675	0.178	1.433	1	1.216	1.594	0.970	0.762
1997	2.265	1.670	0.173	1.416	1	1.223	1.608	0.965	0.747
1998	2.328	1.706	0.175	1.440	1	1.229	1.611	0.967	0.752
1999	2.403	1.750	0.175	1.476	1	1.236	1.631	0.967	0.757
2000	2.450	1.779	0.174	1.508	1	1.243	1.654	0.967	0.758
2001	2.471	1.792	0.176	1.516	1	1.250	1.662	0.966	0.755
2002	2.560	1.838	0.179	1.547	1	1.257	1.706	0.964	0.749
2003	2.619	1.869	0.180	1.551	1	1.264	1.695	0.965	0.750
2004	2.675	1.910	0.182	1.594	1	1.271	1.698	0.968	0.763
2005	2.804	1.993	0.188	1.648	1	1.278	1.693	0.973	0.782
2006	2.860	2.023	0.189	1.673	1	1.286	1.696	0.975	0.787
2007	2.915	2.063	0.191	1.694	1	1.293	1.685	0.977	0.796
2008	2.990	2.122	0.196	1.756	1	1.300	1.694	0.981	0.813
2009	3.087	2.192	0.201	1.834	1	1.307	1.746	0.984	0.816
2010	3.099	2.209	0.201	1.835	1	1.315	1.749	0.983	0.812
2011	3.214	2.305	0.208	1.899	1	1.322	1.769	0.987	0.823
2012	3.316	2.386	0.213	1.948	1	1.329	1.776	0.989	0.834
2013	3.321	2.400	0.214	1.950	1	1.337	1.787	0.987	0.827
2014	3.380	2.451	0.217	1.966	1	1.344	1.778	0.990	0.831
2015	3.442	2.507	0.221	1.992	1	1.352	1.781	0.991	0.835

4.4 Europe

Figure 4.4 reports average changes in productivity in Europe from 1961 to 2015. The index numbers used to construct this figure are reported in Table 4.4. Panel (a) in Figure 4.4 indicates that average land productivity increased steadily, but at a slightly lower rate than average labor productivity, over the sample period. In 2015, average land (respectively labor) productivity was 1.692 (respectively 2.001) times higher than it had been in 1961. Panel (a) also indicates that average capital productivity fell in the first half of the sample period and remained relatively low. In 2015, average capital productivity was only half of what it had been in 1961. Panel (b) in Figure 4.4 indicates that average TFP was only 5.2% higher in 2015 than it had been in 1961. This very modest increase is decomposed as follows:

FIGURE 4.4

AVERAGE PRODUCTIVITY CHANGE IN EUROPE (CF. EUROPE IN 1961)



$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 0.851 \times 0.972 \times 0.941$$
$$= 1.052$$

This decomposition indicates that, on average, (i) changes in the production environment (the EI component) had no impact on measured TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) a fall in scale and mix efficiency (the OSMEI component) led to a 14.9% fall in TFP; (iv) changes in technical efficiency (the OTEI component) led to a 2.8% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) led to a 5.9% fall in TFP.

TABLE 4.4

AVERAGE PRODUCTIVITY CHANGE IN EUROPE (CF. EUROPE IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.009	1.014	0.914	0.968	1	1.006	0.981	0.996	0.986
1963	1.063	1.071	0.864	0.973	1	1.011	0.978	0.997	0.986
1964	1.063	1.077	0.796	0.936	1	1.017	0.962	0.991	0.966
1965	1.059	1.077	0.736	0.904	1	1.023	0.945	0.988	0.947
1966	1.075	1.103	0.696	0.890	1	1.028	0.928	0.987	0.944
1967	1.143	1.183	0.702	0.902	1	1.034	0.916	0.990	0.961
1968	1.158	1.208	0.674	0.882	1	1.040	0.897	0.990	0.956
1969	1.139	1.198	0.619	0.841	1	1.046	0.878	0.983	0.932
1970	1.184	1.247	0.611	0.849	1	1.052	0.871	0.986	0.940
1971	1.199	1.260	0.586	0.831	1	1.057	0.857	0.983	0.932
1972	1.205	1.267	0.564	0.812	1	1.063	0.848	0.980	0.920
1973	1.257	1.324	0.563	0.816	1	1.069	0.828	0.984	0.938
1974	1.298	1.376	0.559	0.854	1	1.075	0.837	0.989	0.960
1975	1.273	1.354	0.524	0.815	1	1.081	0.825	0.982	0.931
1976	1.264	1.354	0.504	0.797	1	1.087	0.815	0.979	0.918
1977	1.273	1.369	0.492	0.781	1	1.093	0.794	0.979	0.919
1978	1.344	1.456	0.507	0.807	1	1.100	0.794	0.983	0.939
1979	1.375	1.498	0.501	0.809	1	1.106	0.789	0.984	0.942
1980	1.388	1.506	0.484	0.810	1	1.112	0.788	0.983	0.940
1981	1.369	1.493	0.467	0.791	1	1.118	0.779	0.978	0.928
1982	1.481	1.627	0.497	0.848	1	1.124	0.779	0.991	0.977
1983	1.414	1.554	0.462	0.790	1	1.131	0.766	0.980	0.930
1984	1.529	1.689	0.495	0.859	1	1.137	0.777	0.992	0.980
1985	1.482	1.643	0.472	0.833	1	1.143	0.777	0.985	0.952
1986	1.510	1.682	0.472	0.836	1	1.150	0.775	0.984	0.954
1987	1.480	1.651	0.459	0.824	1	1.156	0.781	0.978	0.933
1988	1.486	1.675	0.452	0.818	1	1.163	0.764	0.980	0.940
1989	1.540	1.746	0.465	0.856	1	1.169	0.775	0.985	0.960
1990	1.549	1.761	0.470	0.900	1	1.176	0.779	0.994	0.989
1991	1.546	1.732	0.446	0.918	1	1.182	0.800	0.990	0.980

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Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1992	1.509	1.686	0.440	0.928	1	1.189	0.819	0.985	0.967
1993	1.502	1.681	0.439	0.920	1	1.196	0.820	0.983	0.955
1994	1.482	1.663	0.433	0.902	1	1.202	0.819	0.978	0.937
1995	1.505	1.689	0.442	0.927	1	1.209	0.830	0.980	0.943
1996	1.563	1.757	0.461	0.951	1	1.216	0.829	0.983	0.960
1997	1.577	1.763	0.461	0.960	1	1.223	0.835	0.982	0.957
1998	1.571	1.757	0.461	0.966	1	1.229	0.845	0.980	0.949
1999	1.604	1.800	0.473	0.997	1	1.236	0.854	0.982	0.961
2000	1.607	1.800	0.473	1.012	1	1.243	0.859	0.983	0.964
2001	1.592	1.783	0.467	0.999	1	1.250	0.860	0.980	0.949
2002	1.590	1.785	0.464	0.992	1	1.257	0.853	0.978	0.946
2003	1.539	1.729	0.447	0.940	1	1.264	0.836	0.970	0.917
2004	1.683	1.902	0.491	1.047	1	1.271	0.864	0.984	0.968
2005	1.591	1.809	0.466	1.008	1	1.278	0.864	0.975	0.936
2006	1.569	1.788	0.459	1.000	1	1.286	0.868	0.971	0.922
2007	1.551	1.766	0.450	0.974	1	1.293	0.853	0.968	0.913
2008	1.646	1.888	0.480	1.057	1	1.300	0.868	0.980	0.956
2009	1.659	1.903	0.482	1.095	1	1.307	0.876	0.982	0.974
2010	1.620	1.860	0.470	1.040	1	1.315	0.873	0.972	0.933
2011	1.674	1.933	0.487	1.075	1	1.322	0.872	0.977	0.954
2012	1.602	1.859	0.463	1.022	1	1.329	0.858	0.969	0.924
2013	1.671	1.951	0.485	1.055	1	1.337	0.863	0.972	0.940
2014	1.675	1.968	0.488	1.047	1	1.344	0.854	0.972	0.939
2015	1.692	2.001	0.495	1.052	1	1.352	0.851	0.972	0.941

CHAPTER 5

PRODUCTIVITY CHANGE BY COUNTRY

This section reports estimates of productivity and efficiency changes in a total of 23 countries, namely, Australia, PR China, France, Germany, the UK, the USA, and 17 APO member countries. Again, the focus is on measures of land, labor, capital, and total factor productivity (TFP) change.

5.1 Australia

Australia is a major producer of livestock and crop products for both the domestic and export markets. In 2014, the agriculture sector employed 3.7% (respectively 1.8%) of the male (respectively female) labor force and contributed 2.3% of GDP. The beef industry is the largest agricultural activity by value. Wheat is the major cereal in terms of area and value. Major problems facing Australian agriculture include water security and low soil fertility. Figure 5.1 reports estimated changes in agricultural productivity in Australia from 1961 to 2015. The index numbers used to construct this figure are reported in Table 5.1.

Panel (a) in Figure 5.1 indicates that land productivity increased at a slightly faster rate than labor and capital productivity over the sample period. In 2015, output per unit of land was 4.356 times higher than it had been in 1961; on the other hand, output per unit of labor (respectively capital) was only 2.885 (respectively 3.229) times higher than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by 33.5% (respectively 19.3%) while the area of land used for agricultural production fell by 11.6%.

Panel (b) in Figure 5.1 indicates that TFP in Australian agriculture was 3.846 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 1.722 \times 1.075 \times 1.537$$
$$= 3.846.$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 72.2% increase in TFP; (iv) improvements in technical efficiency (the OTEI component) led to a 7.5% increase in TFP; and (v) changes in statistical noise (the SNI component) accounted for a 53.7% increase in measured TFP. In case of Australia, an important source of statistical noise is omitted variables (e.g., rainfall and temperature).

FIGURE 5.1

PRODUCTIVITY CHANGE IN AUSTRALIA

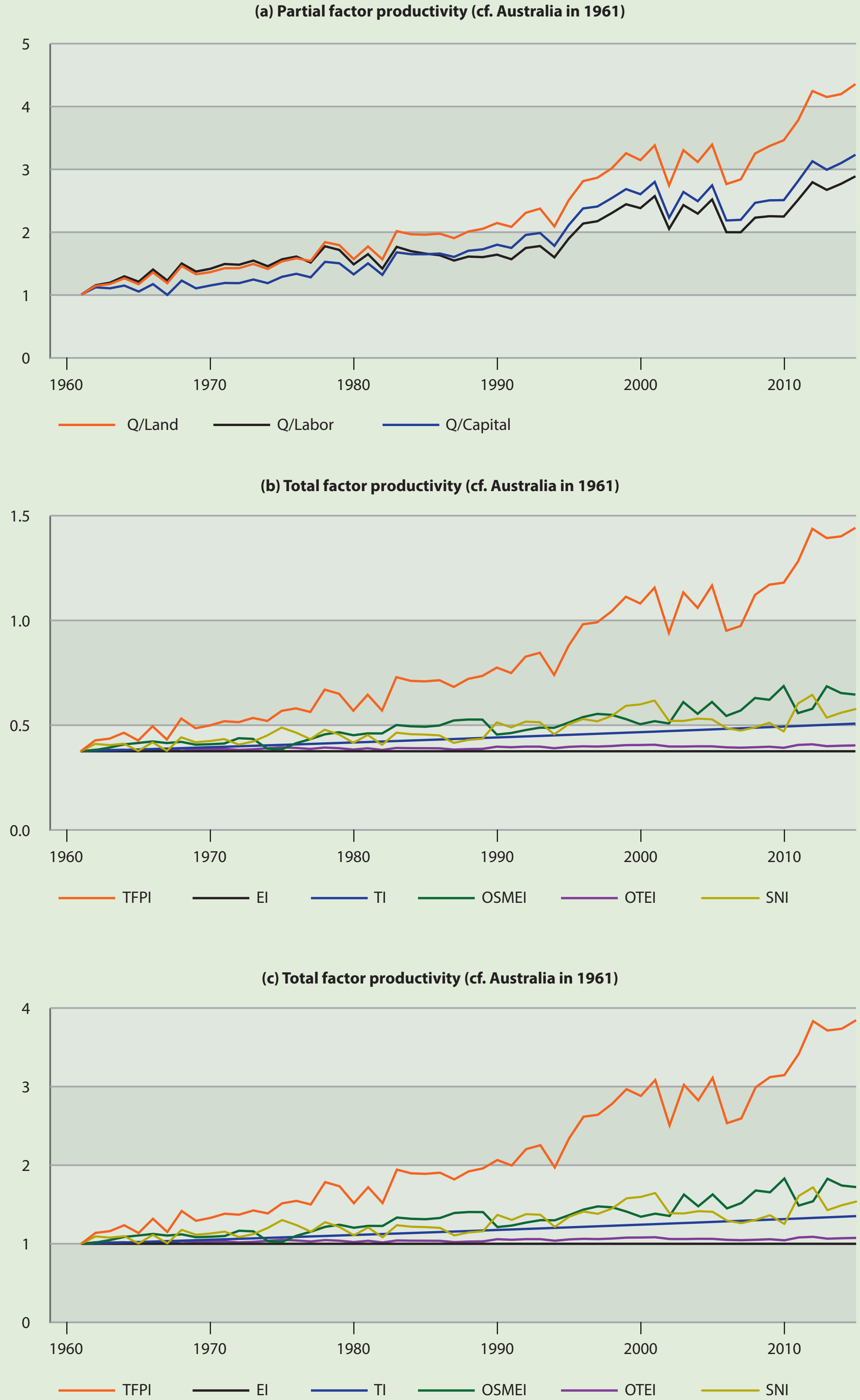


TABLE 5.1

PRODUCTIVITY CHANGE IN AUSTRALIA (CF. AUSTRALIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.139	1.148	1.114	1.139	1	1.006	1.015	1.019	1.094
1963	1.168	1.189	1.099	1.161	1	1.011	1.047	1.016	1.079
1964	1.258	1.290	1.142	1.236	1	1.017	1.087	1.020	1.096
1965	1.164	1.204	1.047	1.137	1	1.023	1.106	1.001	1.004
1966	1.352	1.399	1.166	1.318	1	1.028	1.125	1.023	1.114
1967	1.181	1.223	0.994	1.150	1	1.034	1.105	1.001	1.005
1968	1.456	1.495	1.222	1.417	1	1.040	1.120	1.033	1.177
1969	1.322	1.366	1.098	1.293	1	1.046	1.084	1.023	1.115
1970	1.356	1.410	1.144	1.329	1	1.052	1.090	1.026	1.131
1971	1.419	1.487	1.184	1.383	1	1.057	1.099	1.030	1.155
1972	1.419	1.475	1.181	1.371	1	1.063	1.166	1.018	1.086
1973	1.487	1.541	1.239	1.424	1	1.069	1.158	1.025	1.123
1974	1.408	1.451	1.181	1.386	1	1.075	1.034	1.037	1.202
1975	1.528	1.561	1.282	1.514	1	1.081	1.024	1.051	1.302
1976	1.578	1.606	1.330	1.546	1	1.087	1.102	1.042	1.238
1977	1.535	1.510	1.274	1.500	1	1.093	1.154	1.030	1.155
1978	1.835	1.770	1.521	1.785	1	1.100	1.215	1.047	1.275
1979	1.787	1.711	1.498	1.732	1	1.106	1.242	1.039	1.214
1980	1.564	1.480	1.321	1.516	1	1.112	1.204	1.022	1.108
1981	1.767	1.644	1.497	1.720	1	1.118	1.228	1.038	1.208
1982	1.560	1.413	1.313	1.518	1	1.124	1.227	1.017	1.082
1983	2.010	1.760	1.672	1.944	1	1.131	1.334	1.042	1.237
1984	1.960	1.691	1.642	1.896	1	1.137	1.318	1.039	1.218
1985	1.954	1.652	1.642	1.890	1	1.143	1.313	1.039	1.212
1986	1.970	1.626	1.653	1.905	1	1.150	1.328	1.037	1.202
1987	1.899	1.541	1.599	1.819	1	1.156	1.392	1.022	1.107
1988	2.005	1.605	1.698	1.922	1	1.163	1.404	1.028	1.145
1989	2.048	1.596	1.721	1.960	1	1.169	1.403	1.031	1.159
1990	2.140	1.635	1.794	2.066	1	1.176	1.213	1.059	1.368
1991	2.079	1.562	1.742	1.997	1	1.182	1.232	1.051	1.304
1992	2.303	1.742	1.950	2.204	1	1.189	1.270	1.060	1.378
1993	2.370	1.773	1.981	2.255	1	1.196	1.300	1.059	1.370
1994	2.085	1.592	1.776	1.971	1	1.202	1.299	1.039	1.215
1995	2.504	1.891	2.107	2.342	1	1.209	1.365	1.056	1.344
1996	2.808	2.132	2.373	2.617	1	1.216	1.435	1.063	1.411
1997	2.863	2.168	2.403	2.642	1	1.223	1.476	1.060	1.381
1998	3.012	2.299	2.537	2.782	1	1.229	1.464	1.067	1.449
1999	3.253	2.439	2.680	2.968	1	1.236	1.410	1.078	1.579
2000	3.142	2.377	2.600	2.882	1	1.243	1.344	1.080	1.597
2001	3.378	2.569	2.796	3.084	1	1.250	1.383	1.084	1.646
2002	2.739	2.047	2.224	2.507	1	1.257	1.354	1.061	1.388
2003	3.301	2.426	2.635	3.024	1	1.264	1.627	1.061	1.386
2004	3.113	2.289	2.488	2.826	1	1.271	1.477	1.064	1.415
2005	3.391	2.516	2.741	3.111	1	1.278	1.628	1.063	1.407
2006	2.761	1.993	2.181	2.535	1	1.286	1.450	1.050	1.295
2007	2.836	1.993	2.191	2.595	1	1.293	1.519	1.046	1.264
2008	3.249	2.225	2.462	2.992	1	1.300	1.678	1.051	1.305
2009	3.368	2.248	2.502	3.122	1	1.307	1.656	1.058	1.363
2010	3.460	2.243	2.505	3.147	1	1.315	1.831	1.044	1.252
2011	3.776	2.510	2.809	3.417	1	1.322	1.486	1.081	1.609
2012	4.244	2.790	3.125	3.833	1	1.329	1.541	1.089	1.719
2013	4.149	2.668	2.989	3.715	1	1.337	1.828	1.065	1.428
2014	4.196	2.765	3.096	3.737	1	1.344	1.741	1.071	1.491
2015	4.356	2.885	3.229	3.846	1	1.352	1.722	1.075	1.537

5.2 Bangladesh

Bangladesh is one of the world's largest producers of rice (ranked 4th), fish (5th), jute (2nd), tea (10th) and tropical fruits (5th). In 2014, the agriculture sector employed 34.9% (respectively 61.7%) of the male (respectively female) labor force and contributed 15.4% to the GDP. Most land in Bangladesh is fertile but prone to flooding. Figure 5.2 reports estimated changes in agricultural productivity in Bangladesh from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.2.

Panel (a) in Figure 5.2 indicates that land productivity increased at a much faster rate than labor productivity over the sample period. In 2015, output per unit of land (respectively labor) was 3.786 (respectively 1.657) times higher than it had been in 1961. On the other hand, capital productivity decreased over the sample period. In 2015, output per unit of capital was 51.8% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 2.184 (respectively 7.512) while the area of land used for agricultural production fell by almost 5%.

Panel (b) in Figure 5.2 indicates that TFP in Bangladesh agriculture was 42.7% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.960 × 0.929 × 0.580
= 1.427.

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 96% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 7.1% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 42% fall in measured TFP. In the case of Bangladesh, an important source of statistical noise is measurement error, especially the measurement of capital.

Panel (c) in Figure 5.2 indicates that TFP in Bangladesh in 2015 was 6.888 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 4.269 × 1.022 × 1.109
= 6.888.

This decomposition indicates that (i) the production environment in Bangladesh (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Bangladesh were 4.269 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Bangladesh were 2.2% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.2

PRODUCTIVITY CHANGE IN BANGLADESH

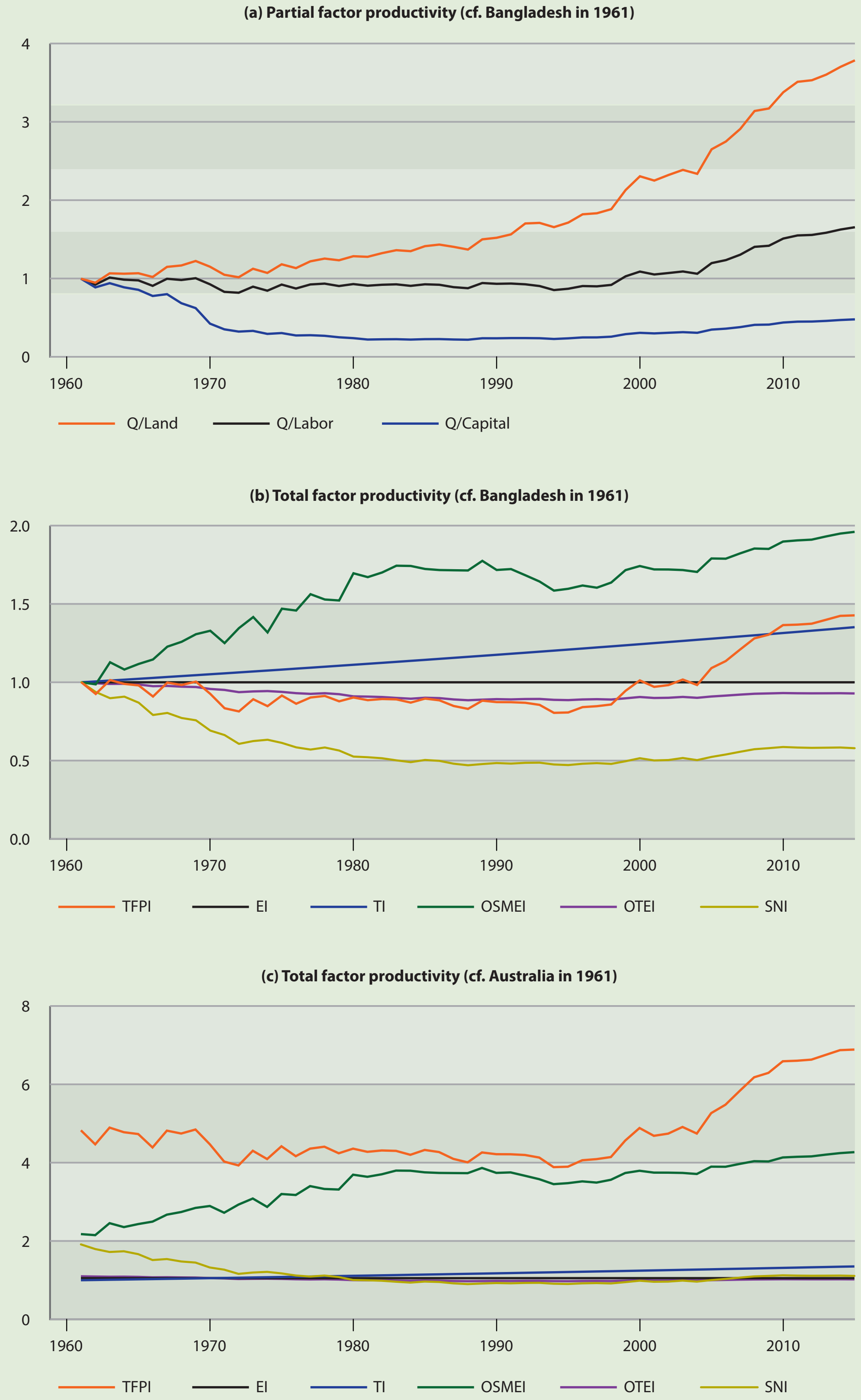


TABLE 5.2

PRODUCTIVITY CHANGE IN BANGLADESH (CF. BANGLADESH IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.949	0.925	0.890	0.926	1	1.006	0.987	0.994	0.938
1963	1.069	1.015	0.943	1.014	1	1.011	1.128	0.990	0.899
1964	1.064	0.988	0.891	0.990	1	1.017	1.082	0.991	0.909
1965	1.070	0.979	0.859	0.980	1	1.023	1.117	0.986	0.870
1966	1.022	0.909	0.780	0.909	1	1.028	1.146	0.975	0.791
1967	1.152	1.000	0.803	0.998	1	1.034	1.228	0.977	0.805
1968	1.169	0.984	0.688	0.983	1	1.040	1.259	0.972	0.772
1969	1.226	1.007	0.626	1.004	1	1.046	1.307	0.970	0.758
1970	1.153	0.929	0.427	0.926	1	1.052	1.329	0.958	0.692
1971	1.050	0.832	0.355	0.835	1	1.057	1.250	0.951	0.663
1972	1.019	0.821	0.326	0.814	1	1.063	1.346	0.937	0.607
1973	1.127	0.899	0.335	0.892	1	1.069	1.417	0.942	0.625
1974	1.074	0.847	0.297	0.848	1	1.075	1.318	0.944	0.634
1975	1.184	0.926	0.307	0.916	1	1.081	1.470	0.939	0.614
1976	1.135	0.875	0.276	0.863	1	1.087	1.458	0.931	0.585
1977	1.222	0.927	0.280	0.903	1	1.093	1.562	0.926	0.571
1978	1.257	0.938	0.272	0.913	1	1.100	1.528	0.930	0.584
1979	1.236	0.907	0.253	0.879	1	1.106	1.522	0.924	0.565
1980	1.288	0.932	0.242	0.903	1	1.112	1.696	0.910	0.526
1981	1.280	0.911	0.225	0.886	1	1.118	1.671	0.909	0.522
1982	1.326	0.923	0.228	0.893	1	1.124	1.701	0.906	0.515
1983	1.364	0.928	0.229	0.891	1	1.131	1.744	0.900	0.502
1984	1.352	0.909	0.224	0.871	1	1.137	1.743	0.895	0.491
1985	1.416	0.929	0.229	0.896	1	1.143	1.724	0.902	0.504
1986	1.436	0.923	0.230	0.885	1	1.150	1.717	0.899	0.499
1987	1.407	0.892	0.225	0.849	1	1.156	1.715	0.891	0.481
1988	1.372	0.879	0.222	0.831	1	1.163	1.714	0.886	0.471
1989	1.503	0.945	0.241	0.883	1	1.169	1.775	0.890	0.478
1990	1.523	0.935	0.241	0.874	1	1.176	1.717	0.893	0.485
1991	1.566	0.938	0.244	0.873	1	1.182	1.723	0.891	0.481
1992	1.705	0.929	0.243	0.870	1	1.189	1.684	0.893	0.486
1993	1.712	0.907	0.241	0.856	1	1.196	1.643	0.894	0.487
1994	1.658	0.855	0.232	0.805	1	1.202	1.585	0.888	0.476
1995	1.716	0.873	0.240	0.808	1	1.209	1.597	0.886	0.472
1996	1.822	0.907	0.251	0.842	1	1.216	1.618	0.891	0.480
1997	1.835	0.903	0.252	0.848	1	1.223	1.604	0.892	0.484
1998	1.888	0.921	0.261	0.859	1	1.229	1.637	0.890	0.479
1999	2.131	1.031	0.293	0.946	1	1.236	1.716	0.898	0.496
2000	2.307	1.091	0.310	1.012	1	1.243	1.742	0.906	0.516
2001	2.252	1.054	0.303	0.971	1	1.250	1.720	0.900	0.501
2002	2.324	1.073	0.311	0.982	1	1.257	1.720	0.901	0.504
2003	2.389	1.093	0.319	1.018	1	1.264	1.717	0.907	0.517
2004	2.338	1.063	0.311	0.983	1	1.271	1.704	0.901	0.503
2005	2.651	1.200	0.352	1.091	1	1.278	1.790	0.910	0.524
2006	2.751	1.238	0.363	1.136	1	1.286	1.789	0.915	0.539
2007	2.911	1.306	0.383	1.209	1	1.293	1.823	0.922	0.557
2008	3.139	1.407	0.412	1.281	1	1.300	1.854	0.927	0.573
2009	3.172	1.421	0.415	1.304	1	1.307	1.851	0.929	0.580
2010	3.378	1.512	0.442	1.365	1	1.315	1.898	0.931	0.587
2011	3.512	1.552	0.453	1.368	1	1.322	1.906	0.930	0.584
2012	3.532	1.559	0.454	1.374	1	1.329	1.911	0.930	0.582
2013	3.603	1.587	0.462	1.399	1	1.337	1.931	0.930	0.583
2014	3.703	1.628	0.474	1.424	1	1.344	1.949	0.930	0.584
2015	3.786	1.657	0.482	1.427	1	1.352	1.960	0.929	0.580

5.3 Cambodia

Agriculture is the most important sector in the Cambodian economy. In 2014, the agriculture sector employed 47.3% (respectively 43.1%) of the male (respectively female) labor force and contributed 28.7% to the GDP. Rice is the largest agricultural industry. The structure of the sector has changed significantly since the government transformed the country's economic system from a planned system to a market-based system in 1995. Figure 5.3 reports estimated changes in agricultural productivity in Cambodia from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.3.

Panel (a) in Figure 5.3 indicates that land and labor productivity increased steadily since the transition to a market-based economy in 1995. In 2015, output per unit of land (respectively labor) was 2.864 (respectively 1.443) times higher than it had been in 1995. On the other hand, capital productivity fell slightly since the transition to a market-based economy. In 2015, output per unit of capital was 5% lower than it had been in 1995. Taken together, these results indicate that labor per hectare and capital per hectare both increased after 1995. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.396 (respectively 3.603) while the area of land used for agricultural production increased only by a factor of 1.194.

Panel (b) in Figure 5.3 indicates that TFP in Cambodian agriculture was 98.9% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$\begin{aligned} TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\ &= 1 \times 1.352 \times 2.204 \times 0.950 \times 0.703 \\ &= 1.989. \end{aligned}$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 120.4% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 5% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 29.7% fall in measured TFP. In the case of Cambodia, an important source of statistical noise is measurement error, especially the measurement of capital.

Panel (c) in Figure 5.3 indicates that TFP in Cambodia in 2015 was 11.928 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$$\begin{aligned} TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\ &= 1.053 \times 1.352 \times 7.171 \times 1.027 \times 1.138 \\ &= 11.928. \end{aligned}$$

This decomposition indicates that (i) the production environment in Cambodia (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Cambodia were 7.171 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Cambodia were 2.7% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.3

PRODUCTIVITY CHANGE IN CAMBODIA

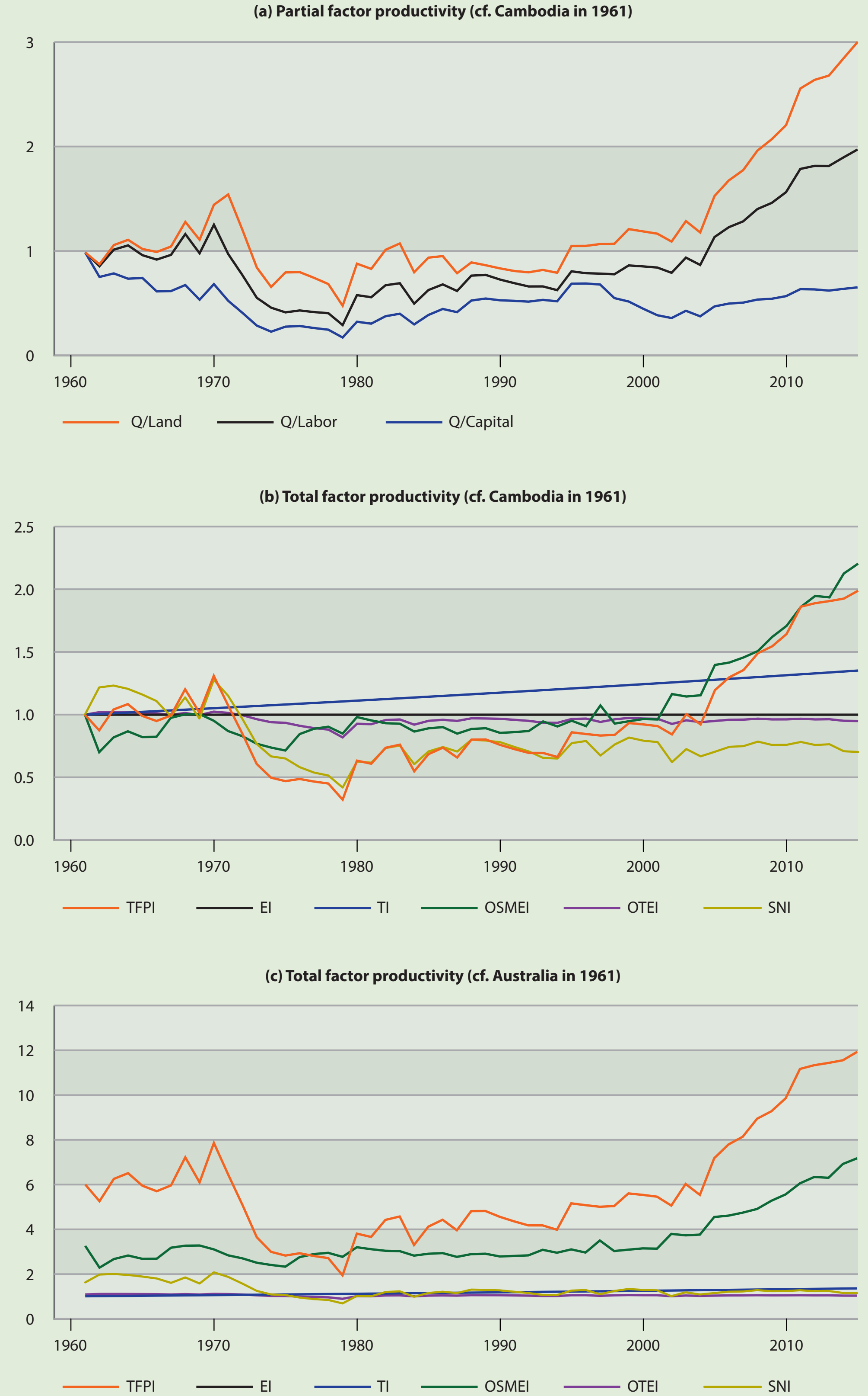


TABLE 5.3

PRODUCTIVITY CHANGE IN CAMBODIA (CF. CAMBODIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.885	0.866	0.762	0.875	1	1.006	0.701	1.02	1.217
1963	1.071	1.027	0.796	1.041	1	1.011	0.819	1.021	1.232
1964	1.122	1.068	0.745	1.084	1	1.017	0.867	1.019	1.206
1965	1.034	0.973	0.752	0.991	1	1.023	0.822	1.016	1.161
1966	1.005	0.930	0.621	0.950	1	1.028	0.824	1.011	1.109
1967	1.057	0.976	0.625	0.993	1	1.034	0.975	0.998	0.987
1968	1.297	1.179	0.683	1.203	1	1.040	1.003	1.014	1.138
1969	1.123	0.992	0.540	1.016	1	1.046	1.005	0.996	0.970
1970	1.463	1.269	0.692	1.310	1	1.052	0.952	1.024	1.278
1971	1.563	0.984	0.530	1.074	1	1.057	0.869	1.015	1.152
1972	1.216	0.778	0.412	0.847	1	1.063	0.828	0.996	0.966
1973	0.853	0.559	0.289	0.607	1	1.069	0.768	0.964	0.766
1974	0.664	0.463	0.230	0.498	1	1.075	0.738	0.940	0.667
1975	0.806	0.418	0.279	0.470	1	1.081	0.714	0.935	0.651
1976	0.808	0.436	0.285	0.487	1	1.087	0.846	0.911	0.582
1977	0.753	0.420	0.266	0.467	1	1.093	0.888	0.893	0.539
1978	0.693	0.410	0.249	0.451	1	1.100	0.904	0.881	0.515
1979	0.481	0.294	0.173	0.322	1	1.106	0.849	0.819	0.419
1980	0.891	0.585	0.326	0.634	1	1.112	0.981	0.928	0.626
1981	0.840	0.565	0.308	0.609	1	1.118	0.954	0.925	0.617
1982	1.025	0.681	0.380	0.736	1	1.124	0.932	0.957	0.734
1983	1.087	0.701	0.405	0.761	1	1.131	0.928	0.962	0.755
1984	0.807	0.502	0.301	0.549	1	1.137	0.866	0.920	0.605
1985	0.949	0.635	0.393	0.686	1	1.143	0.891	0.951	0.707
1986	0.964	0.690	0.451	0.737	1	1.150	0.901	0.959	0.742
1987	0.798	0.625	0.420	0.659	1	1.156	0.849	0.950	0.706
1988	0.903	0.774	0.533	0.801	1	1.163	0.886	0.971	0.801
1989	0.876	0.782	0.552	0.802	1	1.169	0.892	0.970	0.793
1990	0.845	0.737	0.535	0.759	1	1.176	0.855	0.967	0.781
1991	0.820	0.701	0.530	0.725	1	1.182	0.861	0.959	0.743
1992	0.807	0.669	0.522	0.695	1	1.189	0.870	0.951	0.707
1993	0.830	0.670	0.539	0.695	1	1.196	0.946	0.937	0.656
1994	0.802	0.633	0.525	0.663	1	1.202	0.906	0.935	0.650
1995	1.063	0.816	0.696	0.859	1	1.209	0.952	0.966	0.773
1996	1.063	0.798	0.698	0.846	1	1.216	0.908	0.969	0.790
1997	1.081	0.794	0.688	0.834	1	1.223	1.074	0.942	0.674
1998	1.085	0.788	0.556	0.839	1	1.229	0.929	0.963	0.762
1999	1.226	0.874	0.523	0.933	1	1.236	0.948	0.974	0.818
2000	1.205	0.864	0.454	0.922	1	1.243	0.965	0.969	0.793
2001	1.182	0.853	0.390	0.909	1	1.250	0.962	0.967	0.781
2002	1.105	0.802	0.363	0.843	1	1.257	1.165	0.926	0.622
2003	1.305	0.950	0.433	1.004	1	1.264	1.145	0.955	0.726
2004	1.194	0.878	0.379	0.922	1	1.271	1.155	0.940	0.668
2005	1.548	1.150	0.476	1.196	1	1.278	1.397	0.950	0.705
2006	1.699	1.245	0.503	1.298	1	1.286	1.416	0.959	0.744
2007	1.799	1.301	0.512	1.356	1	1.293	1.457	0.961	0.750
2008	1.989	1.421	0.542	1.490	1	1.300	1.508	0.968	0.785
2009	2.100	1.481	0.550	1.545	1	1.307	1.620	0.962	0.758
2010	2.236	1.585	0.575	1.643	1	1.315	1.708	0.963	0.760
2011	2.593	1.811	0.643	1.861	1	1.322	1.860	0.967	0.782
2012	2.676	1.841	0.641	1.889	1	1.329	1.947	0.963	0.758
2013	2.718	1.840	0.629	1.906	1	1.337	1.936	0.964	0.764
2014	2.882	1.922	0.646	1.926	1	1.344	2.126	0.951	0.709
2015	3.044	2.000	0.661	1.989	1	1.352	2.204	0.950	0.703

5.4 PR China

PR China is the world's largest producer and consumer of agricultural products. In 2014, the agriculture sector employed 26.1% (respectively 34.4%) of the male (respectively female) labor force and contributed 9.4% to the GDP. Approximately 75% of arable land area is used for food crops. The most important crop is rice. Figure 5.4 reports estimated changes in agricultural productivity in PR China from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.4.

Panel (a) in Figure 5.4 indicates that land and labor productivity increased significantly over the sample period. In 2015, output per unit of land (respectively labor) was 5.456 (respectively 7.296) times higher than it had been in 1961. On the other hand, capital productivity fell significantly over the sample period. In 2015, output per unit of capital was 71.2% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.123 (respectively 28.484) while the area of land used for agricultural production increased by a factor of 1.501.

Panel (b) in Figure 5.4 indicates that TFP in Chinese agriculture was 3.81 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 2.483 × 1.025 × 1.107
= 3.81.

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 2.483; (iv) improvements in technical efficiency (the OTEI component) led to a 2.5% increase in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 10.7% increase in measured TFP. In case of PR China, the increase in scale and mix efficiency can be partly attributed to using 25.2% less labor per hectare (i.e., a more productive input mix).

Panel (c) in Figure 5.4 indicates that TFP in PR China in 2015 was 13.33 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 9.789 × 1.001 × 1.006
= 13.33.

This decomposition indicates that (i) the production environment in PR China is the same as the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in PR China were 9.789 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in PR China were marginally more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.4

PRODUCTIVITY CHANGE IN PR CHINA

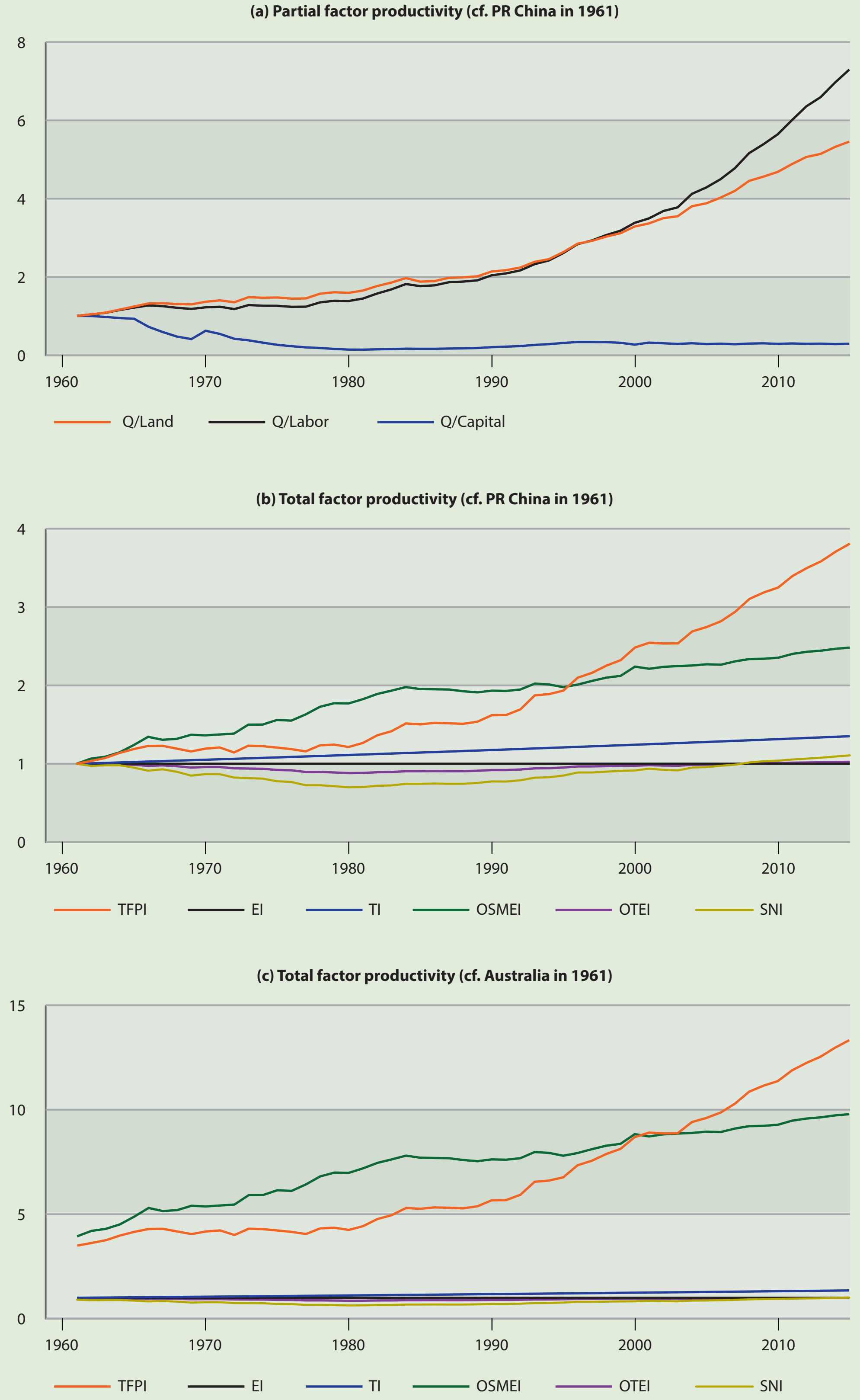


TABLE 5.4

PRODUCTIVITY CHANGE IN PR CHINA (CF. PR CHINA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.041	1.039	0.998	1.035	1	1.006	1.065	0.993	0.973
1963	1.085	1.080	0.973	1.073	1	1.011	1.090	0.994	0.979
1964	1.162	1.152	0.946	1.138	1	1.017	1.145	0.995	0.982
1965	1.241	1.213	0.927	1.188	1	1.023	1.239	0.986	0.951
1966	1.318	1.267	0.723	1.227	1	1.028	1.344	0.974	0.912
1967	1.323	1.249	0.587	1.229	1	1.034	1.306	0.980	0.929
1968	1.305	1.208	0.471	1.193	1	1.040	1.318	0.969	0.898
1969	1.296	1.179	0.408	1.158	1	1.046	1.370	0.952	0.849
1970	1.362	1.220	0.621	1.193	1	1.052	1.363	0.959	0.868
1971	1.398	1.234	0.539	1.208	1	1.057	1.374	0.959	0.867
1972	1.349	1.174	0.416	1.144	1	1.063	1.386	0.942	0.825
1973	1.480	1.277	0.376	1.231	1	1.069	1.500	0.939	0.817
1974	1.464	1.260	0.316	1.225	1	1.075	1.501	0.936	0.811
1975	1.472	1.259	0.261	1.207	1	1.081	1.559	0.921	0.777
1976	1.443	1.232	0.226	1.187	1	1.087	1.551	0.917	0.768
1977	1.447	1.236	0.196	1.159	1	1.093	1.630	0.896	0.726
1978	1.568	1.346	0.180	1.235	1	1.100	1.727	0.896	0.726
1979	1.606	1.387	0.156	1.245	1	1.106	1.773	0.889	0.714
1980	1.590	1.381	0.140	1.214	1	1.112	1.770	0.881	0.700
1981	1.649	1.444	0.138	1.266	1	1.118	1.825	0.883	0.703
1982	1.764	1.573	0.147	1.363	1	1.124	1.891	0.892	0.719
1983	1.853	1.680	0.152	1.416	1	1.131	1.934	0.895	0.724
1984	1.967	1.816	0.163	1.515	1	1.137	1.979	0.905	0.744
1985	1.875	1.760	0.159	1.504	1	1.143	1.954	0.905	0.744
1986	1.891	1.781	0.160	1.522	1	1.150	1.951	0.907	0.748
1987	1.972	1.861	0.166	1.517	1	1.156	1.948	0.905	0.744
1988	1.986	1.877	0.171	1.510	1	1.163	1.926	0.905	0.745
1989	2.012	1.909	0.180	1.538	1	1.169	1.912	0.911	0.755
1990	2.135	2.039	0.201	1.620	1	1.176	1.933	0.920	0.775
1991	2.168	2.087	0.214	1.623	1	1.182	1.930	0.920	0.773
1992	2.238	2.164	0.229	1.695	1	1.189	1.948	0.927	0.789
1993	2.382	2.323	0.258	1.873	1	1.196	2.023	0.941	0.823
1994	2.451	2.418	0.279	1.889	1	1.202	2.013	0.943	0.828
1995	2.630	2.605	0.308	1.934	1	1.209	1.978	0.952	0.850
1996	2.845	2.834	0.334	2.099	1	1.216	2.011	0.966	0.889
1997	2.917	2.928	0.334	2.161	1	1.223	2.058	0.966	0.889
1998	3.027	3.066	0.330	2.253	1	1.229	2.099	0.970	0.900
1999	3.113	3.178	0.313	2.323	1	1.236	2.123	0.973	0.909
2000	3.286	3.380	0.266	2.484	1	1.243	2.240	0.975	0.915
2001	3.365	3.493	0.318	2.546	1	1.250	2.213	0.982	0.937
2002	3.499	3.680	0.301	2.535	1	1.257	2.238	0.977	0.922
2003	3.547	3.775	0.283	2.538	1	1.264	2.247	0.975	0.916
2004	3.804	4.120	0.302	2.690	1	1.271	2.255	0.986	0.951
2005	3.877	4.283	0.280	2.746	1	1.278	2.270	0.988	0.958
2006	4.023	4.494	0.289	2.820	1	1.286	2.265	0.993	0.975
2007	4.195	4.775	0.276	2.941	1	1.293	2.308	0.997	0.989
2008	4.452	5.161	0.293	3.106	1	1.300	2.337	1.005	1.017
2009	4.560	5.388	0.300	3.188	1	1.307	2.341	1.008	1.033
2010	4.682	5.642	0.285	3.251	1	1.315	2.354	1.010	1.040
2011	4.882	6.006	0.297	3.398	1	1.322	2.403	1.014	1.055
2012	5.062	6.357	0.286	3.499	1	1.329	2.430	1.016	1.066
2013	5.141	6.592	0.290	3.585	1	1.337	2.444	1.019	1.077
2014	5.317	6.962	0.280	3.707	1	1.344	2.468	1.022	1.093
2015	5.456	7.296	0.288	3.810	1	1.352	2.483	1.025	1.107

5.5 Republic of China

In 2014, the agriculture sector in the Republic of China (ROC) employed 6.3% (respectively 3.2%) of the male (respectively female) labor force and contributed less than 2% to the GDP. The sector is highly mechanized (some crops are completely mechanized) [15]. Figure 5.5 reports estimated changes in agricultural productivity in the ROC from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.5.

Panel (a) in Figure 5.5 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 2.008 (respectively 2.653) times higher than it had been in 1961. On the other hand, capital productivity fell significantly over the sample period. In 2015, output per unit of capital was 95.5% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 31.8% (respectively increased by a factor of 40.568) while the area of land used for agricultural production fell by 9.9%.

Panel (b) in Figure 5.5 indicates that TFP in ROC agriculture was 2.025 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 1 \times 1.352 \times 2.117 \times 0.941 \times 0.752 \\
&= 2.025
\end{aligned}
$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 111.7% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 5.9% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 24.8% fall in measured TFP.

Panel (c) in Figure 5.5 indicates that TFP in the ROC in 2015 was 13.319 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 1.053 \times 1.352 \times 10.516 \times 0.977 \times 0.911 \\
&= 13.319.
\end{aligned}
$$

This decomposition indicates that (i) the production environment in the ROC (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in the ROC were 10.516 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in the ROC were 2.3% less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.5

PRODUCTIVITY CHANGE IN ROC

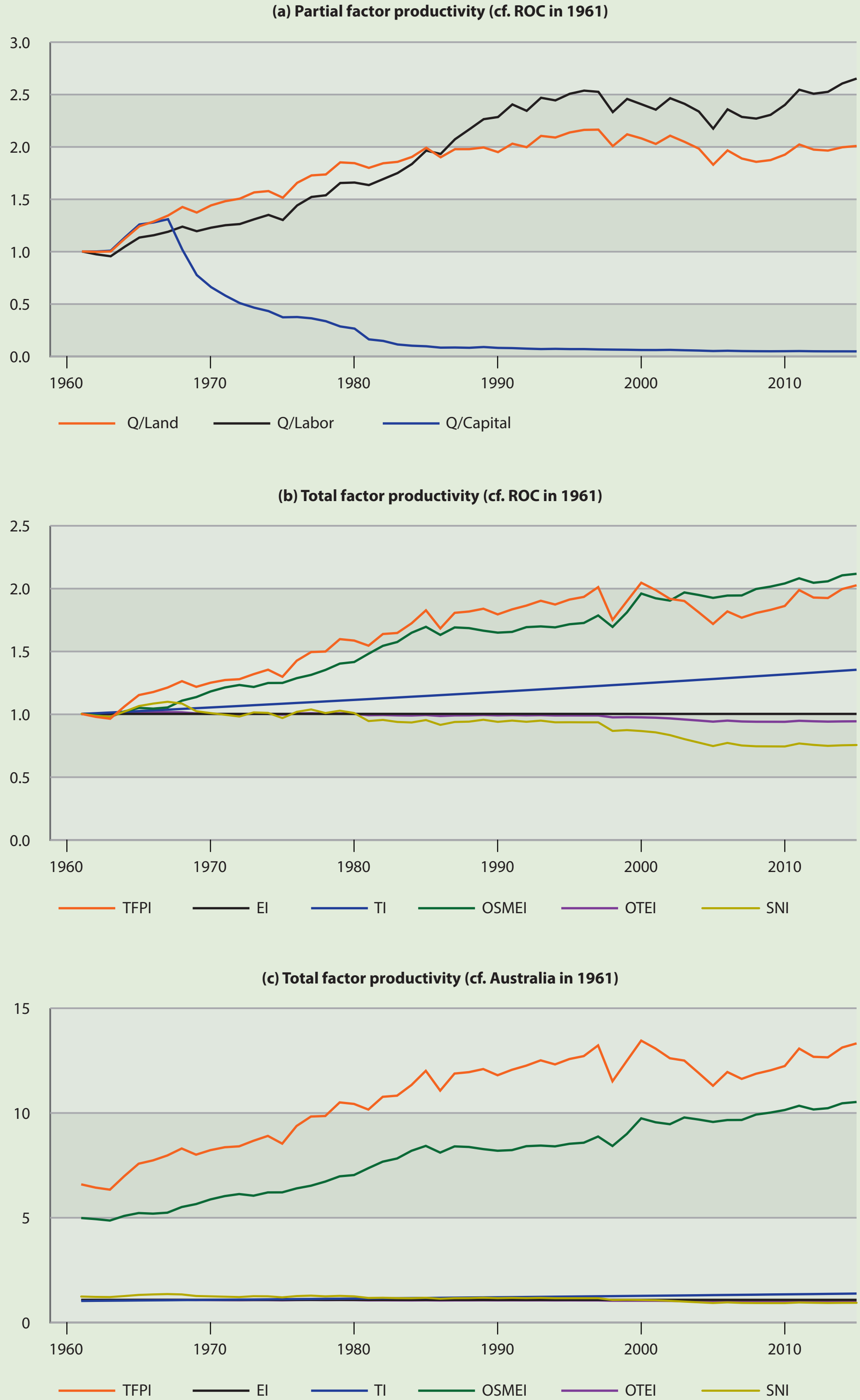


TABLE 5.5

PRODUCTIVITY CHANGE IN ROC (CF. ROC IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.996	0.972	0.999	0.976	1	1.006	0.989	0.997	0.984
1963	1.000	0.954	1.007	0.961	1	1.011	0.976	0.996	0.978
1964	1.124	1.047	1.135	1.060	1	1.017	1.020	1.003	1.018
1965	1.241	1.133	1.258	1.150	1	1.023	1.048	1.010	1.063
1966	1.285	1.155	1.277	1.175	1	1.028	1.042	1.013	1.082
1967	1.343	1.188	1.308	1.210	1	1.034	1.051	1.015	1.097
1968	1.425	1.237	1.016	1.261	1	1.040	1.106	1.013	1.083
1969	1.372	1.193	0.774	1.216	1	1.046	1.134	1.004	1.022
1970	1.440	1.227	0.659	1.249	1	1.052	1.179	1.001	1.006
1971	1.480	1.251	0.577	1.270	1	1.057	1.211	0.999	0.993
1972	1.504	1.262	0.506	1.277	1	1.063	1.231	0.996	0.979
1973	1.564	1.307	0.462	1.317	1	1.069	1.215	1.002	1.012
1974	1.577	1.349	0.429	1.353	1	1.075	1.246	1.001	1.008
1975	1.514	1.300	0.370	1.296	1	1.081	1.247	0.994	0.967
1976	1.656	1.440	0.373	1.425	1	1.087	1.285	1.003	1.017
1977	1.727	1.521	0.361	1.493	1	1.093	1.311	1.006	1.036
1978	1.736	1.537	0.333	1.497	1	1.100	1.351	1.001	1.007
1979	1.851	1.654	0.283	1.596	1	1.106	1.401	1.004	1.026
1980	1.844	1.658	0.262	1.585	1	1.112	1.414	1.001	1.007
1981	1.799	1.634	0.159	1.544	1	1.118	1.480	0.990	0.943
1982	1.843	1.692	0.144	1.637	1	1.124	1.543	0.991	0.952
1983	1.856	1.749	0.111	1.645	1	1.131	1.573	0.988	0.936
1984	1.904	1.835	0.099	1.723	1	1.137	1.647	0.987	0.932
1985	1.991	1.964	0.093	1.826	1	1.143	1.694	0.991	0.951
1986	1.900	1.932	0.080	1.682	1	1.150	1.630	0.983	0.913
1987	1.977	2.072	0.082	1.806	1	1.156	1.690	0.988	0.936
1988	1.978	2.167	0.079	1.816	1	1.163	1.684	0.989	0.938
1989	1.994	2.264	0.086	1.839	1	1.169	1.663	0.992	0.953
1990	1.949	2.285	0.078	1.794	1	1.176	1.648	0.988	0.937
1991	2.030	2.405	0.076	1.834	1	1.182	1.654	0.990	0.947
1992	1.996	2.344	0.071	1.864	1	1.189	1.692	0.988	0.937
1993	2.104	2.469	0.067	1.902	1	1.196	1.698	0.990	0.946
1994	2.089	2.444	0.069	1.872	1	1.202	1.690	0.988	0.933
1995	2.137	2.507	0.066	1.912	1	1.209	1.715	0.988	0.934
1996	2.162	2.537	0.067	1.933	1	1.216	1.725	0.988	0.933
1997	2.164	2.525	0.063	2.011	1	1.223	1.785	0.988	0.933
1998	2.007	2.332	0.062	1.750	1	1.229	1.693	0.973	0.864
1999	2.120	2.457	0.060	1.898	1	1.236	1.809	0.974	0.871
2000	2.080	2.407	0.058	2.046	1	1.243	1.960	0.972	0.863
2001	2.028	2.355	0.057	1.988	1	1.250	1.922	0.970	0.853
2002	2.106	2.465	0.059	1.917	1	1.257	1.904	0.964	0.831
2003	2.048	2.411	0.055	1.901	1	1.264	1.968	0.956	0.799
2004	1.983	2.338	0.053	1.810	1	1.271	1.948	0.947	0.772
2005	1.829	2.173	0.048	1.717	1	1.278	1.925	0.938	0.744
2006	1.966	2.358	0.051	1.817	1	1.286	1.944	0.946	0.769
2007	1.888	2.286	0.048	1.767	1	1.293	1.944	0.940	0.748
2008	1.856	2.270	0.046	1.805	1	1.300	1.996	0.938	0.742
2009	1.873	2.305	0.046	1.829	1	1.307	2.015	0.937	0.741
2010	1.925	2.401	0.046	1.861	1	1.315	2.040	0.937	0.740
2011	2.022	2.546	0.048	1.988	1	1.322	2.081	0.945	0.764
2012	1.973	2.507	0.046	1.928	1	1.329	2.045	0.941	0.753
2013	1.964	2.525	0.045	1.924	1	1.337	2.057	0.939	0.745
2014	1.996	2.605	0.045	1.995	1	1.344	2.105	0.940	0.750
2015	2.008	2.653	0.045	2.025	1	1.352	2.117	0.941	0.752

5.6 France

France is the world's sixth-largest producer and second-largest exporter of agricultural products. In 2014, the agriculture sector employed 3.9% (respectively 1.6%) of the male (respectively female) labor force and contributed 1.5% to the GDP. The main cereal crop is wheat. France has a reputation for producing high-quality cheese and wine. Figure 5.6 reports estimated changes in agricultural productivity in France from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.6.

Panel (a) in Figure 5.6 indicates that land and labor productivity increased until 2000 and remained fairly constant thereafter. In 2000, output per unit of land (respectively labor) was 1.803 (respectively 1.886) times higher than it had been in 1961, while in 2015, output per unit of land (respectively labor) was 5.2% (respectively 1.9%) lower than it had been in 2000. On the other hand, capital productivity fell over the sample period. In 2015, output per unit of capital was 18.7% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 23.2% (respectively increased by 74.9%) while the area of land used for agricultural production fell by 16.8%.

Panel (b) in Figure 5.6 indicates that TFP in French agriculture was 16.9% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 1 \times 1.352 \times 0.846 \times 1.003 \times 1.019 \\
&= 1.169
\end{aligned}
$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP, (ii) technical progress (the TI component) led to a 35.2% increase in TFP, (iii) lower scale and mix efficiency (the OSMEI component) led to a 15.4% fall in TFP, (iv) changes in technical efficiency (the OTEI component) had a negligible effect on TFP, and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 1.9% increase in measured TFP.

Panel (c) in Figure 5.6 indicates that TFP in France in 2015 was 11.275 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 1 \times 1.352 \times 6.682 \times 1.037 \times 1.203 \\
&= 11.275.
\end{aligned}
$$

This decomposition indicates that (i) the production environment in France is the same as the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in France were 6.682 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in France were 3.7% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.6

PRODUCTIVITY CHANGE IN FRANCE

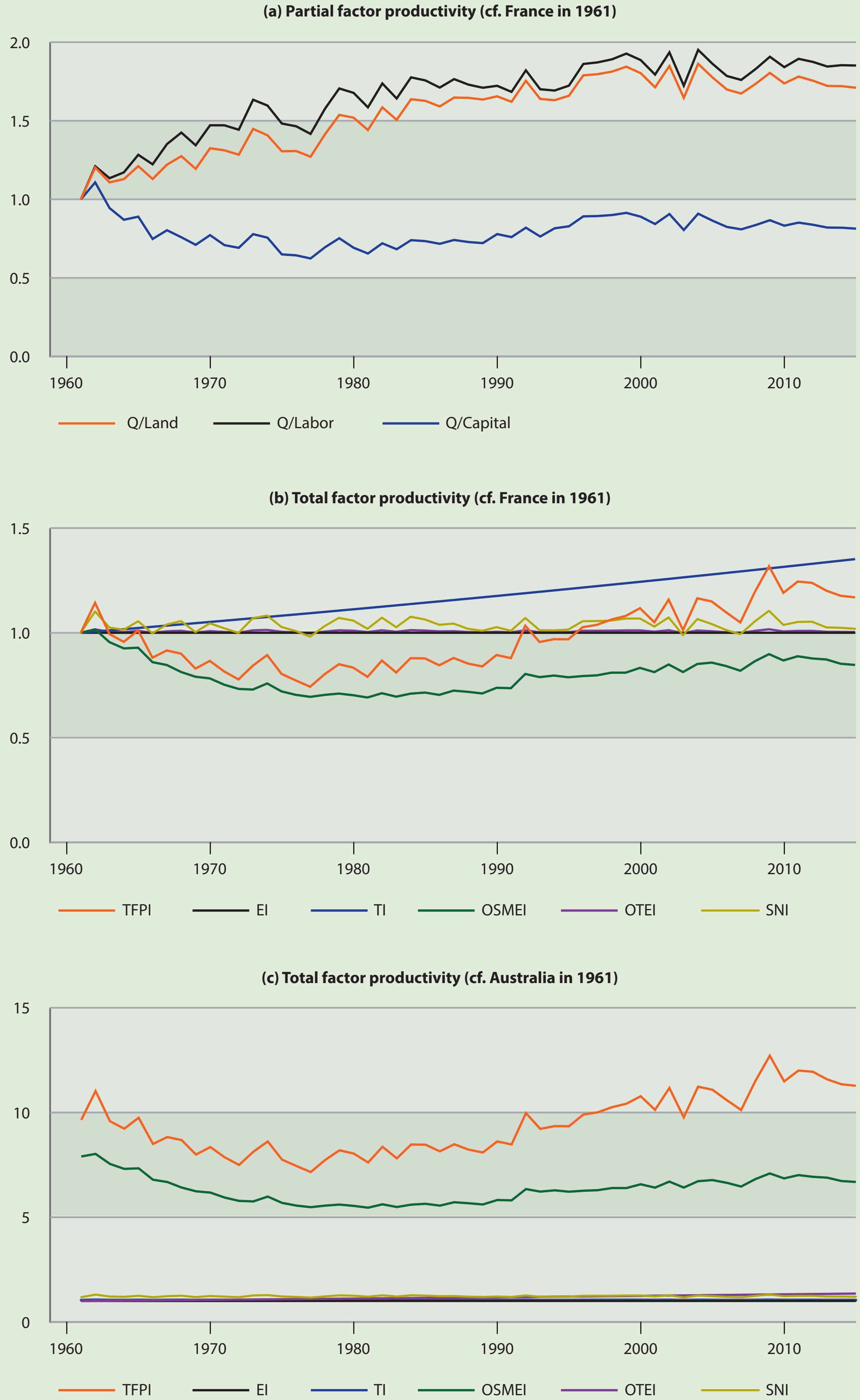


TABLE 5.6

PRODUCTIVITY CHANGE IN FRANCE (CF. FRANCE IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.202	1.210	1.108	1.143	1	1.006	1.016	1.016	1.101
1963	1.108	1.134	0.944	0.994	1	1.011	0.955	1.004	1.025
1964	1.129	1.172	0.870	0.956	1	1.017	0.925	1.002	1.014
1965	1.211	1.283	0.890	1.011	1	1.023	0.928	1.009	1.055
1966	1.129	1.223	0.748	0.881	1	1.028	0.859	1.000	0.997
1967	1.221	1.352	0.803	0.915	1	1.034	0.846	1.007	1.040
1968	1.275	1.425	0.759	0.900	1	1.040	0.812	1.009	1.056
1969	1.194	1.344	0.710	0.828	1	1.046	0.790	1.001	1.003
1970	1.325	1.471	0.772	0.866	1	1.052	0.782	1.008	1.045
1971	1.312	1.471	0.709	0.815	1	1.057	0.752	1.004	1.021
1972	1.284	1.443	0.691	0.777	1	1.063	0.732	1.000	0.999
1973	1.448	1.634	0.778	0.843	1	1.069	0.728	1.011	1.070
1974	1.407	1.597	0.756	0.893	1	1.075	0.758	1.013	1.082
1975	1.306	1.482	0.649	0.803	1	1.081	0.720	1.005	1.027
1976	1.307	1.465	0.644	0.772	1	1.087	0.703	1.001	1.008
1977	1.271	1.416	0.623	0.742	1	1.093	0.694	0.997	0.981
1978	1.413	1.576	0.694	0.801	1	1.100	0.703	1.005	1.031
1979	1.537	1.706	0.752	0.850	1	1.106	0.709	1.012	1.071
1980	1.520	1.677	0.692	0.833	1	1.112	0.701	1.010	1.058
1981	1.441	1.585	0.655	0.789	1	1.118	0.691	1.003	1.019
1982	1.585	1.738	0.720	0.867	1	1.124	0.711	1.012	1.072
1983	1.506	1.642	0.682	0.810	1	1.131	0.695	1.005	1.026
1984	1.637	1.776	0.740	0.878	1	1.137	0.709	1.012	1.076
1985	1.627	1.757	0.734	0.877	1	1.143	0.714	1.010	1.063
1986	1.591	1.711	0.717	0.844	1	1.150	0.703	1.006	1.038
1987	1.647	1.765	0.741	0.879	1	1.156	0.723	1.007	1.044
1988	1.646	1.730	0.728	0.853	1	1.163	0.718	1.003	1.019
1989	1.635	1.710	0.721	0.839	1	1.169	0.710	1.002	1.009
1990	1.656	1.722	0.779	0.894	1	1.176	0.737	1.005	1.027
1991	1.621	1.684	0.760	0.878	1	1.182	0.735	1.002	1.009
1992	1.754	1.821	0.819	1.034	1	1.189	0.803	1.012	1.070
1993	1.639	1.701	0.763	0.955	1	1.196	0.788	1.002	1.012
1994	1.631	1.692	0.816	0.969	1	1.202	0.796	1.002	1.011
1995	1.659	1.723	0.828	0.969	1	1.209	0.787	1.003	1.015
1996	1.789	1.861	0.891	1.026	1	1.216	0.793	1.009	1.055
1997	1.796	1.872	0.893	1.038	1	1.223	0.796	1.009	1.056
1998	1.813	1.891	0.900	1.063	1	1.229	0.809	1.010	1.058
1999	1.844	1.927	0.914	1.080	1	1.236	0.809	1.011	1.068
2000	1.803	1.886	0.890	1.117	1	1.243	0.832	1.011	1.068
2001	1.713	1.794	0.843	1.050	1	1.250	0.812	1.005	1.029
2002	1.849	1.935	0.906	1.158	1	1.257	0.848	1.012	1.073
2003	1.646	1.723	0.805	1.013	1	1.264	0.812	0.998	0.988
2004	1.863	1.951	0.908	1.165	1	1.271	0.851	1.011	1.065
2005	1.776	1.862	0.864	1.150	1	1.278	0.857	1.007	1.042
2006	1.699	1.785	0.824	1.098	1	1.286	0.841	1.002	1.013
2007	1.673	1.760	0.809	1.049	1	1.293	0.818	0.999	0.993
2008	1.735	1.829	0.836	1.193	1	1.300	0.863	1.009	1.054
2009	1.805	1.907	0.867	1.318	1	1.307	0.898	1.017	1.105
2010	1.738	1.841	0.832	1.191	1	1.315	0.868	1.006	1.037
2011	1.781	1.894	0.852	1.244	1	1.322	0.888	1.009	1.051
2012	1.755	1.875	0.838	1.238	1	1.329	0.877	1.009	1.053
2013	1.722	1.845	0.820	1.201	1	1.337	0.872	1.004	1.026
2014	1.720	1.854	0.819	1.176	1	1.344	0.852	1.004	1.023
2015	1.710	1.851	0.813	1.169	1	1.352	0.846	1.003	1.019

5.7 Germany

Agriculture is a small but politically important sector of the German economy. In 2014, the agriculture sector employed 1.8% (respectively 1%) of the male (respectively female) labor force and contributed 0.6% to the GDP. The main agricultural products are potatoes and grains. Figure 5.7 reports estimated changes in agricultural productivity in Germany from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.7.

Panel (a) in Figure 5.7 indicates that land and labor productivity both increased over the sample period. In 2015, output per unit of land (respectively labor) was 54.1% (respectively 36.5%) higher than it had been in 1961. Capital productivity also increased over the sample period, particularly after the fall of the Berlin Wall in 1989. In 1989, output per unit of capital was 13.5% lower than it had been in 1961; by 2015, output per unit of capital was 72.6% higher than it had been in 1961. Taken together, these results indicate that labor per hectare increased and capital per hectare fell over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 2.5% (respectively 22.9%) while the area of land used for agricultural production fell by 13.6%.

Panel (b) in Figure 5.7 indicates that TFP in German agriculture was 61% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.248 × 0.991 × 0.962
= 1.61.

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 24.8% increase in TFP; (iv) changes in technical efficiency (the OTEI component) had a negligible effect on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 3.8% fall in measured TFP.

Panel (c) in Figure 5.7 indicates that TFP in Germany in 2015 was 11.07 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 8.277 × 0.998 × 0.991
= 11.07.

This decomposition indicates that (i) the production environment in Germany is the same as the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Germany were 8.277 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Germany were marginally less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.7

PRODUCTIVITY CHANGE IN GERMANY

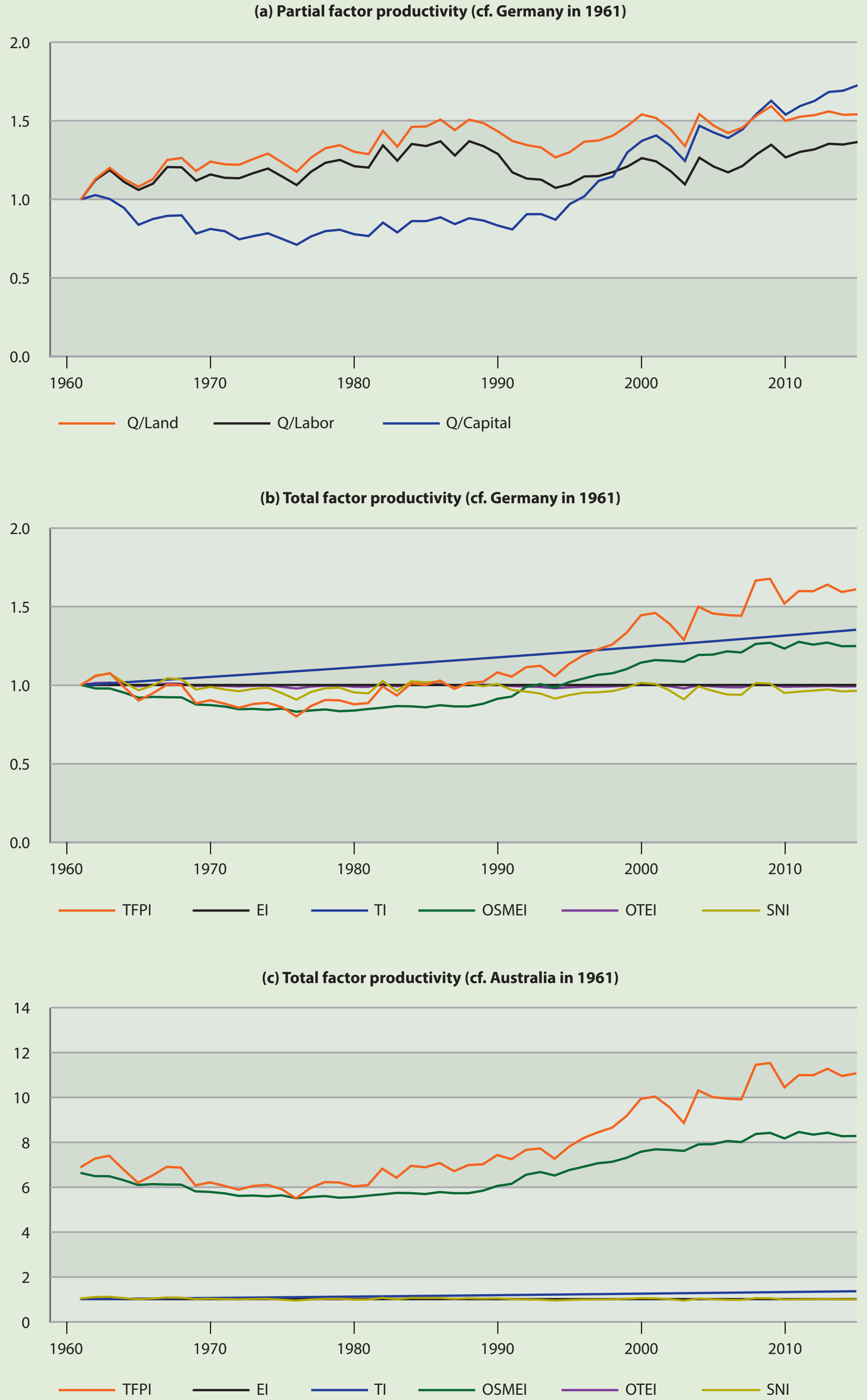


TABLE 5.7

PRODUCTIVITY CHANGE IN GERMANY (CF. GERMANY IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.129	1.123	1.027	1.057	1	1.006	0.978	1.012	1.061
1963	1.201	1.186	1.002	1.076	1	1.011	0.978	1.015	1.072
1964	1.129	1.111	0.945	0.985	1	1.017	0.951	1.003	1.016
1965	1.081	1.060	0.838	0.900	1	1.023	0.919	0.992	0.966
1966	1.128	1.100	0.875	0.947	1	1.028	0.924	0.999	0.997
1967	1.251	1.205	0.895	1.003	1	1.034	0.922	1.009	1.043
1968	1.264	1.204	0.898	0.998	1	1.040	0.921	1.007	1.035
1969	1.180	1.119	0.782	0.883	1	1.046	0.876	0.993	0.971
1970	1.240	1.159	0.812	0.903	1	1.052	0.872	0.997	0.988
1971	1.223	1.137	0.798	0.881	1	1.057	0.863	0.994	0.972
1972	1.220	1.134	0.746	0.855	1	1.063	0.845	0.991	0.960
1973	1.257	1.167	0.767	0.879	1	1.069	0.848	0.994	0.975
1974	1.291	1.196	0.784	0.886	1	1.075	0.842	0.996	0.983
1975	1.234	1.144	0.748	0.859	1	1.081	0.849	0.988	0.947
1976	1.175	1.091	0.711	0.799	1	1.087	0.830	0.977	0.906
1977	1.266	1.176	0.764	0.865	1	1.093	0.837	0.990	0.955
1978	1.326	1.233	0.798	0.904	1	1.100	0.844	0.995	0.979
1979	1.345	1.251	0.807	0.902	1	1.106	0.833	0.996	0.983
1980	1.303	1.211	0.778	0.877	1	1.112	0.837	0.989	0.953
1981	1.288	1.202	0.767	0.885	1	1.118	0.847	0.987	0.946
1982	1.436	1.343	0.852	0.991	1	1.124	0.856	1.005	1.025
1983	1.335	1.246	0.790	0.933	1	1.131	0.865	0.991	0.962
1984	1.461	1.352	0.862	1.010	1	1.137	0.864	1.005	1.023
1985	1.464	1.339	0.861	1.000	1	1.143	0.858	1.004	1.017
1986	1.508	1.370	0.886	1.028	1	1.150	0.871	1.005	1.022
1987	1.441	1.279	0.842	0.975	1	1.156	0.863	0.996	0.981
1988	1.508	1.370	0.880	1.015	1	1.163	0.864	1.002	1.009
1989	1.485	1.338	0.865	1.019	1	1.169	0.880	0.998	0.992
1990	1.432	1.288	0.833	1.080	1	1.176	0.912	1.001	1.006
1991	1.372	1.172	0.809	1.053	1	1.182	0.926	0.993	0.969
1992	1.346	1.132	0.906	1.113	1	1.189	0.987	0.990	0.958
1993	1.330	1.126	0.906	1.122	1	1.196	1.006	0.987	0.945
1994	1.267	1.073	0.871	1.056	1	1.202	0.982	0.979	0.913
1995	1.301	1.097	0.970	1.134	1	1.209	1.018	0.985	0.935
1996	1.367	1.146	1.019	1.190	1	1.216	1.041	0.989	0.951
1997	1.375	1.148	1.118	1.227	1	1.223	1.065	0.989	0.953
1998	1.406	1.174	1.146	1.257	1	1.229	1.074	0.991	0.961
1999	1.468	1.209	1.299	1.333	1	1.236	1.101	0.996	0.983
2000	1.541	1.262	1.372	1.444	1	1.243	1.142	1.003	1.014
2001	1.517	1.241	1.407	1.459	1	1.250	1.158	1.001	1.006
2002	1.446	1.180	1.340	1.390	1	1.257	1.155	0.992	0.965
2003	1.338	1.095	1.244	1.288	1	1.264	1.148	0.978	0.908
2004	1.543	1.265	1.469	1.499	1	1.271	1.191	0.998	0.992
2005	1.468	1.208	1.425	1.456	1	1.278	1.193	0.991	0.962
2006	1.422	1.172	1.390	1.446	1	1.286	1.214	0.986	0.940
2007	1.457	1.212	1.444	1.441	1	1.293	1.207	0.985	0.937
2008	1.534	1.288	1.546	1.666	1	1.300	1.262	1.003	1.013
2009	1.593	1.348	1.627	1.677	1	1.307	1.269	1.002	1.009
2010	1.500	1.267	1.539	1.519	1	1.315	1.232	0.988	0.949
2011	1.526	1.302	1.593	1.599	1	1.322	1.275	0.990	0.958
2012	1.536	1.318	1.626	1.598	1	1.329	1.257	0.992	0.964
2013	1.560	1.354	1.683	1.640	1	1.337	1.270	0.994	0.972
2014	1.538	1.349	1.691	1.593	1	1.344	1.247	0.991	0.959
2015	1.541	1.365	1.726	1.610	1	1.352	1.248	0.991	0.962

5.8 India

India is among the top three global producers of many crops. In 2014, the agriculture sector employed 41.7% (respectively 62.0%) of the male (respectively female) labor force and contributed 15.7% to the GDP. The agricultural sector in India is large and diverse, with an arable land area which is second only to the USA. Figure 5.8 reports estimated changes in agricultural productivity in India from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.8.

Panel (a) in Figure 5.8 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 4.315 (respectively 1.931) times higher than it had been in 1961. On the other hand, capital productivity fell dramatically over the sample period. In 2015, output per unit of capital was 97.3% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 2.294 (respectively 161.2) while the area of land used for agricultural production increased only by a factor of 1.027.

Panel (b) in Figure 5.8 indicates that TFP in Indian agriculture was 45.8% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 2.550 \times 0.922 \times 0.459$$
$$= 1.458.$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 2.550; (iv) lower technical efficiency (the OTEI component) led to a 7.8% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 54.1% fall in measured TFP. In case of India, important sources of statistical noise are omitted variables (e.g., rainfall) and measurement errors (especially the measurement of capital).

Panel (c) in Figure 5.8 indicates that TFP in India in 2015 was 7.06 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

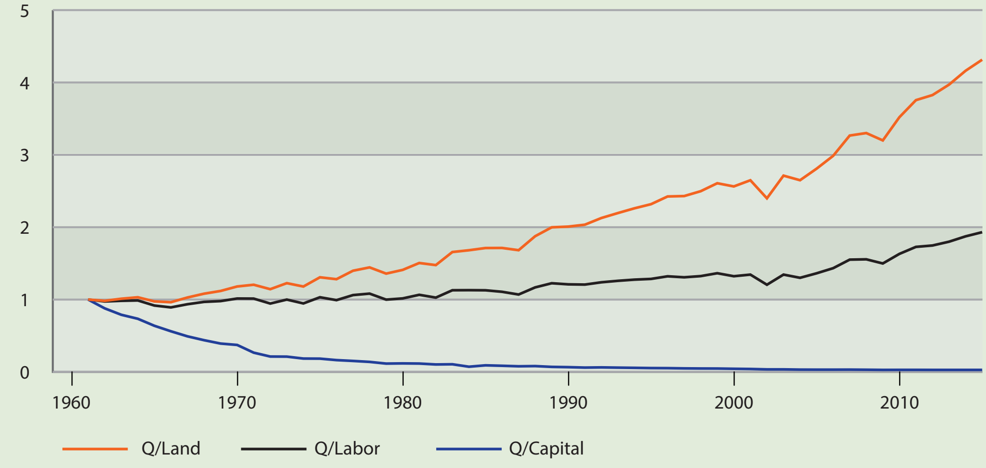
$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 0.547 \times 1.352 \times 7.526 \times 1.040 \times 1.221$$
$$= 7.06.$$

This decomposition indicates that (i) the production environment in India (dry tropical/subtropical) is 45.3% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in India were 7.526 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in India were 4% more technically efficient in 2015 than Australian farmers had been in 1961.

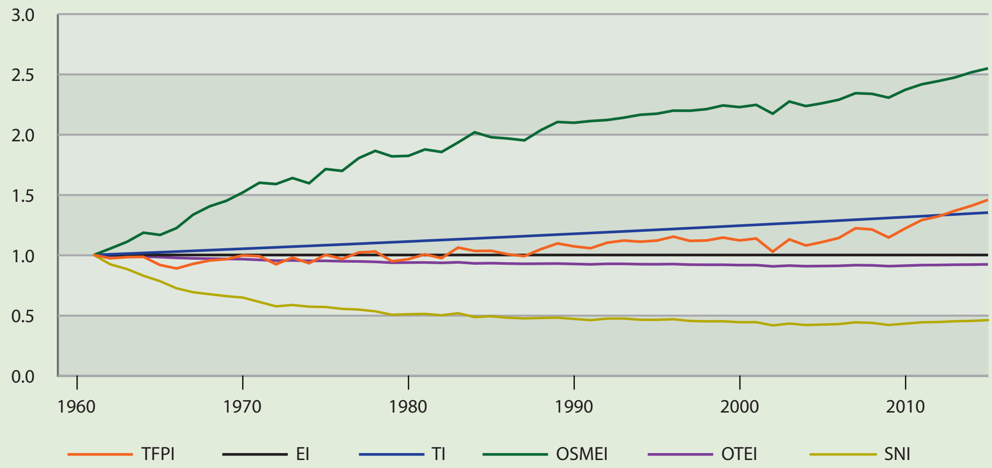
FIGURE 5.8

PRODUCTIVITY CHANGE IN INDIA

(a) Partial factor productivity (cf. India in 1961)



(b) Total factor productivity (cf. India in 1961)



(c) Total factor productivity (cf. Australia in 1961)

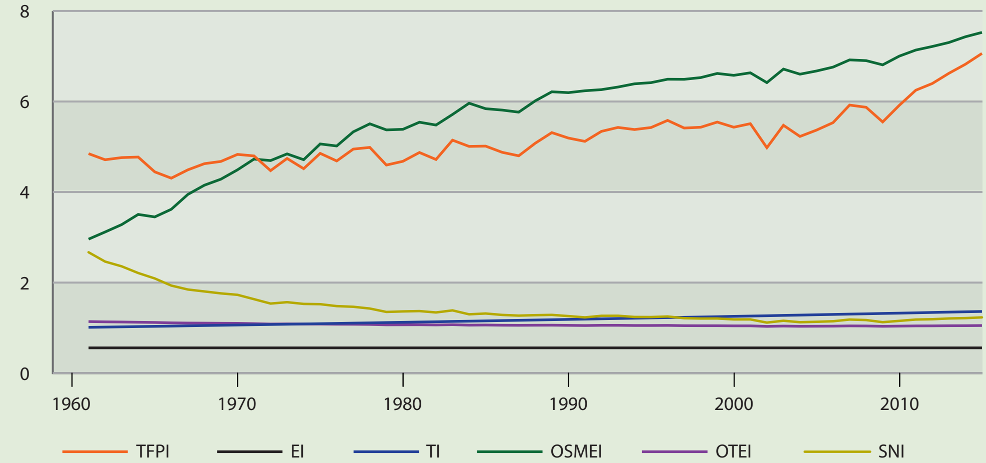


TABLE 5.8

PRODUCTIVITY CHANGE IN INDIA (CF. INDIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.982	0.973	0.878	0.972	1	1.006	1.054	0.995	0.922
1963	1.011	0.982	0.789	0.982	1	1.011	1.109	0.992	0.883
1964	1.032	0.987	0.735	0.984	1	1.017	1.185	0.987	0.828
1965	0.974	0.917	0.637	0.917	1	1.023	1.167	0.983	0.782
1966	0.963	0.892	0.561	0.888	1	1.028	1.224	0.976	0.723
1967	1.029	0.935	0.491	0.926	1	1.034	1.335	0.972	0.690
1968	1.081	0.967	0.438	0.954	1	1.040	1.404	0.969	0.674
1969	1.119	0.978	0.392	0.965	1	1.046	1.450	0.967	0.658
1970	1.181	1.014	0.373	0.997	1	1.052	1.519	0.965	0.646
1971	1.205	1.013	0.266	0.990	1	1.057	1.600	0.959	0.610
1972	1.143	0.945	0.212	0.923	1	1.063	1.589	0.952	0.573
1973	1.227	0.999	0.211	0.978	1	1.069	1.639	0.954	0.585
1974	1.180	0.946	0.184	0.931	1	1.075	1.595	0.952	0.571
1975	1.308	1.032	0.183	1.001	1	1.081	1.713	0.951	0.568
1976	1.281	0.992	0.163	0.967	1	1.087	1.698	0.948	0.552
1977	1.398	1.061	0.151	1.021	1	1.093	1.804	0.946	0.547
1978	1.445	1.082	0.138	1.029	1	1.100	1.864	0.943	0.532
1979	1.359	0.999	0.115	0.948	1	1.106	1.819	0.936	0.504
1980	1.410	1.016	0.118	0.965	1	1.112	1.823	0.937	0.508
1981	1.505	1.065	0.115	1.005	1	1.118	1.876	0.938	0.511
1982	1.476	1.027	0.103	0.973	1	1.124	1.855	0.935	0.499
1983	1.657	1.128	0.105	1.062	1	1.131	1.935	0.939	0.517
1984	1.681	1.130	0.071	1.033	1	1.137	2.019	0.930	0.484
1985	1.712	1.128	0.091	1.035	1	1.143	1.978	0.932	0.491
1986	1.713	1.107	0.085	1.006	1	1.150	1.967	0.929	0.479
1987	1.682	1.069	0.078	0.990	1	1.156	1.952	0.927	0.473
1988	1.875	1.168	0.080	1.048	1	1.163	2.037	0.928	0.477
1989	1.998	1.226	0.069	1.096	1	1.169	2.104	0.929	0.480
1990	2.008	1.210	0.065	1.071	1	1.176	2.098	0.926	0.469
1991	2.035	1.207	0.060	1.056	1	1.182	2.112	0.922	0.459
1992	2.127	1.239	0.062	1.102	1	1.189	2.121	0.926	0.472
1993	2.196	1.259	0.059	1.120	1	1.196	2.140	0.927	0.472
1994	2.261	1.275	0.056	1.110	1	1.202	2.164	0.923	0.462
1995	2.318	1.285	0.053	1.119	1	1.209	2.173	0.923	0.462
1996	2.425	1.321	0.052	1.152	1	1.216	2.198	0.925	0.466
1997	2.430	1.307	0.049	1.117	1	1.223	2.198	0.920	0.452
1998	2.498	1.324	0.047	1.121	1	1.229	2.211	0.919	0.449
1999	2.608	1.364	0.046	1.144	1	1.236	2.242	0.919	0.449
2000	2.563	1.322	0.043	1.121	1	1.243	2.228	0.916	0.442
2001	2.649	1.345	0.040	1.137	1	1.250	2.247	0.916	0.442
2002	2.399	1.205	0.035	1.027	1	1.257	2.173	0.906	0.415
2003	2.713	1.345	0.035	1.130	1	1.264	2.275	0.912	0.431
2004	2.649	1.300	0.031	1.079	1	1.271	2.236	0.907	0.418
2005	2.809	1.363	0.031	1.108	1	1.278	2.260	0.908	0.422
2006	2.986	1.434	0.031	1.142	1	1.286	2.289	0.910	0.426
2007	3.266	1.552	0.032	1.222	1	1.293	2.343	0.916	0.441
2008	3.301	1.556	0.030	1.212	1	1.300	2.338	0.914	0.436
2009	3.199	1.498	0.028	1.145	1	1.307	2.306	0.907	0.419
2010	3.520	1.631	0.028	1.221	1	1.315	2.372	0.911	0.430
2011	3.756	1.728	0.028	1.290	1	1.322	2.417	0.916	0.441
2012	3.826	1.747	0.028	1.321	1	1.329	2.444	0.917	0.443
2013	3.971	1.800	0.027	1.367	1	1.337	2.474	0.919	0.450
2014	4.162	1.874	0.028	1.408	1	1.344	2.517	0.920	0.453
2015	4.315	1.931	0.027	1.458	1	1.352	2.550	0.922	0.459

5.9 Indonesia

The Indonesian agricultural sector is a key global player in the production of tropical products. In 2014, the agriculture sector employed 33.5% (respectively 30.6%) of the male (respectively female) labor force and contributed 13.4% to the GDP. Indonesia is the world's largest producer of palm oil and the third-largest producer of rice. Other important products include rubber, coffee, and tobacco. Figure 5.9 reports estimated changes in agricultural productivity in Indonesia from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.9.

Panel (a) in Figure 5.9 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 4.582 (respectively 4.454) times higher than it had been in 1961. On the other hand, capital productivity fell sharply in the early 1960s and fell slowly thereafter. In 1965, output per unit of capital was 81.4% lower than it had been in 1961; by 2015, output per unit of capital was 91.9% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.528 (respectively 84.087) while the area of land used for agricultural production increased only by a factor of 1.486.

Panel (b) in Figure 5.9 indicates that TFP in Indonesian agriculture was 3.24 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$
$= 1 \times 1.352 \times 2.642 \times 0.985 \times 0.921$
$= 3.24.$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 2.642; (iv) lower technical efficiency (the OTEI component) led to a 1.5% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 7.9% fall in measured TFP.

Panel (c) in Figure 5.9 indicates that TFP in Indonesia in 2015 was 13.424 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$
$= 1.053 \times 1.352 \times 8.589 \times 1.017 \times 1.080$
$= 13.424.$

This decomposition indicates that (i) the production environment in Indonesia (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Indonesia were 8.589 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Indonesia were 1.7% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.9

PRODUCTIVITY CHANGE IN INDONESIA

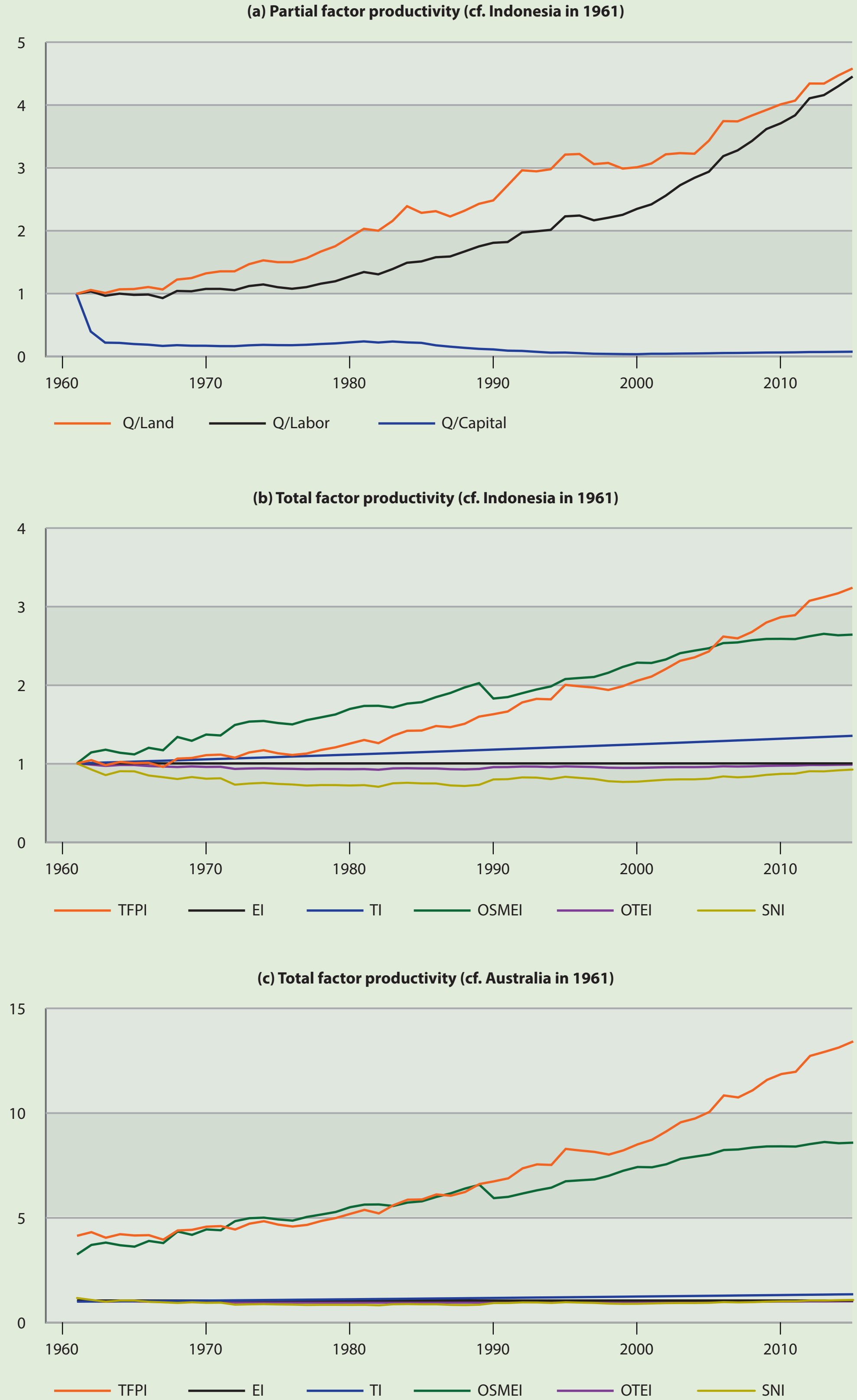


TABLE 5.9

PRODUCTIVITY CHANGE IN INDONESIA (CF. INDONESIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.062	1.040	0.402	1.042	1	1.006	1.140	0.985	0.923
1963	1.015	0.970	0.226	0.978	1	1.011	1.175	0.968	0.850
1964	1.073	1.003	0.221	1.019	1	1.017	1.136	0.980	0.900
1965	1.078	0.985	0.203	1.004	1	1.023	1.115	0.979	0.899
1966	1.109	0.989	0.193	1.007	1	1.028	1.199	0.966	0.846
1967	1.070	0.933	0.173	0.956	1	1.034	1.168	0.961	0.824
1968	1.228	1.047	0.185	1.061	1	1.040	1.337	0.954	0.800
1969	1.251	1.041	0.177	1.069	1	1.046	1.288	0.961	0.826
1970	1.325	1.079	0.176	1.105	1	1.052	1.368	0.955	0.805
1971	1.358	1.080	0.170	1.112	1	1.057	1.356	0.957	0.810
1972	1.359	1.059	0.170	1.073	1	1.063	1.490	0.930	0.729
1973	1.471	1.124	0.183	1.140	1	1.069	1.533	0.935	0.744
1974	1.533	1.150	0.190	1.168	1	1.075	1.541	0.938	0.752
1975	1.504	1.107	0.186	1.129	1	1.081	1.515	0.933	0.738
1976	1.504	1.082	0.184	1.107	1	1.087	1.497	0.931	0.731
1977	1.567	1.107	0.191	1.126	1	1.093	1.552	0.925	0.717
1978	1.672	1.162	0.204	1.171	1	1.100	1.587	0.928	0.724
1979	1.757	1.200	0.213	1.205	1	1.106	1.624	0.928	0.723
1980	1.898	1.276	0.229	1.252	1	1.112	1.694	0.926	0.718
1981	2.035	1.347	0.245	1.299	1	1.118	1.733	0.927	0.723
1982	2.004	1.311	0.227	1.258	1	1.124	1.734	0.919	0.702
1983	2.161	1.395	0.243	1.352	1	1.131	1.712	0.936	0.746
1984	2.394	1.495	0.229	1.416	1	1.137	1.762	0.938	0.753
1985	2.288	1.516	0.222	1.419	1	1.143	1.780	0.936	0.745
1986	2.314	1.582	0.183	1.476	1	1.150	1.845	0.935	0.744
1987	2.231	1.594	0.162	1.462	1	1.156	1.898	0.926	0.719
1988	2.322	1.674	0.143	1.505	1	1.163	1.968	0.923	0.712
1989	2.431	1.755	0.126	1.597	1	1.169	2.023	0.929	0.727
1990	2.486	1.812	0.118	1.627	1	1.176	1.827	0.952	0.796
1991	2.724	1.824	0.098	1.662	1	1.182	1.846	0.953	0.799
1992	2.964	1.975	0.094	1.777	1	1.189	1.895	0.960	0.822
1993	2.948	1.995	0.079	1.823	1	1.196	1.942	0.959	0.819
1994	2.981	2.018	0.066	1.817	1	1.202	1.981	0.954	0.800
1995	3.214	2.232	0.068	2.001	1	1.209	2.075	0.962	0.829
1996	3.223	2.245	0.059	1.983	1	1.216	2.089	0.958	0.815
1997	3.063	2.170	0.049	1.966	1	1.223	2.102	0.954	0.802
1998	3.081	2.210	0.046	1.936	1	1.229	2.156	0.945	0.773
1999	2.991	2.256	0.043	1.984	1	1.236	2.230	0.942	0.764
2000	3.012	2.351	0.041	2.053	1	1.243	2.285	0.943	0.767
2001	3.073	2.423	0.049	2.107	1	1.250	2.280	0.947	0.780
2002	3.218	2.561	0.048	2.203	1	1.257	2.325	0.951	0.792
2003	3.237	2.727	0.051	2.308	1	1.264	2.405	0.953	0.797
2004	3.227	2.845	0.053	2.352	1	1.271	2.438	0.953	0.797
2005	3.435	2.942	0.056	2.428	1	1.278	2.468	0.955	0.805
2006	3.746	3.189	0.060	2.617	1	1.286	2.534	0.963	0.834
2007	3.742	3.281	0.062	2.594	1	1.293	2.542	0.960	0.822
2008	3.836	3.431	0.064	2.676	1	1.300	2.570	0.963	0.832
2009	3.923	3.620	0.068	2.796	1	1.307	2.587	0.969	0.854
2010	4.012	3.711	0.069	2.864	1	1.315	2.588	0.972	0.866
2011	4.071	3.838	0.071	2.890	1	1.322	2.585	0.973	0.870
2012	4.343	4.108	0.076	3.073	1	1.329	2.621	0.980	0.900
2013	4.342	4.159	0.076	3.119	1	1.337	2.652	0.979	0.898
2014	4.471	4.300	0.079	3.169	1	1.344	2.633	0.982	0.911
2015	4.582	4.454	0.081	3.240	1	1.352	2.642	0.985	0.921

5.10 IR Iran

Approximately one-third of Islamic Republic of Iran (IR Iran)'s total land area is suitable for farming. Approximately 12% of total land area is cultivated. In 2014, the agriculture sector employed 17.1% (respectively 22.2%) of the male (respectively female) labor force and contributed 7.5% to the GDP. Figure 5.10 reports estimated changes in agricultural productivity in IR Iran from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.10.

Panel (a) in Figure 5.10 indicates that land and labor productivity have both increased over the sample period. In 2015, output per unit of land (respectively labor) was 10.921 (respectively 5.897) times higher than it had been in 1961. On the other hand, capital productivity fell significantly over the sample period. In 2015, output per unit of capital was 80.6% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.431 (respectively 43.611) while the area of land used for agricultural production fell by 22.7%.

Panel (b) in Figure 5.10 indicates that TFP in Iranian agriculture was 5.988 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 3.856 × 1.014 × 1.133
= 5.988.

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 3.856; (iv) improved technical efficiency (the OTEI component) led to a 1.4% increase in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 13.3% fall in measured TFP. In case of IR Iran, the increase in scale and mix efficiency can be partly attributed to a shift from crops to livestock (i.e., a more productive output mix).

Panel (c) in Figure 5.10 indicates that TFP in IR Iran in 2015 was 16.865 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 0.547 × 1.352 × 11.822 × 1.092 × 1.768
= 16.865.

This decomposition indicates that (i) the production environment in IR Iran (dry tropical/subtropical) is 45.3% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in IR Iran were 11.822 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in IR Iran were 9.2% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.10

PRODUCTIVITY CHANGE IN IR IRAN

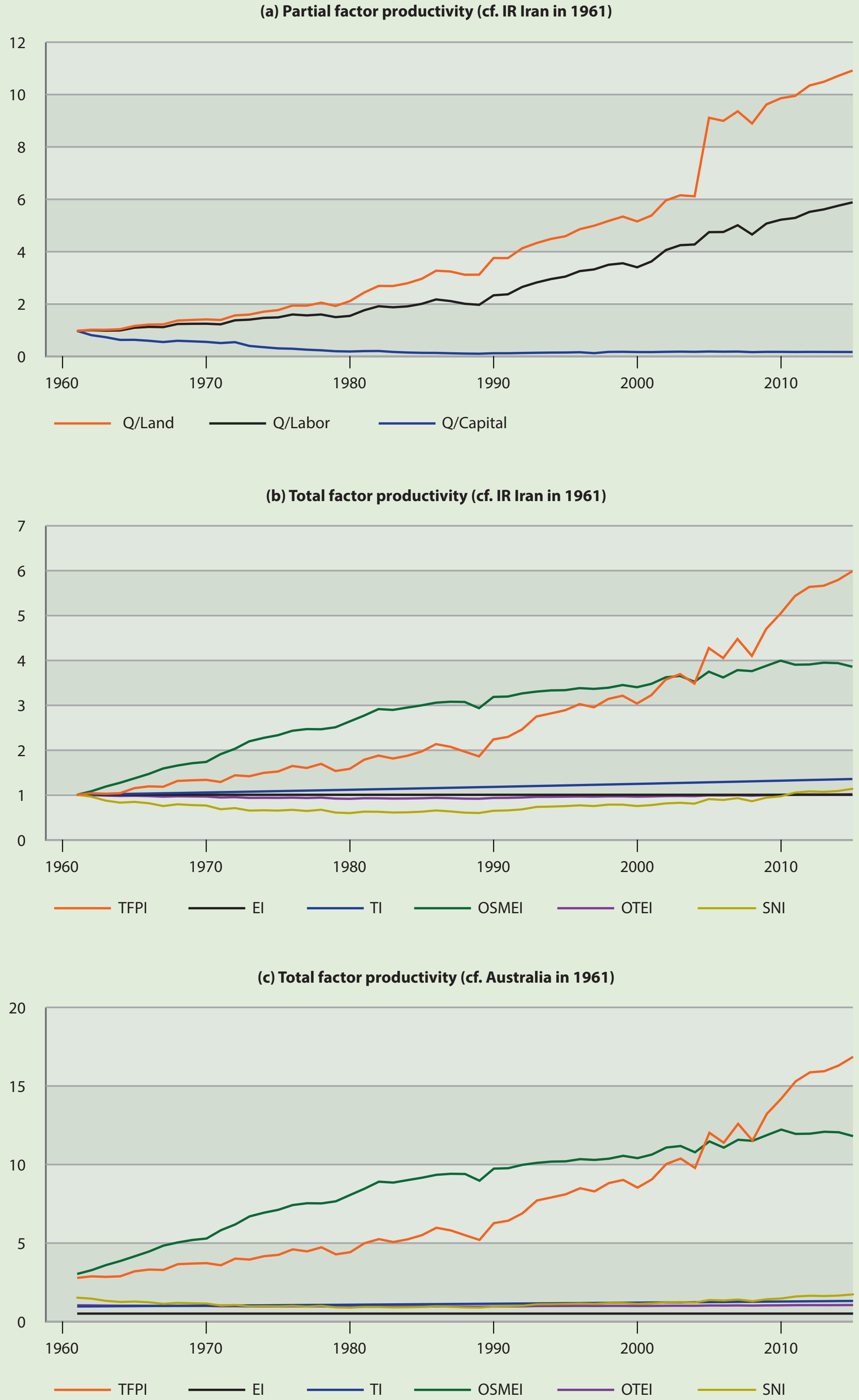


TABLE 5.10

PRODUCTIVITY CHANGE IN IR IRAN (CF. IR IRAN IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.043	1.027	0.834	1.034	1	1.006	1.078	0.995	0.959
1963	1.039	1.008	0.757	1.022	1	1.011	1.183	0.982	0.870
1964	1.062	1.015	0.655	1.036	1	1.017	1.268	0.974	0.824
1965	1.187	1.118	0.657	1.148	1	1.023	1.366	0.977	0.841
1966	1.240	1.150	0.622	1.187	1	1.028	1.465	0.972	0.811
1967	1.246	1.142	0.572	1.179	1	1.034	1.587	0.959	0.750
1968	1.391	1.260	0.622	1.309	1	1.040	1.653	0.967	0.788
1969	1.416	1.268	0.600	1.323	1	1.046	1.704	0.963	0.771
1970	1.436	1.272	0.578	1.332	1	1.052	1.733	0.961	0.761
1971	1.414	1.247	0.534	1.285	1	1.057	1.906	0.940	0.678
1972	1.589	1.401	0.568	1.435	1	1.063	2.026	0.947	0.703
1973	1.619	1.427	0.424	1.413	1	1.069	2.193	0.931	0.647
1974	1.729	1.494	0.376	1.489	1	1.075	2.270	0.933	0.654
1975	1.789	1.512	0.332	1.519	1	1.081	2.329	0.931	0.648
1976	1.963	1.623	0.318	1.643	1	1.087	2.428	0.936	0.665
1977	1.960	1.588	0.282	1.598	1	1.093	2.466	0.928	0.639
1978	2.071	1.624	0.259	1.689	1	1.100	2.462	0.937	0.666
1979	1.947	1.522	0.222	1.531	1	1.106	2.505	0.915	0.604
1980	2.132	1.569	0.213	1.579	1	1.112	2.637	0.911	0.591
1981	2.461	1.785	0.228	1.782	1	1.118	2.767	0.923	0.624
1982	2.712	1.937	0.232	1.874	1	1.124	2.912	0.922	0.621
1983	2.708	1.897	0.197	1.809	1	1.131	2.893	0.916	0.604
1984	2.813	1.932	0.174	1.870	1	1.137	2.945	0.917	0.609
1985	2.982	2.027	0.162	1.965	1	1.143	2.995	0.922	0.622
1986	3.291	2.197	0.159	2.131	1	1.150	3.054	0.932	0.651
1987	3.262	2.135	0.145	2.071	1	1.156	3.075	0.925	0.630
1988	3.137	2.032	0.134	1.963	1	1.163	3.071	0.914	0.601
1989	3.142	1.991	0.128	1.856	1	1.169	2.932	0.912	0.594
1990	3.774	2.353	0.146	2.236	1	1.176	3.183	0.929	0.643
1991	3.772	2.392	0.146	2.290	1	1.182	3.191	0.932	0.651
1992	4.148	2.673	0.157	2.459	1	1.189	3.261	0.939	0.675
1993	4.346	2.843	0.165	2.747	1	1.196	3.302	0.954	0.729
1994	4.504	2.974	0.171	2.814	1	1.202	3.328	0.955	0.736
1995	4.604	3.067	0.175	2.886	1	1.209	3.333	0.958	0.747
1996	4.873	3.276	0.185	3.022	1	1.216	3.379	0.962	0.765
1997	5.005	3.340	0.149	2.951	1	1.223	3.362	0.958	0.749
1998	5.186	3.517	0.197	3.138	1	1.229	3.388	0.965	0.780
1999	5.353	3.575	0.202	3.210	1	1.236	3.448	0.965	0.780
2000	5.170	3.422	0.192	3.036	1	1.243	3.400	0.959	0.749
2001	5.395	3.646	0.190	3.222	1	1.250	3.474	0.963	0.770
2002	5.969	4.078	0.201	3.568	1	1.257	3.619	0.971	0.808
2003	6.166	4.263	0.207	3.692	1	1.264	3.651	0.973	0.822
2004	6.127	4.291	0.201	3.479	1	1.271	3.521	0.970	0.802
2005	9.120	4.761	0.213	4.273	1	1.278	3.747	0.987	0.904
2006	9.002	4.767	0.206	4.049	1	1.286	3.617	0.984	0.885
2007	9.367	5.024	0.210	4.476	1	1.293	3.781	0.990	0.925
2008	8.902	4.672	0.189	4.098	1	1.300	3.758	0.980	0.856
2009	9.625	5.088	0.199	4.701	1	1.307	3.876	0.992	0.935
2010	9.863	5.235	0.199	5.043	1	1.315	3.992	0.996	0.965
2011	9.953	5.303	0.195	5.433	1	1.322	3.902	1.005	1.048
2012	10.350	5.534	0.198	5.636	1	1.329	3.906	1.008	1.076
2013	10.492	5.629	0.195	5.662	1	1.337	3.946	1.007	1.066
2014	10.717	5.768	0.195	5.791	1	1.344	3.936	1.009	1.084
2015	10.921	5.897	0.194	5.988	1	1.352	3.856	1.014	1.133

5.11 Japan

Japanese agriculture is characterized by a shortage of farmland. Farmland constitutes less than 15% of the total land area and is intensively cultivated. In 2014, the agriculture sector employed 4.1% (respectively 3.5%) of the male (respectively female) labor force and contributed 1.2% to the GDP. Figure 5.11 reports estimated changes in agricultural productivity in Japan from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.11.

Panel (a) in Figure 5.11 indicates that labor productivity increased significantly this century. In 2015, output per unit of labor was almost three times higher than it had been in 2000. On the other hand, capital productivity fell sharply in the 1960s and was relatively stable thereafter. In 2015, output per unit of capital was 99.6% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased significantly over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 75.3% (respectively increased by a factor of 272.284) while the area of land used for agricultural production fell by 36.7%.

Panel (b) in Figure 5.11 indicates that TFP in Japanese agriculture was 40.8% lower in 2015 than it had been in 1961. The breakdown of this decrease is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 0.602 × 0.951 × 0.765
= 0.592.

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) a fall in scale and mix efficiency (the OSMEI component) led to a 39.8% fall in TFP; (iv) lower technical efficiency (the OTEI component) led to a 4.9% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 23.5% fall in measured TFP. In case of Japan, the fall in scale and mix efficiency can be partly attributed to a shift from livestock into crops (i.e., a less productive output mix).

Panel (c) in Figure 5.11 indicates that TFP in Japan in 2015 was 5.351 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 0.986 × 1.352 × 4.008 × 1 × 1.001
= 5.351.

This decomposition indicates that (i) the production environment in Japan (wet temperate) is 1.4% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Japan were four times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Japan were as technically efficient in 2015 as Australian farmers had been in 1961.

FIGURE 5.11

PRODUCTIVITY CHANGE IN JAPAN

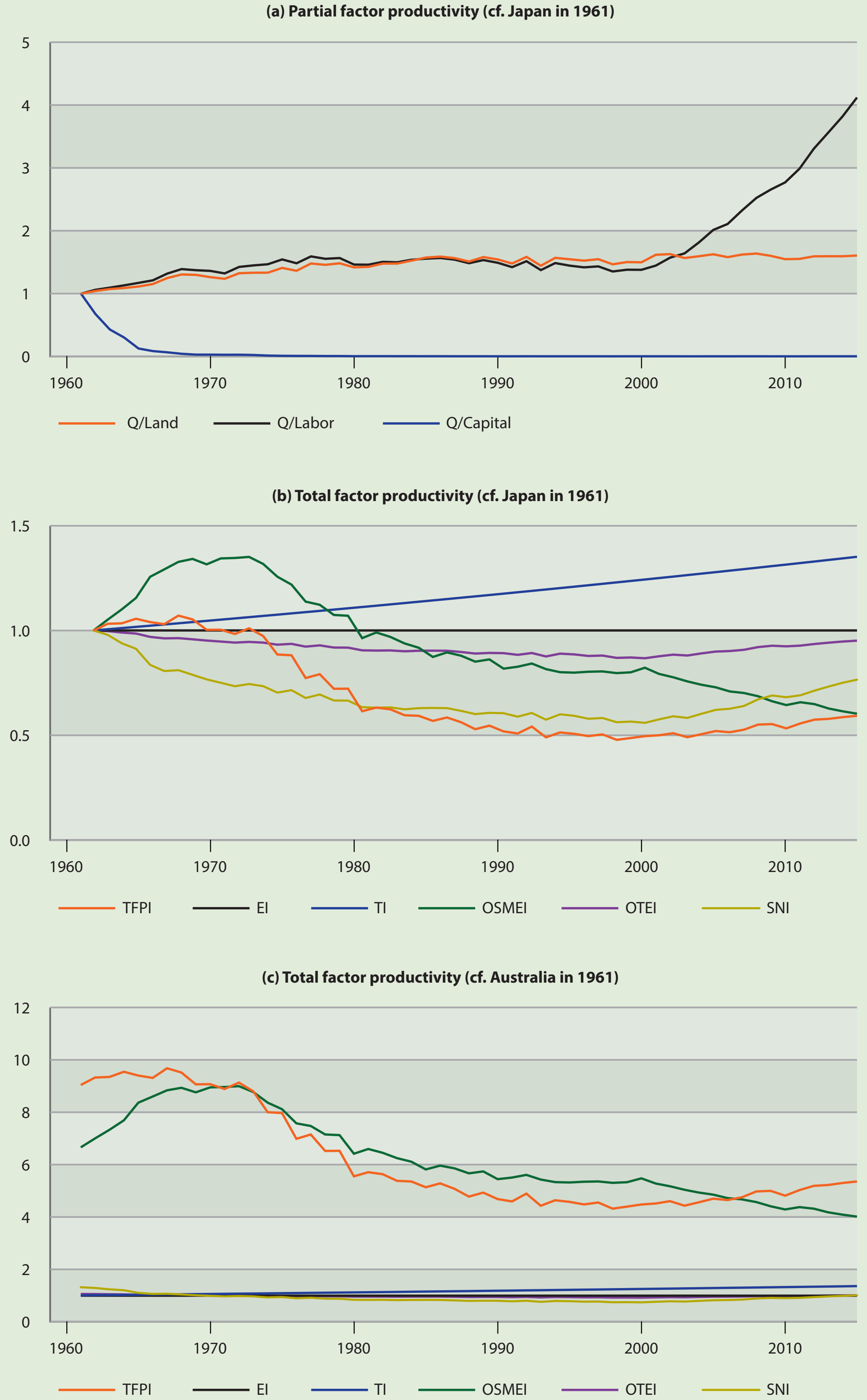


TABLE 5.11

PRODUCTIVITY CHANGE IN JAPAN (CF. JAPAN IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.042	1.061	0.678	1.032	1	1.006	1.051	0.997	0.979
1963	1.073	1.096	0.431	1.034	1	1.011	1.101	0.990	0.938
1964	1.090	1.132	0.303	1.056	1	1.017	1.155	0.985	0.912
1965	1.114	1.172	0.128	1.040	1	1.023	1.256	0.969	0.835
1966	1.153	1.212	0.087	1.030	1	1.028	1.292	0.962	0.806
1967	1.248	1.319	0.067	1.071	1	1.034	1.327	0.963	0.810
1968	1.306	1.391	0.044	1.053	1	1.040	1.342	0.957	0.788
1969	1.299	1.373	0.031	1.003	1	1.046	1.316	0.951	0.766
1970	1.263	1.362	0.030	1.003	1	1.052	1.344	0.947	0.750
1971	1.236	1.322	0.029	0.983	1	1.057	1.346	0.942	0.733
1972	1.325	1.426	0.029	1.010	1	1.063	1.351	0.945	0.744
1973	1.333	1.450	0.025	0.973	1	1.069	1.317	0.942	0.733
1974	1.334	1.468	0.015	0.885	1	1.075	1.257	0.932	0.703
1975	1.410	1.545	0.012	0.881	1	1.081	1.219	0.936	0.715
1976	1.364	1.483	0.010	0.773	1	1.087	1.138	0.923	0.677
1977	1.480	1.593	0.009	0.791	1	1.093	1.122	0.929	0.694
1978	1.459	1.555	0.008	0.721	1	1.100	1.074	0.918	0.665
1979	1.483	1.567	0.008	0.722	1	1.106	1.070	0.918	0.665
1980	1.418	1.462	0.006	0.614	1	1.112	0.963	0.905	0.633
1981	1.427	1.461	0.006	0.631	1	1.118	0.990	0.904	0.631
1982	1.478	1.506	0.006	0.623	1	1.124	0.969	0.904	0.632
1983	1.479	1.499	0.005	0.595	1	1.131	0.938	0.900	0.623
1984	1.526	1.540	0.005	0.592	1	1.137	0.917	0.903	0.629
1985	1.574	1.557	0.005	0.567	1	1.143	0.873	0.903	0.629
1986	1.590	1.567	0.005	0.584	1	1.150	0.895	0.903	0.629
1987	1.566	1.541	0.005	0.561	1	1.156	0.879	0.897	0.615
1988	1.511	1.485	0.004	0.528	1	1.163	0.851	0.889	0.600
1989	1.582	1.535	0.004	0.545	1	1.169	0.862	0.892	0.606
1990	1.544	1.491	0.004	0.518	1	1.176	0.817	0.891	0.604
1991	1.479	1.422	0.004	0.508	1	1.182	0.827	0.883	0.588
1992	1.585	1.517	0.004	0.541	1	1.189	0.842	0.892	0.605
1993	1.445	1.375	0.004	0.489	1	1.196	0.815	0.876	0.573
1994	1.570	1.487	0.004	0.513	1	1.202	0.800	0.889	0.599
1995	1.547	1.446	0.004	0.506	1	1.209	0.798	0.885	0.592
1996	1.525	1.419	0.004	0.495	1	1.216	0.803	0.878	0.578
1997	1.548	1.434	0.004	0.503	1	1.223	0.804	0.880	0.581
1998	1.467	1.353	0.004	0.477	1	1.229	0.796	0.869	0.561
1999	1.503	1.381	0.004	0.486	1	1.236	0.800	0.871	0.564
2000	1.499	1.380	0.004	0.495	1	1.243	0.822	0.867	0.558
2001	1.619	1.446	0.004	0.499	1	1.250	0.792	0.876	0.575
2002	1.629	1.573	0.004	0.509	1	1.257	0.776	0.884	0.590
2003	1.567	1.641	0.004	0.490	1	1.264	0.756	0.880	0.582
2004	1.595	1.815	0.004	0.504	1	1.271	0.740	0.890	0.602
2005	1.626	2.014	0.004	0.519	1	1.278	0.728	0.899	0.620
2006	1.581	2.109	0.004	0.514	1	1.286	0.708	0.901	0.626
2007	1.622	2.324	0.004	0.525	1	1.293	0.701	0.907	0.639
2008	1.638	2.523	0.004	0.550	1	1.300	0.686	0.920	0.671
2009	1.602	2.656	0.004	0.552	1	1.307	0.661	0.927	0.689
2010	1.549	2.770	0.003	0.532	1	1.315	0.643	0.924	0.681
2011	1.553	2.988	0.004	0.556	1	1.322	0.657	0.927	0.690
2012	1.594	3.306	0.004	0.574	1	1.329	0.648	0.935	0.712
2013	1.595	3.562	0.004	0.577	1	1.337	0.627	0.941	0.732
2014	1.595	3.821	0.004	0.586	1	1.344	0.613	0.947	0.750
2015	1.606	4.120	0.004	0.592	1	1.352	0.602	0.951	0.765

5.12 Republic of Korea

In 2014, the agriculture sector in the Republic of Korea (ROK) employed 5.6% (respectively 5.7%) of the male (respectively female) labor force and contributed 2.1% to the GDP. The most important agricultural industry is rice: rice accounts for more than 90% of total grain production and almost one half of farm income. Figure 5.12 reports estimated changes in agricultural productivity in ROK from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.12.

Panel (a) in Figure 5.12 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 3.617 (respectively 6.309) times higher than it had been in 1961. On the other hand, capital productivity fell significantly over the sample period. In 2015, output per unit of capital was negligible. Taken together, these results indicate that labor per hectare fell and capital per hectare increased significantly over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 52.7% (respectively increased by a factor of more than 12,000) while the area of land used for agricultural production fell by 17.6%.

Panel (b) in Figure 5.12 indicates that TFP in Korean agriculture was 2.5 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 2.552 × 0.953 × 0.760
= 2.5

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 2.552; (iv) lower technical efficiency (the OTEI component) led to a 4.7% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 24% fall in measured TFP.

Panel (c) in Figure 5.12 indicates that TFP in the ROK in 2015 was 11.037 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 0.986 × 1.352 × 7.841 × 1.010 × 1.046
= 11.037.

This decomposition indicates that (i) the production environment in the ROK (wet temperate) is 1.4% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in the ROK were 7.841 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and farmers in the ROK were 1% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.12

PRODUCTIVITY CHANGE IN ROK

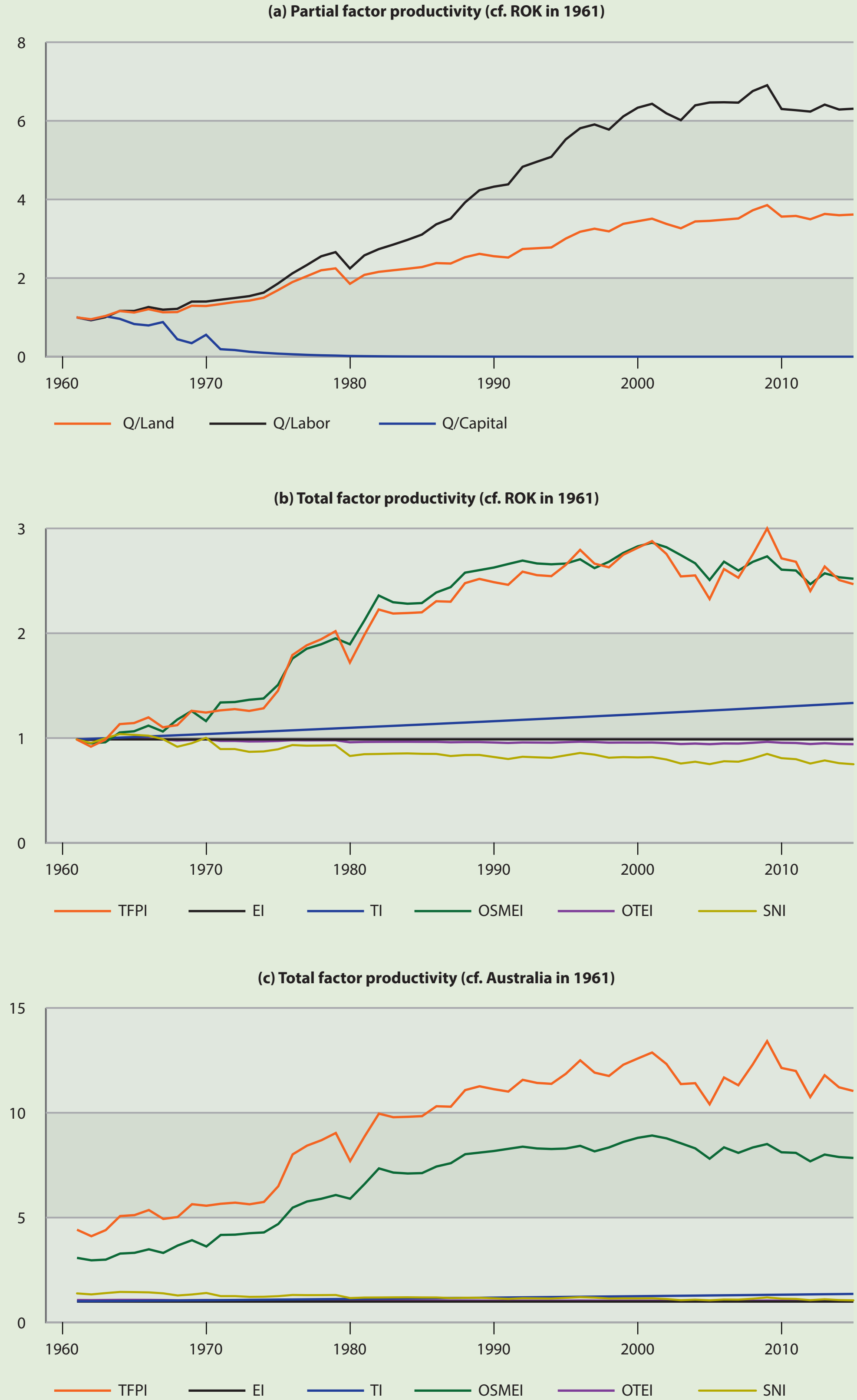


TABLE 5.12

PRODUCTIVITY CHANGE IN ROK (CF. ROK IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.953	0.926	0.939	0.930	1	1.006	0.962	0.995	0.966
1963	1.035	1.005	1.029	0.996	1	1.011	0.972	1.002	1.011
1964	1.161	1.165	0.963	1.148	1	1.017	1.066	1.007	1.051
1965	1.124	1.163	0.831	1.158	1	1.023	1.078	1.006	1.044
1966	1.209	1.264	0.795	1.213	1	1.028	1.133	1.005	1.036
1967	1.129	1.196	0.881	1.117	1	1.034	1.076	1.000	1.003
1968	1.136	1.218	0.444	1.137	1	1.040	1.191	0.989	0.929
1969	1.296	1.401	0.344	1.276	1	1.046	1.274	0.994	0.963
1970	1.290	1.403	0.558	1.259	1	1.052	1.177	1.002	1.016
1971	1.338	1.450	0.191	1.280	1	1.057	1.356	0.985	0.906
1972	1.390	1.494	0.169	1.292	1	1.063	1.361	0.985	0.907
1973	1.426	1.541	0.126	1.275	1	1.069	1.383	0.980	0.880
1974	1.499	1.630	0.100	1.300	1	1.075	1.395	0.981	0.883
1975	1.694	1.862	0.077	1.470	1	1.081	1.526	0.985	0.905
1976	1.898	2.119	0.062	1.814	1	1.087	1.780	0.992	0.945
1977	2.048	2.331	0.047	1.909	1	1.093	1.876	0.991	0.939
1978	2.199	2.554	0.035	1.967	1	1.100	1.918	0.991	0.941
1979	2.247	2.660	0.028	2.045	1	1.106	1.976	0.992	0.944
1980	1.854	2.244	0.018	1.742	1	1.112	1.919	0.972	0.840
1981	2.081	2.577	0.014	2.007	1	1.118	2.146	0.976	0.857
1982	2.158	2.737	0.010	2.255	1	1.124	2.390	0.976	0.859
1983	2.199	2.851	0.007	2.216	1	1.131	2.325	0.977	0.863
1984	2.238	2.973	0.006	2.221	1	1.137	2.311	0.977	0.865
1985	2.281	3.107	0.005	2.227	1	1.143	2.317	0.977	0.861
1986	2.381	3.368	0.004	2.334	1	1.150	2.419	0.976	0.860
1987	2.370	3.512	0.003	2.330	1	1.156	2.470	0.972	0.839
1988	2.531	3.925	0.003	2.509	1	1.163	2.610	0.974	0.849
1989	2.617	4.235	0.002	2.551	1	1.169	2.635	0.974	0.850
1990	2.556	4.325	0.002	2.519	1	1.176	2.660	0.970	0.830
1991	2.522	4.384	0.001	2.493	1	1.182	2.694	0.966	0.810
1992	2.739	4.832	0.001	2.620	1	1.189	2.727	0.971	0.832
1993	2.760	4.960	0.001	2.586	1	1.196	2.700	0.969	0.827
1994	2.779	5.085	0.001	2.577	1	1.202	2.691	0.968	0.822
1995	3.005	5.528	0.001	2.685	1	1.209	2.698	0.973	0.846
1996	3.179	5.811	0.001	2.831	1	1.216	2.740	0.978	0.869
1997	3.256	5.908	0.001	2.698	1	1.223	2.655	0.975	0.853
1998	3.189	5.778	<0.001	2.662	1	1.229	2.716	0.969	0.823
1999	3.380	6.113	<0.001	2.784	1	1.236	2.801	0.970	0.829
2000	3.446	6.334	<0.001	2.851	1	1.243	2.865	0.969	0.826
2001	3.511	6.434	<0.001	2.915	1	1.250	2.900	0.970	0.829
2002	3.378	6.190	<0.001	2.791	1	1.257	2.856	0.965	0.806
2003	3.266	6.017	<0.001	2.574	1	1.264	2.780	0.955	0.767
2004	3.441	6.395	<0.001	2.584	1	1.271	2.701	0.959	0.784
2005	3.456	6.467	<0.001	2.356	1	1.278	2.540	0.954	0.761
2006	3.486	6.473	<0.001	2.646	1	1.286	2.717	0.961	0.789
2007	3.517	6.463	<0.001	2.561	1	1.293	2.631	0.960	0.785
2008	3.726	6.758	<0.001	2.787	1	1.300	2.715	0.967	0.816
2009	3.856	6.906	<0.001	3.038	1	1.307	2.768	0.976	0.860
2010	3.564	6.301	<0.001	2.748	1	1.315	2.640	0.968	0.818
2011	3.581	6.271	<0.001	2.716	1	1.322	2.631	0.965	0.809
2012	3.496	6.235	<0.001	2.433	1	1.329	2.499	0.955	0.767
2013	3.632	6.413	<0.001	2.670	1	1.337	2.604	0.963	0.797
2014	3.599	6.288	<0.001	2.540	1	1.344	2.566	0.956	0.770
2015	3.617	6.309	<0.001	2.500	1	1.352	2.552	0.953	0.760

5.13 Lao PDR

In 2014, the agriculture sector in the Lao PDR employed 75.2% (respectively 84.7%) of the male (respectively female) labor force and contributed 23.2% to the GDP. The main agricultural products are rice, coffee, and opium. Slash-and-burn cultivation techniques appear to be causing serious erosion and deforestation problems. Figure 5.13 reports estimated changes in agricultural productivity in Lao PDR from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.13.

Panel (a) in Figure 5.13 indicates that land and labor productivity both increased over the sample period, with particularly strong growth after 1998. In 2015, output per unit of land (respectively labor) was 6.194 (respectively 4.452) times higher than it had been in 1961. On the other hand, capital productivity fell sharply in the mid-to-late 1960s and remained relatively low thereafter. In 2015, output per unit of capital was 73.6% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 2.16 (respectively 36.433) while the area of land used for agricultural production increased by a factor of only 1.552.

Panel (b) in Figure 5.13 indicates that agricultural TFP in Lao PDR was 4.74 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 3.594 × 0.998 × 0.977
= 4.74

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 3.594; (iv) changes in technical efficiency (the OTEI component) had a negligible impact on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 2.3% fall in measured TFP. In case of Lao PDR, the increase in scale and mix efficiency can be partly attributed to a shift from crops to livestock (i.e., a more productive output mix).

Panel (c) in Figure 5.13 indicates that TFP in Lao PDR in 2015 was 16.697 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 4.613 × 1.116 × 2.279
= 16.697.

This decomposition indicates that (i) the production environment in the Lao PDR (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Lao PDR were 4.613 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Lao PDR were 11.6% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.13

PRODUCTIVITY CHANGE IN LAO PDR

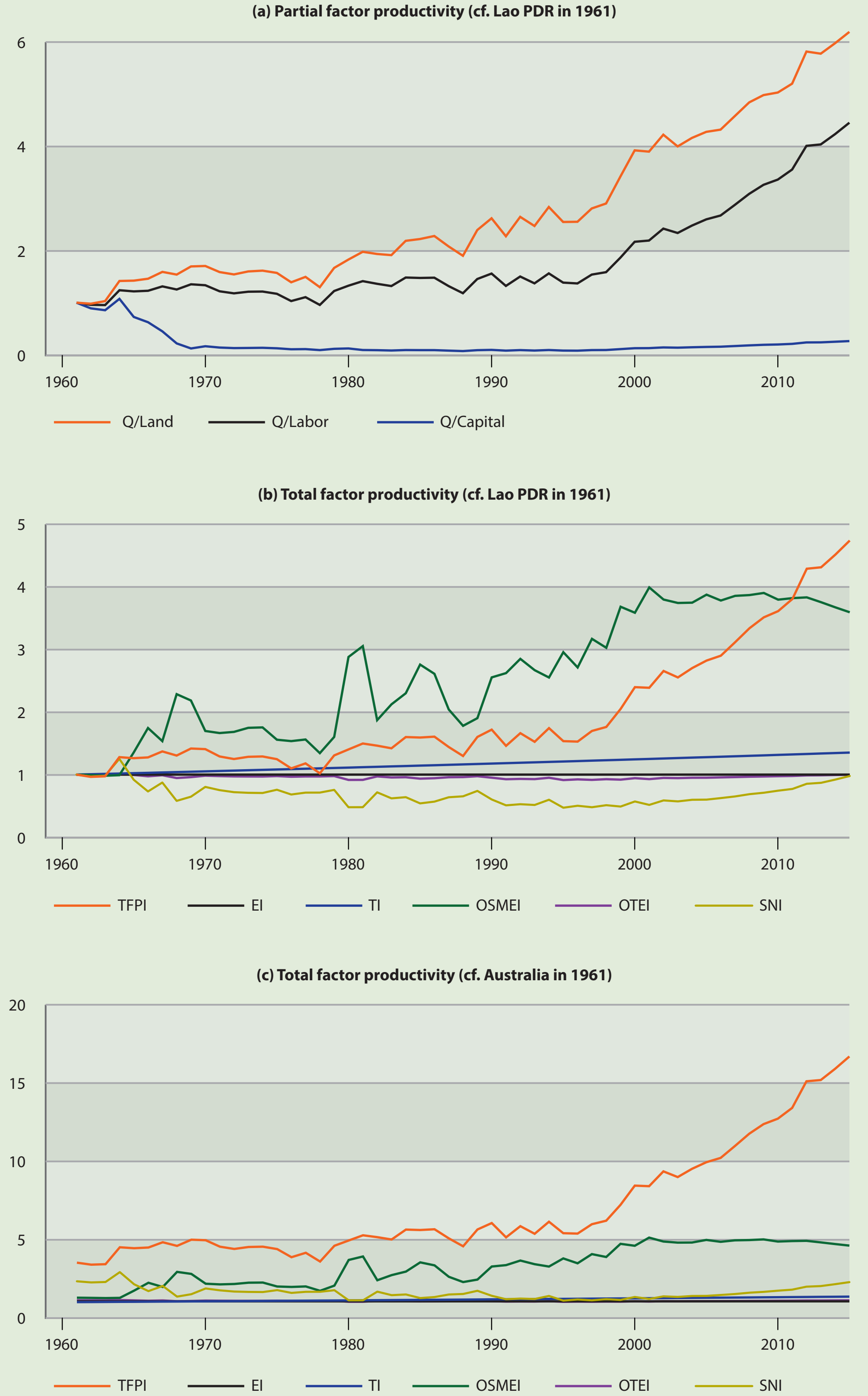


TABLE 5.13

PRODUCTIVITY CHANGE IN LAO PDR (CF. LAO PDR IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.980	0.959	0.891	0.964	1	1.006	0.992	0.998	0.969
1963	1.031	0.954	0.855	0.972	1	1.011	0.982	0.999	0.981
1964	1.416	1.238	1.074	1.279	1	1.017	0.991	1.014	1.251
1965	1.423	1.217	0.726	1.262	1	1.023	1.353	0.994	0.918
1966	1.459	1.229	0.625	1.274	1	1.028	1.744	0.973	0.730
1967	1.591	1.312	0.450	1.370	1	1.034	1.534	0.989	0.873
1968	1.539	1.253	0.219	1.304	1	1.040	2.286	0.945	0.580
1969	1.695	1.353	0.122	1.416	1	1.046	2.184	0.959	0.647
1970	1.704	1.335	0.165	1.407	1	1.052	1.697	0.982	0.803
1971	1.587	1.218	0.140	1.289	1	1.057	1.664	0.976	0.751
1972	1.542	1.179	0.129	1.249	1	1.063	1.682	0.971	0.719
1973	1.599	1.210	0.132	1.284	1	1.069	1.747	0.970	0.709
1974	1.615	1.213	0.135	1.290	1	1.075	1.754	0.969	0.706
1975	1.571	1.171	0.125	1.247	1	1.081	1.557	0.977	0.758
1976	1.391	1.031	0.106	1.099	1	1.087	1.535	0.965	0.682
1977	1.495	1.106	0.110	1.179	1	1.093	1.561	0.970	0.712
1978	1.297	0.957	0.091	1.020	1	1.100	1.342	0.970	0.713
1979	1.667	1.224	0.115	1.306	1	1.106	1.601	0.976	0.756
1980	1.827	1.326	0.122	1.402	1	1.112	2.880	0.915	0.478
1981	1.976	1.413	0.093	1.496	1	1.118	3.053	0.915	0.479
1982	1.934	1.362	0.089	1.462	1	1.124	1.870	0.971	0.716
1983	1.912	1.319	0.083	1.420	1	1.131	2.123	0.954	0.620
1984	2.186	1.482	0.092	1.600	1	1.137	2.300	0.958	0.639
1985	2.221	1.475	0.090	1.592	1	1.143	2.758	0.935	0.540
1986	2.279	1.479	0.090	1.606	1	1.150	2.610	0.942	0.568
1987	2.078	1.318	0.080	1.441	1	1.156	2.040	0.958	0.638
1988	1.900	1.182	0.072	1.297	1	1.163	1.779	0.960	0.653
1989	2.393	1.454	0.089	1.602	1	1.169	1.902	0.974	0.740
1990	2.618	1.559	0.095	1.718	1	1.176	2.553	0.950	0.602
1991	2.273	1.322	0.080	1.459	1	1.182	2.622	0.926	0.509
1992	2.646	1.502	0.091	1.662	1	1.189	2.850	0.931	0.527
1993	2.471	1.371	0.082	1.524	1	1.196	2.669	0.928	0.515
1994	2.836	1.561	0.093	1.742	1	1.202	2.552	0.949	0.598
1995	2.548	1.385	0.081	1.534	1	1.209	2.956	0.912	0.471
1996	2.551	1.369	0.080	1.527	1	1.216	2.712	0.923	0.502
1997	2.807	1.539	0.091	1.697	1	1.223	3.169	0.915	0.479
1998	2.902	1.585	0.093	1.761	1	1.229	3.026	0.926	0.511
1999	3.418	1.863	0.110	2.048	1	1.236	3.682	0.919	0.489
2000	3.921	2.168	0.127	2.397	1	1.243	3.586	0.943	0.570
2001	3.897	2.192	0.129	2.387	1	1.250	3.991	0.928	0.516
2002	4.222	2.420	0.142	2.656	1	1.257	3.797	0.947	0.587
2003	3.996	2.336	0.137	2.552	1	1.264	3.743	0.943	0.572
2004	4.160	2.478	0.145	2.702	1	1.271	3.747	0.949	0.597
2005	4.276	2.598	0.152	2.822	1	1.278	3.876	0.950	0.600
2006	4.319	2.672	0.156	2.900	1	1.286	3.782	0.955	0.625
2007	4.580	2.876	0.169	3.116	1	1.293	3.856	0.960	0.651
2008	4.841	3.088	0.182	3.339	1	1.300	3.869	0.966	0.687
2009	4.981	3.260	0.192	3.513	1	1.307	3.903	0.970	0.710
2010	5.031	3.361	0.199	3.612	1	1.315	3.796	0.975	0.743
2011	5.200	3.554	0.210	3.807	1	1.322	3.819	0.978	0.771
2012	5.816	4.007	0.237	4.290	1	1.329	3.832	0.987	0.853
2013	5.775	4.035	0.239	4.313	1	1.337	3.754	0.989	0.869
2014	5.976	4.232	0.251	4.516	1	1.344	3.672	0.994	0.921
2015	6.194	4.452	0.264	4.740	1	1.352	3.594	0.998	0.977

5.14 Malaysia

Agriculture is an important part of the Malaysian economy. In 2014, the agriculture sector employed 14.6% (respectively 8.5%) of the male (respectively female) labor force and contributed 9.1% to the GDP. Large-scale plantations are mainly used to produce tropical crops that are suitable for export (e.g., palm oil). The climate in Malaysia is quite stable. Thus, agriculture is rarely affected by extreme weather events. Figure 5.14 reports estimated changes in agricultural productivity in Malaysia from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.14.

Panel (a) in Figure 5.14 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 3.071 (respectively 6.18) times higher than it had been in 1961. On the other hand, capital productivity fell steadily over the sample period. In 2015, output per unit of capital was 71.1% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.264 (respectively 27.063) while the area of land used for agricultural production increased by a factor of 2.544.

Panel (b) in Figure 5.14 indicates that TFP in Malaysian agriculture was 93.3% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 1.142 \times 1.042 \times 1.201$$
$$= 1.933$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 14.2% increase in TFP; (iv) higher technical efficiency (the OTEI component) led to a 4.2% increase in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 20.1% increase in measured TFP.

Panel (c) in Figure 5.14 indicates that TFP in Malaysia in 2015 was 17.088 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1.053 \times 1.352 \times 10.637 \times 1.021 \times 1.105$$
$$= 17.088.$$

This decomposition indicates that (i) the production environment in Malaysia (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate), (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961, (iii) farmers in Malaysia were 10.637 times more scale and mix efficient in 2015 than Australian farmers had been in 1961, and (iv) farmers in Malaysia were 2.1% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.14

PRODUCTIVITY CHANGE IN MALAYSIA

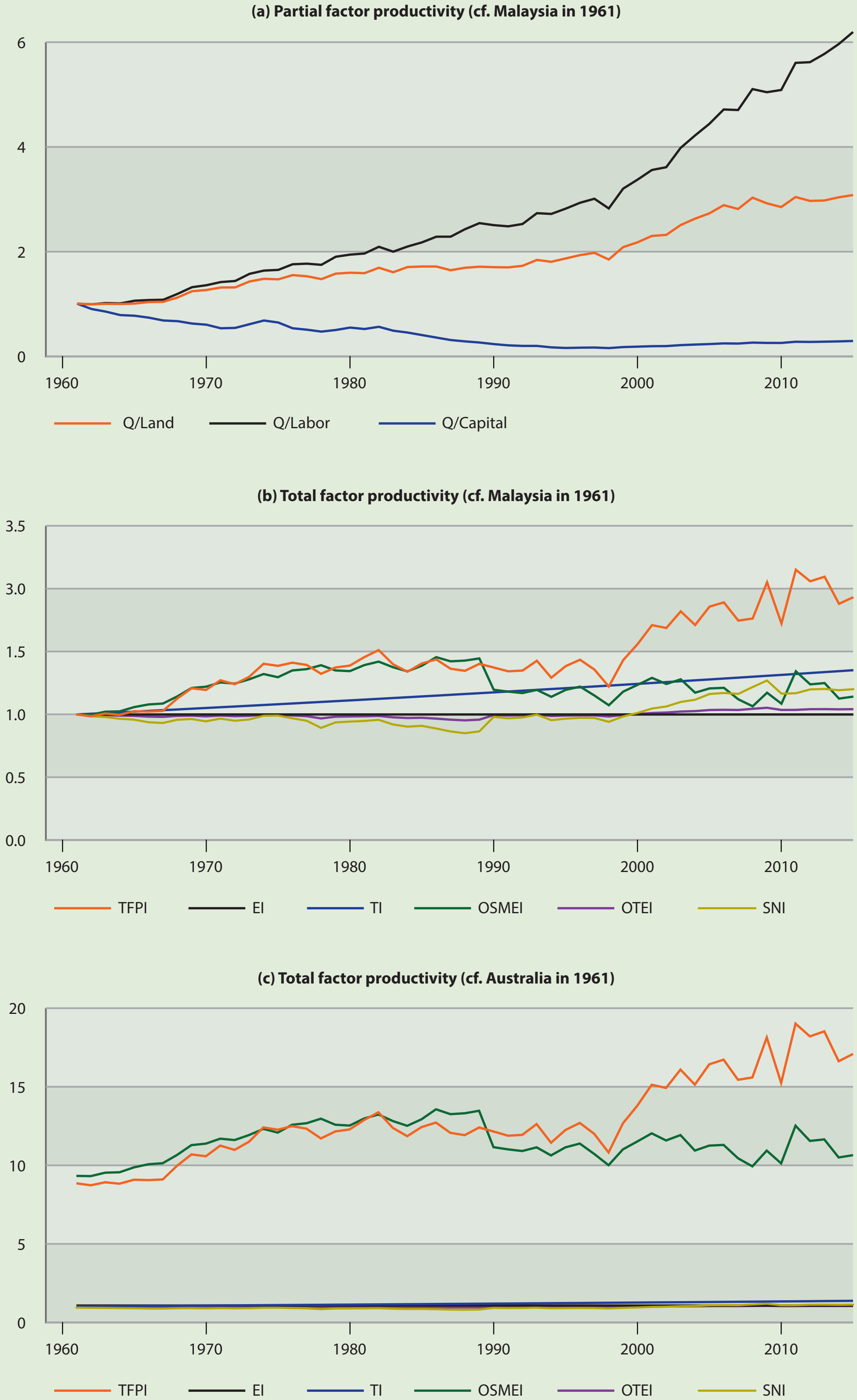


TABLE 5.14

PRODUCTIVITY CHANGE IN MALAYSIA (CF. MALAYSIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	0.990	0.988	0.899	0.986	1	1.006	0.998	0.996	0.986
1963	0.998	1.012	0.848	1.007	1	1.011	1.022	0.995	0.980
1964	0.994	1.005	0.783	0.997	1	1.017	1.025	0.991	0.966
1965	1.002	1.057	0.770	1.026	1	1.023	1.058	0.989	0.959
1966	1.031	1.070	0.733	1.023	1	1.028	1.080	0.983	0.938
1967	1.036	1.075	0.679	1.028	1	1.034	1.087	0.981	0.932
1968	1.119	1.188	0.667	1.127	1	1.040	1.143	0.989	0.958
1969	1.238	1.314	0.621	1.208	1	1.046	1.211	0.990	0.964
1970	1.261	1.352	0.599	1.195	1	1.052	1.221	0.985	0.945
1971	1.308	1.412	0.531	1.272	1	1.057	1.255	0.991	0.967
1972	1.311	1.433	0.538	1.241	1	1.063	1.245	0.986	0.950
1973	1.424	1.569	0.609	1.299	1	1.069	1.279	0.989	0.960
1974	1.475	1.631	0.679	1.403	1	1.075	1.321	0.997	0.990
1975	1.464	1.645	0.641	1.387	1	1.081	1.296	0.998	0.992
1976	1.545	1.752	0.531	1.412	1	1.087	1.350	0.992	0.970
1977	1.523	1.763	0.504	1.394	1	1.093	1.360	0.986	0.950
1978	1.468	1.741	0.467	1.323	1	1.100	1.391	0.968	0.893
1979	1.573	1.895	0.498	1.374	1	1.106	1.350	0.982	0.937
1980	1.590	1.935	0.545	1.388	1	1.112	1.345	0.984	0.943
1981	1.582	1.956	0.517	1.456	1	1.118	1.392	0.986	0.948
1982	1.685	2.085	0.560	1.512	1	1.124	1.420	0.988	0.958
1983	1.600	1.992	0.485	1.399	1	1.131	1.375	0.977	0.921
1984	1.698	2.090	0.449	1.340	1	1.137	1.343	0.972	0.903
1985	1.709	2.169	0.402	1.406	1	1.143	1.388	0.974	0.910
1986	1.709	2.277	0.354	1.438	1	1.150	1.456	0.967	0.888
1987	1.638	2.277	0.307	1.364	1	1.156	1.423	0.959	0.865
1988	1.685	2.420	0.281	1.347	1	1.163	1.428	0.953	0.851
1989	1.705	2.536	0.260	1.403	1	1.169	1.445	0.959	0.866
1990	1.696	2.497	0.229	1.373	1	1.176	1.196	0.995	0.981
1991	1.692	2.474	0.206	1.343	1	1.182	1.182	0.992	0.969
1992	1.722	2.520	0.195	1.349	1	1.189	1.170	0.994	0.976
1993	1.834	2.725	0.195	1.427	1	1.196	1.195	1.000	0.999
1994	1.799	2.711	0.167	1.292	1	1.202	1.140	0.988	0.955
1995	1.862	2.812	0.156	1.384	1	1.209	1.195	0.991	0.967
1996	1.926	2.924	0.161	1.435	1	1.216	1.221	0.993	0.973
1997	1.969	3.000	0.165	1.357	1	1.223	1.150	0.992	0.972
1998	1.842	2.816	0.154	1.222	1	1.229	1.073	0.984	0.942
1999	2.079	3.194	0.173	1.432	1	1.236	1.182	0.996	0.985
2000	2.169	3.364	0.180	1.559	1	1.243	1.235	1.003	1.012
2001	2.292	3.548	0.190	1.710	1	1.250	1.291	1.012	1.047
2002	2.311	3.602	0.192	1.688	1	1.257	1.242	1.015	1.064
2003	2.499	3.970	0.210	1.820	1	1.264	1.279	1.023	1.100
2004	2.620	4.206	0.221	1.711	1	1.271	1.173	1.027	1.117
2005	2.722	4.429	0.230	1.858	1	1.278	1.207	1.035	1.162
2006	2.878	4.702	0.243	1.891	1	1.286	1.212	1.037	1.171
2007	2.805	4.692	0.240	1.746	1	1.293	1.121	1.036	1.164
2008	3.021	5.092	0.258	1.763	1	1.300	1.065	1.045	1.218
2009	2.914	5.032	0.252	2.051	1	1.307	1.173	1.053	1.270
2010	2.843	5.074	0.251	1.723	1	1.315	1.086	1.036	1.165
2011	3.034	5.592	0.274	2.151	1	1.322	1.343	1.037	1.168
2012	2.960	5.604	0.271	2.059	1	1.329	1.239	1.042	1.199
2013	2.967	5.761	0.276	2.095	1	1.337	1.250	1.043	1.203
2014	3.028	5.949	0.281	1.880	1	1.344	1.126	1.041	1.193
2015	3.071	6.180	0.289	1.933	1	1.352	1.142	1.042	1.201

5.15 Mongolia

The agriculture sector in Mongolia is heavily focused on nomadic animal husbandry. In 2014, the agriculture sector employed 29.5% (respectively 26.2%) of the male (respectively female) labor force and contributed 14.2% to the GDP. The high altitude of Mongolia makes the climate quite unstable, with extreme fluctuations in temperature. One consequence of this is that most of the land is allocated to pasture and less than 3% of arable land area is used for cropping. Figure 5.15 reports estimated changes in agricultural productivity in Mongolia from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.15.

Panel (a) in Figure 5.15 indicates that land and labor productivity fluctuated considerably but generally increased over the sample period. In 2015, output per unit of land (respectively labor) was 2.137 (respectively 1.283) times higher than it had been in 1961. On the other hand, capital productivity fluctuated and generally fell over the sample period. In 2015, output per unit of capital was 22.7% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.335 (respectively 2.217) while the area of land used for agricultural production fell by 19.8%.

Panel (b) in Figure 5.15 indicates that TFP in Mongolian agriculture was 2.816 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 0.415 \times 1.927 \times 2.607$$
$$= 2.816$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) lower scale and mix efficiency (the OSMEI component) led to a 58.5% fall in TFP; (iv) higher technical efficiency (the OTEI component) led to a 92.7% increase in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 160.7% increase in measured TFP. In case of Mongolia, an important source of statistical noise is omitted variables (e.g., temperature).

Panel (c) in Figure 5.15 indicates that TFP in Mongolia in 2015 was 62.1% lower than TFP had been in Australia in 1961. The breakdown is as follows:

$$TFPI = EI \times TI \times OSMEI \times OTEI \times SNI$$
$$= 1 \times 1.352 \times 0.588 \times 0.823 \times 0.580$$
$$= 0.379.$$

This decomposition indicates that (i) the production environment in Mongolia is the same as the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Mongolia were 41.2% less scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Mongolia were 17.7% less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.15

PRODUCTIVITY CHANGE IN MONGOLIA

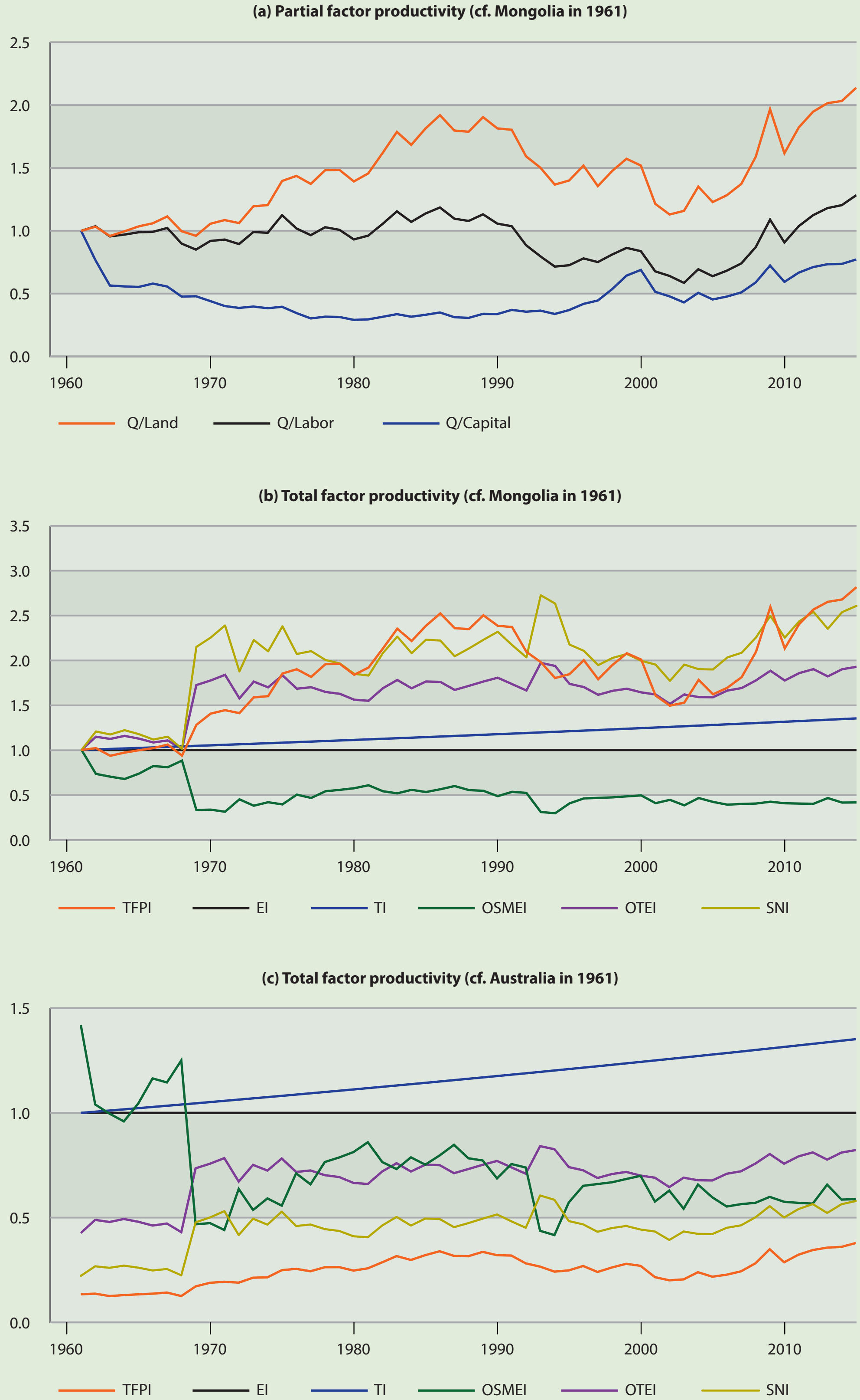


TABLE 5.15

PRODUCTIVITY CHANGE IN MONGOLIA (CF. MONGOLIA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.033	1.037	0.767	1.020	1	1.006	0.733	1.147	1.206
1963	0.959	0.956	0.566	0.935	1	1.011	0.702	1.123	1.172
1964	0.996	0.970	0.559	0.970	1	1.017	0.676	1.157	1.220
1965	1.036	0.989	0.554	0.997	1	1.023	0.736	1.126	1.176
1966	1.061	0.993	0.581	1.021	1	1.028	0.821	1.084	1.116
1967	1.115	1.023	0.558	1.060	1	1.034	0.807	1.106	1.148
1968	0.997	0.899	0.478	0.937	1	1.040	0.881	1.009	1.013
1969	0.961	0.851	0.480	1.279	1	1.046	0.330	1.724	2.149
1970	1.057	0.920	0.442	1.405	1	1.052	0.334	1.775	2.254
1971	1.086	0.931	0.403	1.444	1	1.057	0.311	1.838	2.389
1972	1.062	0.895	0.388	1.411	1	1.063	0.449	1.575	1.875
1973	1.195	0.991	0.398	1.586	1	1.069	0.378	1.762	2.226
1974	1.205	0.985	0.385	1.600	1	1.075	0.417	1.699	2.100
1975	1.397	1.125	0.397	1.853	1	1.081	0.393	1.833	2.379
1976	1.437	1.019	0.347	1.900	1	1.087	0.502	1.683	2.070
1977	1.373	0.966	0.304	1.815	1	1.093	0.464	1.700	2.102
1978	1.482	1.029	0.318	1.958	1	1.100	0.540	1.647	2.003
1979	1.485	1.008	0.315	1.960	1	1.106	0.555	1.626	1.965
1980	1.393	0.932	0.293	1.838	1	1.112	0.573	1.560	1.849
1981	1.456	0.962	0.296	1.919	1	1.118	0.606	1.548	1.829
1982	1.619	1.055	0.317	2.132	1	1.124	0.539	1.689	2.081
1983	1.787	1.155	0.338	2.352	1	1.131	0.516	1.780	2.265
1984	1.684	1.071	0.318	2.215	1	1.137	0.555	1.688	2.079
1985	1.815	1.138	0.333	2.385	1	1.143	0.531	1.764	2.229
1986	1.920	1.186	0.351	2.523	1	1.150	0.562	1.759	2.221
1987	1.797	1.097	0.314	2.358	1	1.156	0.598	1.669	2.045
1988	1.788	1.079	0.308	2.348	1	1.163	0.552	1.715	2.132
1989	1.904	1.132	0.341	2.502	1	1.169	0.545	1.763	2.228
1990	1.815	1.058	0.339	2.385	1	1.176	0.485	1.806	2.318
1991	1.804	1.037	0.372	2.371	1	1.182	0.533	1.734	2.170
1992	1.593	0.887	0.358	2.094	1	1.189	0.521	1.663	2.033
1993	1.503	0.798	0.366	1.980	1	1.196	0.308	1.971	2.726
1994	1.368	0.716	0.340	1.802	1	1.202	0.294	1.937	2.632
1995	1.401	0.727	0.371	1.845	1	1.209	0.404	1.737	2.176
1996	1.519	0.781	0.420	2.001	1	1.216	0.459	1.701	2.106
1997	1.356	0.752	0.446	1.789	1	1.223	0.466	1.615	1.946
1998	1.476	0.812	0.537	1.949	1	1.229	0.471	1.660	2.026
1999	1.573	0.865	0.644	2.078	1	1.236	0.482	1.683	2.071
2000	1.519	0.839	0.690	2.008	1	1.243	0.493	1.642	1.995
2001	1.215	0.678	0.515	1.606	1	1.250	0.407	1.619	1.952
2002	1.131	0.642	0.479	1.494	1	1.257	0.444	1.513	1.770
2003	1.159	0.587	0.431	1.528	1	1.264	0.382	1.619	1.952
2004	1.352	0.695	0.508	1.782	1	1.271	0.464	1.590	1.901
2005	1.229	0.640	0.455	1.621	1	1.278	0.421	1.588	1.898
2006	1.284	0.684	0.478	1.694	1	1.286	0.3900	1.662	2.032
2007	1.374	0.742	0.511	1.812	1	1.293	0.398	1.690	2.084
2008	1.589	0.871	0.590	2.096	1	1.300	0.402	1.776	2.256
2009	1.967	1.089	0.725	2.596	1	1.307	0.422	1.883	2.496
2010	1.617	0.908	0.594	2.132	1	1.315	0.406	1.775	2.252
2011	1.822	1.038	0.668	2.402	1	1.322	0.402	1.857	2.433
2012	1.947	1.125	0.712	2.566	1	1.329	0.400	1.901	2.541
2013	2.015	1.181	0.735	2.652	1	1.337	0.463	1.821	2.351
2014	2.033	1.205	0.737	2.678	1	1.344	0.413	1.900	2.537
2015	2.137	1.283	0.773	2.816	1	1.352	0.415	1.927	2.607

5.16 Nepal

The agriculture sector in Nepal provides the livelihood for most of the population. In 2016, the agriculture sector employed 61.6% (respectively 83.3%) of the male (respectively female) labor force and contributed approximately one-third to the GDP. Only approximately 20% of the total land area of Nepal can be cultivated. Figure 5.16 reports estimated changes in agricultural productivity in Nepal from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.16.

Panel (a) in Figure 5.16 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 4.213 (respectively 1.976) times higher than it had been in 1961. On the other hand, capital productivity fell sharply over the sample period. In 2015, output per unit of capital was 84.3% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 2.472 (respectively 31.1) while the area of land used for agricultural production only increased by a factor of 1.16.

Panel (b) in Figure 5.16 indicates that TFP in Nepalese agriculture was 1.986 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 4.250 × 0.906 × 0.381
= 1.986

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) higher scale and mix efficiency (the OSMEI component) led to a 425% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 9.4% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 61.9% fall in measured TFP. In case of Nepal, an important source of statistical noise is omitted variables (e.g., temperature).

Panel (c) in Figure 5.16 indicates that TFP in Nepal in 2015 was 8.043 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 0.986 × 1.352 × 5.066 × 1.030 × 1.156
= 8.043.

This decomposition indicates that (i) the production environment in Nepal (wet temperate) is 1.4% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Nepal were more than five times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Nepal were 3% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.16

PRODUCTIVITY CHANGE IN NEPAL

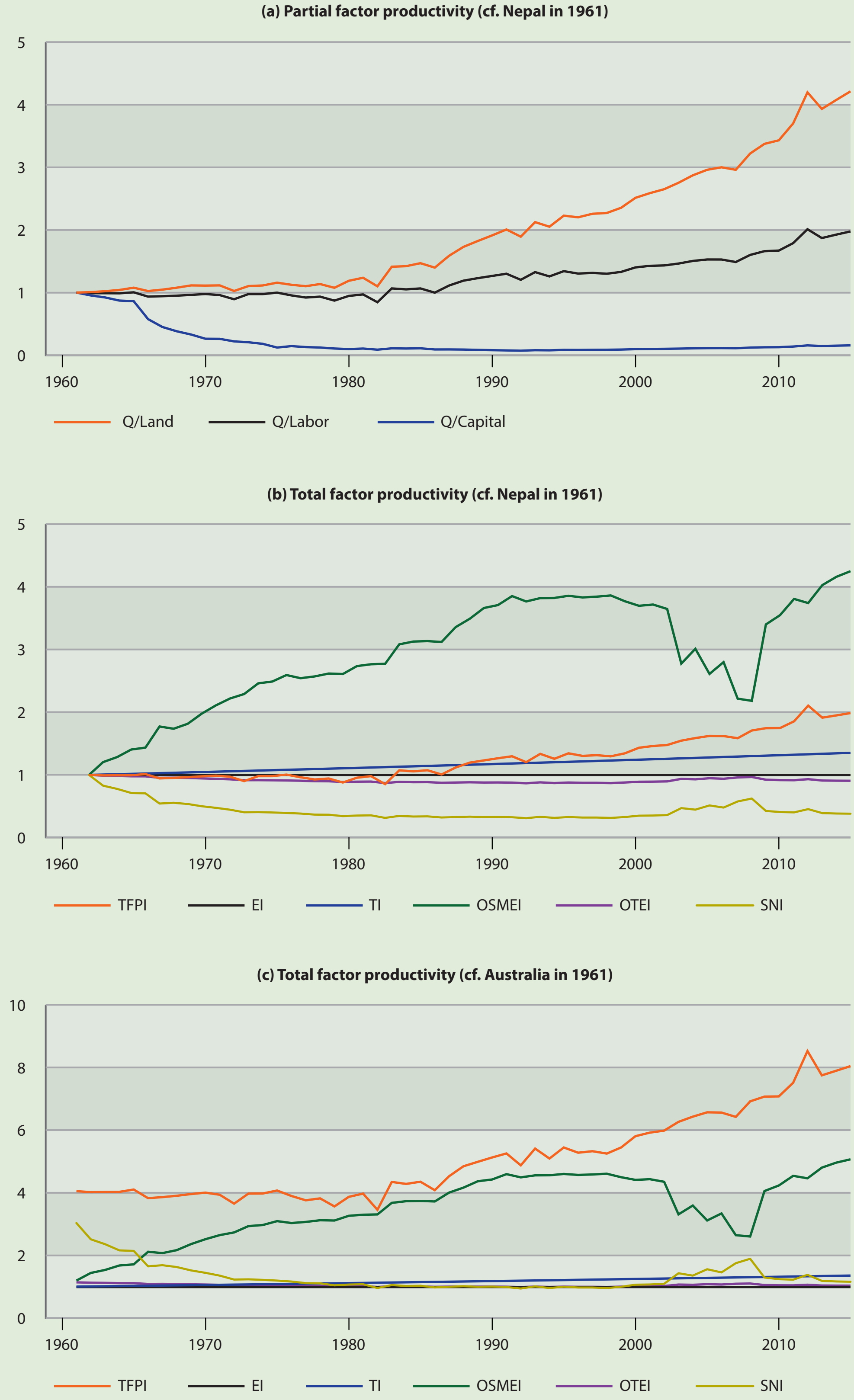


TABLE 5.16

PRODUCTIVITY CHANGE IN NEPAL (CF. NEPAL IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.007	0.990	0.954	0.992	1	1.006	1.204	0.989	0.828
1963	1.022	0.990	0.922	0.994	1	1.011	1.285	0.984	0.777
1964	1.042	0.988	0.872	0.995	1	1.017	1.405	0.978	0.712
1965	1.078	1.004	0.862	1.013	1	1.023	1.435	0.977	0.706
1966	1.024	0.936	0.576	0.944	1	1.028	1.772	0.954	0.543
1967	1.047	0.942	0.451	0.953	1	1.034	1.736	0.956	0.555
1968	1.078	0.951	0.382	0.964	1	1.040	1.816	0.952	0.536
1969	1.114	0.963	0.330	0.977	1	1.046	1.978	0.944	0.500
1970	1.112	0.977	0.263	0.988	1	1.052	2.109	0.938	0.475
1971	1.115	0.960	0.261	0.971	1	1.057	2.219	0.930	0.445
1972	1.025	0.894	0.221	0.901	1	1.063	2.290	0.916	0.404
1973	1.104	0.976	0.207	0.981	1	1.069	2.460	0.917	0.407
1974	1.114	0.976	0.182	0.981	1	1.075	2.489	0.914	0.401
1975	1.158	0.999	0.122	1.005	1	1.081	2.593	0.911	0.393
1976	1.124	0.955	0.145	0.962	1	1.087	2.543	0.907	0.383
1977	1.102	0.921	0.130	0.928	1	1.093	2.571	0.900	0.367
1978	1.136	0.935	0.122	0.943	1	1.100	2.617	0.899	0.365
1979	1.076	0.872	0.107	0.879	1	1.106	2.610	0.888	0.343
1980	1.188	0.947	0.098	0.955	1	1.112	2.736	0.892	0.352
1981	1.237	0.970	0.106	0.981	1	1.118	2.765	0.894	0.355
1982	1.100	0.846	0.088	0.853	1	1.124	2.773	0.870	0.314
1983	1.413	1.066	0.109	1.073	1	1.131	3.083	0.889	0.346
1984	1.421	1.051	0.107	1.057	1	1.137	3.127	0.884	0.336
1985	1.469	1.066	0.110	1.074	1	1.143	3.135	0.885	0.339
1986	1.399	0.999	0.092	1.007	1	1.150	3.120	0.874	0.321
1987	1.588	1.113	0.092	1.118	1	1.156	3.358	0.879	0.328
1988	1.730	1.190	0.090	1.196	1	1.163	3.491	0.882	0.334
1989	1.823	1.230	0.085	1.231	1	1.169	3.662	0.878	0.327
1990	1.913	1.266	0.080	1.265	1	1.176	3.709	0.880	0.330
1991	2.007	1.301	0.076	1.297	1	1.182	3.852	0.877	0.325
1992	1.893	1.204	0.072	1.204	1	1.189	3.767	0.867	0.310
1993	2.125	1.327	0.080	1.336	1	1.196	3.820	0.881	0.332
1994	2.052	1.258	0.078	1.257	1	1.202	3.823	0.870	0.314
1995	2.228	1.342	0.084	1.344	1	1.209	3.857	0.879	0.328
1996	2.202	1.303	0.084	1.303	1	1.216	3.831	0.874	0.320
1997	2.258	1.314	0.086	1.315	1	1.223	3.843	0.874	0.320
1998	2.271	1.301	0.087	1.296	1	1.229	3.863	0.870	0.314
1999	2.354	1.330	0.090	1.345	1	1.236	3.770	0.879	0.328
2000	2.513	1.402	0.097	1.434	1	1.243	3.698	0.891	0.350
2001	2.587	1.427	0.100	1.462	1	1.250	3.718	0.893	0.352
2002	2.650	1.433	0.102	1.477	1	1.257	3.647	0.896	0.359
2003	2.753	1.463	0.105	1.547	1	1.264	2.775	0.937	0.470
2004	2.872	1.505	0.110	1.588	1	1.271	3.011	0.930	0.446
2005	2.961	1.528	0.113	1.622	1	1.278	2.611	0.947	0.513
2006	3.000	1.528	0.114	1.620	1	1.286	2.800	0.939	0.479
2007	2.960	1.488	0.112	1.586	1	1.293	2.217	0.960	0.577
2008	3.221	1.601	0.121	1.708	1	1.300	2.182	0.967	0.623
2009	3.375	1.661	0.126	1.746	1	1.307	3.400	0.923	0.425
2010	3.431	1.671	0.128	1.747	1	1.315	3.548	0.917	0.408
2011	3.701	1.789	0.138	1.855	1	1.322	3.807	0.915	0.403
2012	4.197	2.011	0.156	2.105	1	1.329	3.741	0.932	0.454
2013	3.932	1.871	0.147	1.913	1	1.337	4.027	0.910	0.390
2014	4.075	1.925	0.152	1.949	1	1.344	4.160	0.908	0.384
2015	4.213	1.976	0.157	1.986	1	1.352	4.250	0.906	0.381

5.17 Pakistan

Pakistan is one of the world's largest producers and exporters of food and crop products. It is, for example, the world's fourth-largest producer of rice, cotton, and mangoes, and the fifth-largest producer of milk and sugarcane. In 2014, the agriculture sector employed 36.7% (respectively 70.6%) of the male (respectively female) labor force and contributed 23.8% to the GDP. Figure 5.17 reports estimated changes in agricultural productivity in Pakistan from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.17.

Panel (a) in Figure 5.17 indicates that land productivity increased steadily up until 2009, and then declined. In 2009 (respectively 2015), output per unit of land was 5.501 (respectively 4.614) times higher than it had been in 1961. On the other hand, labor productivity increased slightly, and capital productivity fell significantly over the sample period. In 2015, output per unit of labor (respectively capital) was 48% higher (respectively 91.9% lower) than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 3.186 (respectively 58.273) while the area of land used for agricultural production only increased by a factor of 1.022.

Panel (b) in Figure 5.17 indicates that TFP in Pakistan agriculture was 33% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.658 × 0.888 × 0.668
= 1.33

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 65.8% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 11.2% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 33.2% fall in measured TFP. In case of Pakistan, an important source of statistical noise is measurement error, especially the measurement of capital.

Panel (c) in Figure 5.17 indicates that TFP in Pakistan in 2015 was 5.015 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 5.884 × 0.898 × 0.702
= 5.015.

This decomposition indicates that (i) the production environment in Pakistan is the same as the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Pakistan were 5.884 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Pakistan were 10.2% less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.17

PRODUCTIVITY CHANGE IN PAKISTAN

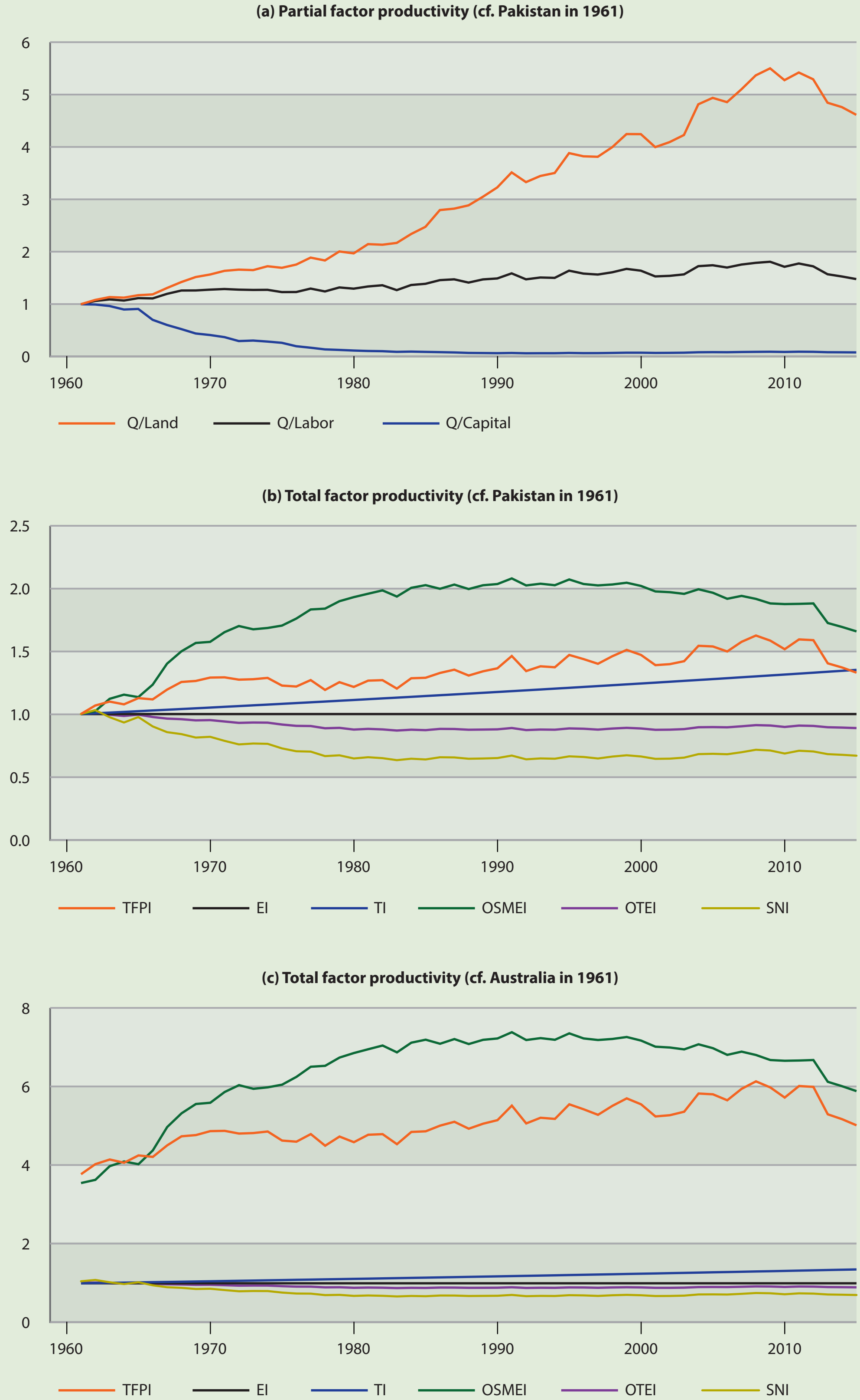


TABLE 5.17

PRODUCTIVITY CHANGE IN PAKISTAN (CF. PAKISTAN IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.082	1.062	0.995	1.068	1	1.006	1.023	1.006	1.031
1963	1.137	1.092	0.966	1.099	1	1.011	1.121	0.995	0.975
1964	1.125	1.071	0.900	1.077	1	1.017	1.154	0.984	0.932
1965	1.173	1.117	0.910	1.127	1	1.023	1.135	0.995	0.976
1966	1.188	1.110	0.703	1.117	1	1.028	1.234	0.977	0.901
1967	1.310	1.198	0.604	1.194	1	1.034	1.401	0.963	0.856
1968	1.423	1.261	0.525	1.256	1	1.040	1.500	0.959	0.840
1969	1.519	1.263	0.442	1.264	1	1.046	1.566	0.950	0.813
1970	1.567	1.278	0.412	1.290	1	1.052	1.575	0.952	0.819
1971	1.637	1.290	0.373	1.292	1	1.057	1.652	0.940	0.787
1972	1.660	1.278	0.297	1.274	1	1.063	1.701	0.929	0.758
1973	1.651	1.273	0.307	1.277	1	1.069	1.675	0.932	0.765
1974	1.725	1.275	0.288	1.288	1	1.075	1.686	0.931	0.763
1975	1.695	1.231	0.263	1.227	1	1.081	1.705	0.916	0.726
1976	1.757	1.233	0.199	1.219	1	1.087	1.761	0.906	0.703
1977	1.889	1.298	0.170	1.270	1	1.093	1.833	0.905	0.701
1978	1.835	1.244	0.138	1.192	1	1.100	1.840	0.886	0.665
1979	2.007	1.320	0.128	1.254	1	1.106	1.899	0.890	0.671
1980	1.971	1.297	0.117	1.216	1	1.112	1.931	0.876	0.646
1981	2.147	1.339	0.108	1.266	1	1.118	1.958	0.882	0.656
1982	2.135	1.362	0.104	1.270	1	1.124	1.985	0.877	0.648
1983	2.170	1.269	0.091	1.203	1	1.131	1.936	0.868	0.633
1984	2.339	1.367	0.096	1.285	1	1.137	2.005	0.875	0.644
1985	2.478	1.390	0.090	1.289	1	1.143	2.027	0.872	0.638
1986	2.797	1.460	0.086	1.327	1	1.150	1.998	0.881	0.656
1987	2.824	1.475	0.080	1.353	1	1.156	2.031	0.881	0.654
1988	2.887	1.413	0.071	1.307	1	1.163	1.996	0.875	0.644
1989	3.051	1.474	0.069	1.340	1	1.169	2.026	0.876	0.646
1990	3.229	1.492	0.066	1.364	1	1.176	2.036	0.878	0.649
1991	3.516	1.589	0.070	1.462	1	1.182	2.081	0.889	0.669
1992	3.330	1.475	0.064	1.342	1	1.189	2.025	0.872	0.639
1993	3.447	1.510	0.065	1.380	1	1.196	2.038	0.876	0.646
1994	3.504	1.503	0.065	1.373	1	1.202	2.026	0.875	0.644
1995	3.884	1.640	0.071	1.471	1	1.209	2.072	0.886	0.663
1996	3.823	1.585	0.066	1.437	1	1.216	2.036	0.883	0.658
1997	3.814	1.566	0.067	1.400	1	1.223	2.025	0.876	0.646
1998	3.996	1.609	0.071	1.461	1	1.229	2.032	0.884	0.661
1999	4.247	1.675	0.075	1.511	1	1.236	2.046	0.890	0.671
2000	4.246	1.641	0.075	1.471	1	1.243	2.021	0.885	0.662
2001	3.998	1.531	0.071	1.389	1	1.250	1.977	0.874	0.643
2002	4.094	1.541	0.073	1.397	1	1.257	1.971	0.875	0.644
2003	4.229	1.570	0.075	1.421	1	1.264	1.958	0.880	0.653
2004	4.815	1.726	0.083	1.544	1	1.271	1.994	0.895	0.681
2005	4.938	1.744	0.085	1.538	1	1.278	1.966	0.896	0.683
2006	4.856	1.701	0.084	1.498	1	1.286	1.918	0.894	0.680
2007	5.100	1.757	0.088	1.575	1	1.293	1.941	0.902	0.696
2008	5.367	1.790	0.091	1.626	1	1.300	1.917	0.911	0.716
2009	5.501	1.810	0.093	1.585	1	1.307	1.881	0.909	0.709
2010	5.276	1.715	0.089	1.517	1	1.315	1.876	0.897	0.685
2011	5.422	1.777	0.094	1.594	1	1.322	1.878	0.908	0.708
2012	5.293	1.724	0.092	1.588	1	1.329	1.881	0.905	0.702
2013	4.845	1.572	0.084	1.404	1	1.337	1.725	0.895	0.680
2014	4.761	1.530	0.083	1.371	1	1.344	1.693	0.892	0.675
2015	4.614	1.480	0.081	1.330	1	1.352	1.658	0.888	0.668

5.18 Philippines

The Philippines is the world's eighth-largest producer of rice, and the largest producer of coconuts. In 2014, the agriculture sector employed 37.2% (respectively 20.2%) of the male (respectively female) labor force and contributed 11.3% to the GDP. Figure 5.18 reports estimated changes in agricultural productivity in the Philippines from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.18.

Panel (a) in Figure 5.18 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 2.619 (respectively 1.417) times higher than it had been in 1961. Capital productivity also increased over the sample period, albeit not as steadily. In 2015, output per unit of capital was 1.516 times higher than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of three (respectively 2.805) while the area of land used for agricultural production increased only by a factor of 1.624.

Panel (b) in Figure 5.18 indicates that TFP in the Philippines agriculture was 33% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.406 × 0.955 × 0.733
= 1.33

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 40.6% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 4.5% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 26.7% fall in measured TFP.

Panel (c) in Figure 5.18 indicates that TFP in the Philippines in 2015 was 10.63 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 6.313 × 1.029 × 1.150
= 10.63.

This decomposition indicates that (i) the production environment in the Philippines (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Philippines were 6.313 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Philippines were 2.9% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.18

PRODUCTIVITY CHANGE IN PHILIPPINES

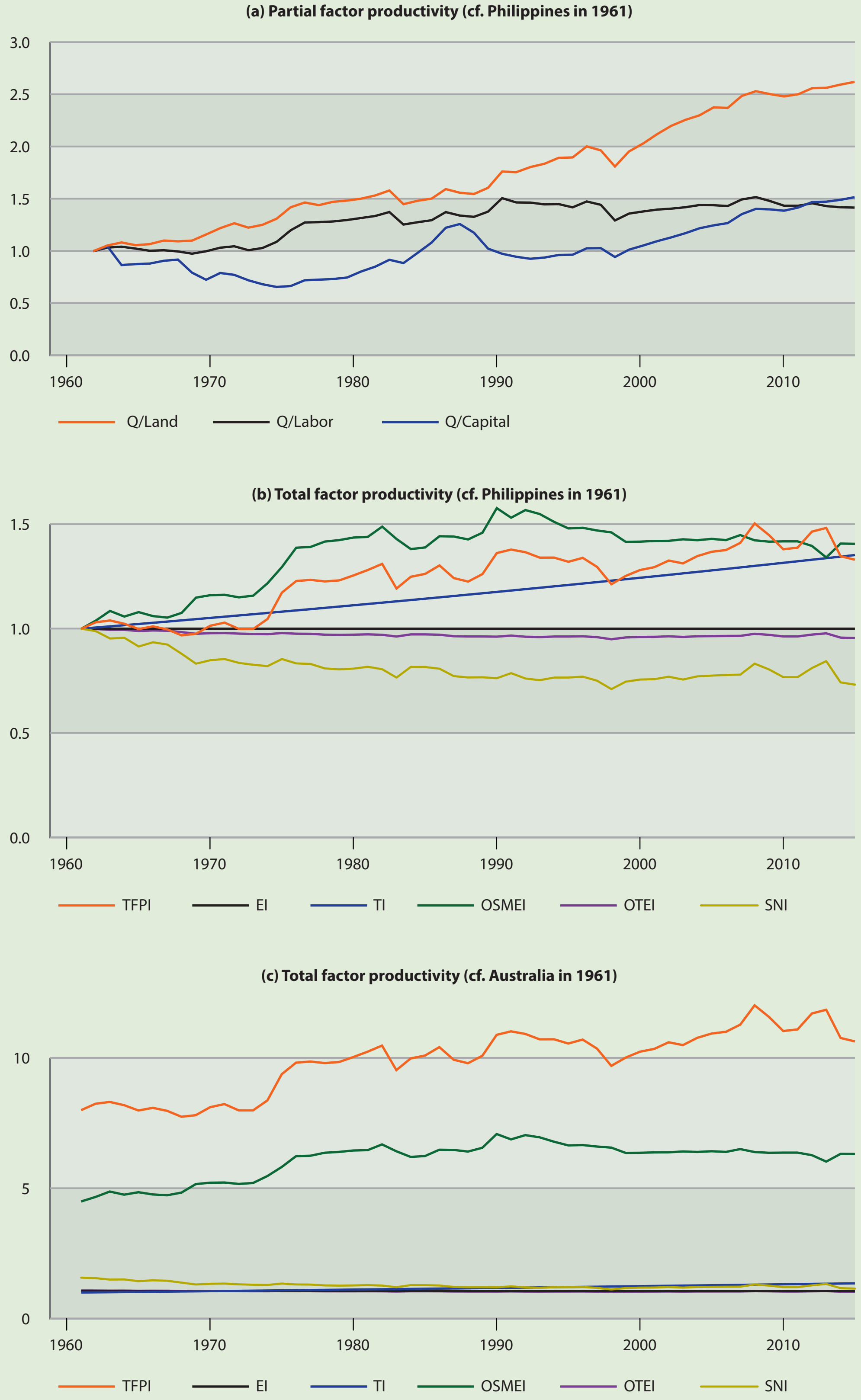


TABLE 5.18

PRODUCTIVITY CHANGE IN PHILIPPINES (CF. PHILIPPINES IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.055	1.034	1.047	1.031	1	1.006	1.038	0.999	0.988
1963	1.083	1.043	0.867	1.039	1	1.011	1.085	0.994	0.953
1964	1.057	1.025	0.876	1.024	1	1.017	1.058	0.995	0.957
1965	1.068	1.004	0.882	0.998	1	1.023	1.079	0.989	0.915
1966	1.102	1.009	0.908	1.011	1	1.028	1.060	0.992	0.935
1967	1.094	0.997	0.920	0.997	1	1.034	1.053	0.990	0.924
1968	1.101	0.976	0.795	0.968	1	1.040	1.076	0.984	0.880
1969	1.159	0.999	0.727	0.976	1	1.046	1.148	0.976	0.833
1970	1.220	1.033	0.791	1.014	1	1.052	1.160	0.979	0.850
1971	1.267	1.047	0.773	1.029	1	1.057	1.162	0.980	0.855
1972	1.225	1.009	0.721	0.999	1	1.063	1.150	0.976	0.837
1973	1.252	1.030	0.684	0.999	1	1.069	1.158	0.975	0.828
1974	1.310	1.089	0.658	1.047	1	1.075	1.217	0.974	0.821
1975	1.420	1.200	0.667	1.173	1	1.081	1.295	0.980	0.855
1976	1.466	1.274	0.722	1.228	1	1.087	1.387	0.976	0.834
1977	1.440	1.278	0.728	1.233	1	1.093	1.391	0.975	0.831
1978	1.472	1.284	0.733	1.226	1	1.100	1.416	0.972	0.810
1979	1.484	1.298	0.748	1.231	1	1.106	1.423	0.971	0.806
1980	1.502	1.317	0.806	1.255	1	1.112	1.436	0.971	0.809
1981	1.533	1.337	0.852	1.281	1	1.118	1.439	0.973	0.818
1982	1.581	1.374	0.918	1.310	1	1.124	1.488	0.971	0.807
1983	1.450	1.254	0.886	1.192	1	1.131	1.429	0.963	0.766
1984	1.482	1.277	0.983	1.248	1	1.137	1.380	0.973	0.817
1985	1.503	1.296	1.083	1.262	1	1.143	1.388	0.973	0.817
1986	1.594	1.374	1.224	1.302	1	1.150	1.442	0.971	0.809
1987	1.559	1.341	1.260	1.242	1	1.156	1.440	0.964	0.773
1988	1.547	1.328	1.177	1.225	1	1.163	1.427	0.963	0.767
1989	1.606	1.378	1.024	1.261	1	1.169	1.459	0.963	0.768
1990	1.762	1.507	0.975	1.361	1	1.176	1.576	0.962	0.764
1991	1.756	1.466	0.947	1.378	1	1.182	1.530	0.967	0.788
1992	1.805	1.465	0.927	1.366	1	1.189	1.567	0.962	0.762
1993	1.836	1.448	0.939	1.340	1	1.196	1.548	0.960	0.754
1994	1.892	1.450	0.963	1.340	1	1.202	1.510	0.963	0.766
1995	1.897	1.420	0.966	1.320	1	1.209	1.479	0.963	0.767
1996	2.002	1.476	1.028	1.339	1	1.216	1.482	0.964	0.771
1997	1.964	1.443	1.029	1.295	1	1.223	1.469	0.959	0.752
1998	1.810	1.294	0.944	1.212	1	1.229	1.460	0.950	0.711
1999	1.954	1.360	1.015	1.252	1	1.236	1.415	0.958	0.747
2000	2.030	1.380	1.054	1.280	1	1.243	1.416	0.961	0.757
2001	2.120	1.398	1.096	1.294	1	1.250	1.419	0.961	0.759
2002	2.199	1.407	1.132	1.326	1	1.257	1.420	0.964	0.771
2003	2.256	1.420	1.172	1.312	1	1.264	1.427	0.961	0.757
2004	2.299	1.441	1.219	1.347	1	1.271	1.423	0.964	0.772
2005	2.376	1.440	1.247	1.367	1	1.278	1.429	0.965	0.776
2006	2.370	1.432	1.269	1.376	1	1.286	1.423	0.965	0.779
2007	2.485	1.495	1.354	1.410	1	1.293	1.447	0.966	0.780
2008	2.530	1.517	1.405	1.503	1	1.300	1.422	0.976	0.833
2009	2.502	1.479	1.400	1.447	1	1.307	1.416	0.971	0.806
2010	2.480	1.435	1.387	1.380	1	1.315	1.417	0.963	0.769
2011	2.501	1.435	1.417	1.387	1	1.322	1.417	0.963	0.769
2012	2.559	1.458	1.471	1.464	1	1.329	1.395	0.972	0.812
2013	2.563	1.431	1.473	1.482	1	1.337	1.341	0.978	0.845
2014	2.593	1.420	1.491	1.346	1	1.344	1.407	0.957	0.744
2015	2.619	1.417	1.516	1.330	1	1.352	1.406	0.955	0.733

5.19 Sri Lanka

In 2014, the agriculture sector in Sri Lanka employed 27.1% (respectively 31.7%) of the male (respectively female) labor force and contributed 9.9% to the GDP. Rice is the main agricultural crop, accounting for 34% of total cultivated area. Tea is also an important product for the export market. Figure 5.19 reports estimated changes in agricultural productivity in Sri Lanka from 1961 to 2015. The index numbers used to construct panels (a) and in this figure are reported in Table 5.19.

Panel (a) in Figure 5.19 indicates that land and labor productivity fluctuated but generally increased over the sample period. In 2015, output per unit of land (respectively labor) was 85.9% (respectively 43.1%) higher than it had been in 1961. On the other hand, capital productivity fluctuated and generally fell over the sample period. In 2015, output per unit of capital was 16.9% lower than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 2.089 (respectively 3.596) while the area of land used for agricultural production increased only by a factor of 1.608.

Panel (b) in Figure 5.19 indicates that TFP in Sri Lankan agriculture was 33.6% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.342 × 0.906 × 0.812
= 1.336

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 34.2% increase in TFP; (iv) lower technical efficiency (the OTEI component) led to a 9.4% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 18.8% fall in measured TFP.

Panel (c) in Figure 5.19 indicates that TFP in Sri Lanka in 2015 was 5.877 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 9.129 × 0.808 × 0.56
= 5.877.

This decomposition indicates that (i) the production environment in Sri Lanka (wet tropical/ subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Sri Lanka were 9.129 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Sri Lanka were 19.2% less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.19

PRODUCTIVITY CHANGE IN SRI LANKA

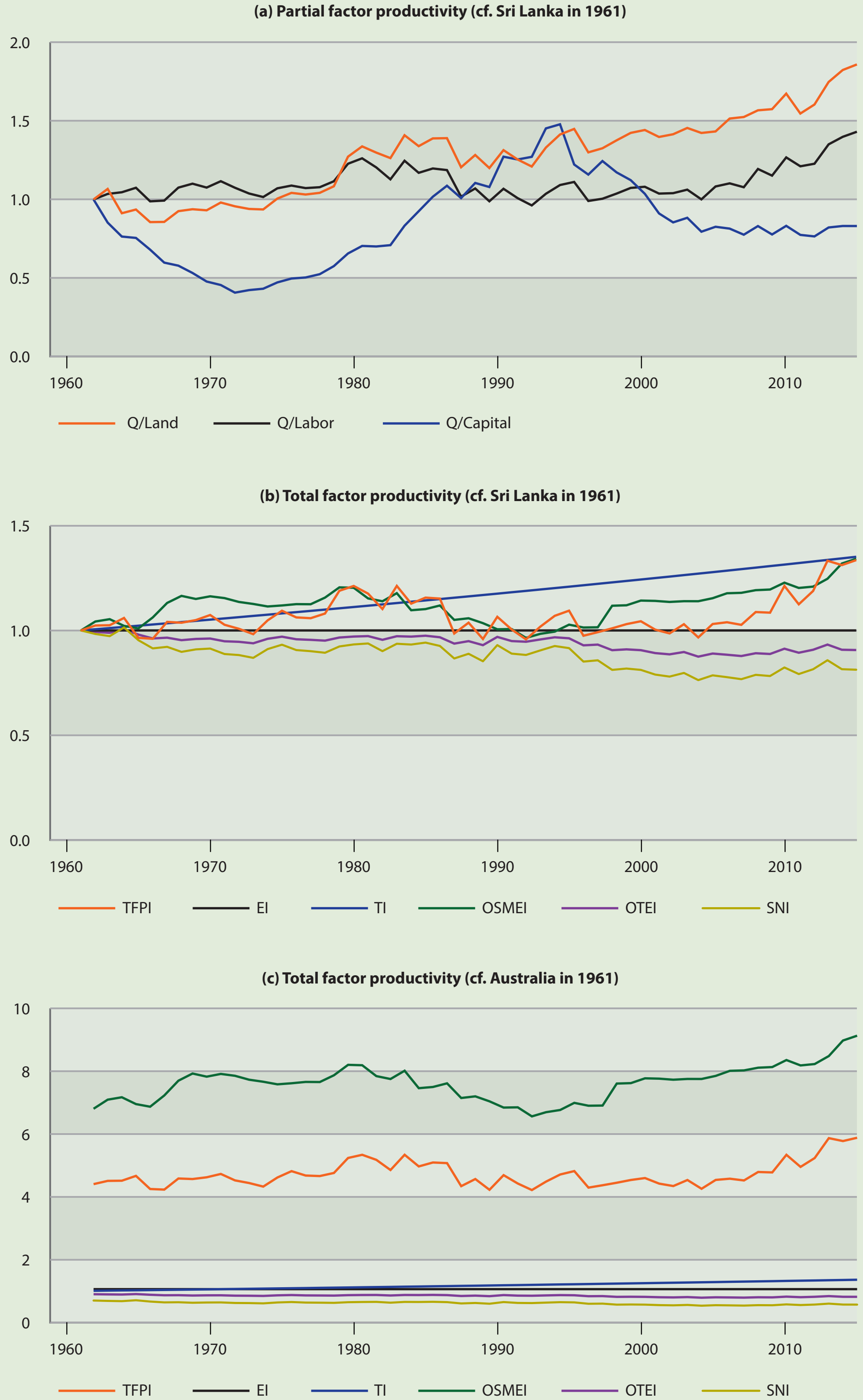


TABLE 5.19

PRODUCTIVITY CHANGE IN SRI LANKA (CF. SRI LANKA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.067	1.035	0.853	1.023	1	1.006	1.043	0.993	0.983
1963	0.912	1.046	0.764	1.025	1	1.011	1.054	0.989	0.973
1964	0.936	1.074	0.755	1.060	1	1.017	1.022	1.006	1.014
1965	0.856	0.988	0.681	0.965	1	1.023	1.010	0.980	0.953
1966	0.857	0.993	0.598	0.960	1	1.028	1.062	0.962	0.914
1967	0.926	1.075	0.579	1.041	1	1.034	1.131	0.965	0.922
1968	0.938	1.100	0.532	1.037	1	1.040	1.165	0.953	0.898
1969	0.931	1.076	0.478	1.049	1	1.046	1.150	0.959	0.909
1970	0.981	1.116	0.456	1.074	1	1.052	1.163	0.961	0.913
1971	0.957	1.075	0.407	1.027	1	1.057	1.154	0.948	0.887
1972	0.940	1.038	0.424	1.008	1	1.063	1.136	0.946	0.882
1973	0.937	1.015	0.432	0.982	1	1.069	1.126	0.938	0.869
1974	1.006	1.071	0.472	1.048	1	1.075	1.115	0.960	0.911
1975	1.042	1.088	0.497	1.094	1	1.081	1.119	0.970	0.932
1976	1.032	1.072	0.504	1.062	1	1.087	1.126	0.958	0.906
1977	1.042	1.078	0.525	1.058	1	1.093	1.125	0.955	0.901
1978	1.084	1.116	0.576	1.081	1	1.100	1.157	0.951	0.893
1979	1.272	1.227	0.656	1.190	1	1.106	1.206	0.966	0.923
1980	1.337	1.262	0.704	1.212	1	1.112	1.204	0.971	0.933
1981	1.298	1.204	0.701	1.176	1	1.118	1.153	0.973	0.938
1982	1.263	1.128	0.709	1.102	1	1.124	1.139	0.955	0.901
1983	1.408	1.246	0.833	1.213	1	1.131	1.178	0.972	0.936
1984	1.339	1.169	0.925	1.128	1	1.137	1.096	0.970	0.932
1985	1.388	1.197	1.017	1.157	1	1.143	1.102	0.975	0.942
1986	1.390	1.187	1.087	1.152	1	1.150	1.119	0.967	0.926
1987	1.205	1.018	1.009	0.985	1	1.156	1.050	0.937	0.866
1988	1.283	1.070	1.105	1.037	1	1.163	1.058	0.949	0.888
1989	1.200	0.988	1.079	0.959	1	1.169	1.035	0.930	0.853
1990	1.314	1.068	1.272	1.065	1	1.176	1.005	0.969	0.930
1991	1.254	1.008	1.254	1.004	1	1.182	1.007	0.949	0.889
1992	1.209	0.962	1.271	0.957	1	1.189	0.964	0.946	0.883
1993	1.330	1.036	1.452	1.018	1	1.196	0.984	0.957	0.905
1994	1.413	1.092	1.478	1.070	1	1.202	0.994	0.967	0.925
1995	1.449	1.111	1.222	1.094	1	1.209	1.028	0.962	0.915
1996	1.300	0.990	1.158	0.975	1	1.216	1.014	0.929	0.851
1997	1.325	1.005	1.244	0.992	1	1.223	1.015	0.932	0.857
1998	1.376	1.037	1.172	1.010	1	1.229	1.118	0.906	0.811
1999	1.423	1.073	1.123	1.030	1	1.236	1.120	0.910	0.818
2000	1.442	1.081	1.036	1.044	1	1.243	1.143	0.906	0.811
2001	1.397	1.037	0.911	1.004	1	1.250	1.141	0.892	0.789
2002	1.415	1.040	0.854	0.986	1	1.257	1.136	0.886	0.779
2003	1.455	1.062	0.883	1.030	1	1.264	1.140	0.897	0.797
2004	1.423	1.001	0.795	0.966	1	1.271	1.139	0.875	0.763
2005	1.432	1.083	0.826	1.031	1	1.278	1.154	0.889	0.785
2006	1.515	1.102	0.815	1.039	1	1.286	1.178	0.884	0.777
2007	1.524	1.078	0.776	1.027	1	1.293	1.180	0.878	0.767
2008	1.567	1.194	0.831	1.088	1	1.300	1.192	0.891	0.788
2009	1.574	1.152	0.777	1.085	1	1.307	1.195	0.887	0.782
2010	1.673	1.267	0.832	1.213	1	1.315	1.228	0.913	0.823
2011	1.546	1.211	0.775	1.125	1	1.322	1.203	0.893	0.792
2012	1.604	1.227	0.765	1.189	1	1.329	1.209	0.908	0.815
2013	1.747	1.350	0.822	1.333	1	1.337	1.247	0.932	0.858
2014	1.823	1.398	0.831	1.312	1	1.344	1.320	0.908	0.815
2015	1.859	1.431	0.831	1.336	1	1.352	1.342	0.906	0.812

5.20 Thailand

In 2014, the agriculture sector in Thailand employed 37.2% (respectively 32,9%) of the male (respectively female) labor force and contributed 10.5% to the GDP. Thailand is a successful exporter of rice. Other major commodities include rubber, sugar, fish, and fishery products. Figure 5.20 reports estimated changes in agricultural productivity in Thailand from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.20.

Panel (a) in Figure 5.20 indicates that land and labor productivity increased steadily over the sample period: in 2015, output per unit of land (respectively labor) was 3.21 (respectively 4.167) times higher than it had been in 1961. On the other hand, capital productivity fell significantly over the sample period. In 2015, output per unit of capital was 86% lower than it had been in 1961. Taken together, these results indicate that labor per hectare fell and capital per hectare increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.479 (respectively 44) while the area of land used for agricultural production increased by a factor of 1.92.

Panel (b) in Figure 5.20 indicates that TFP in Thai agriculture was 2.203 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 3.224 × 0.922 × 0.548
= 2.203

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 3.224; (iv) lower technical efficiency (the OTEI component) led to a 7.8% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 45.2% fall in measured TFP. In case of Thailand, the increase in scale and mix efficiency can be partly attributed to a shift from crops into livestock (i.e., a more productive output mix).

Panel (c) in Figure 5.20 indicates that TFP in Thailand in 2015 was 17.657 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 11.201 × 1.018 × 1.088
= 17.657.

This decomposition indicates that (i) the production environment in Thailand (wet tropical/ subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Thailand were 11.201 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Thailand were 1.8% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.20

PRODUCTIVITY CHANGE IN THAILAND

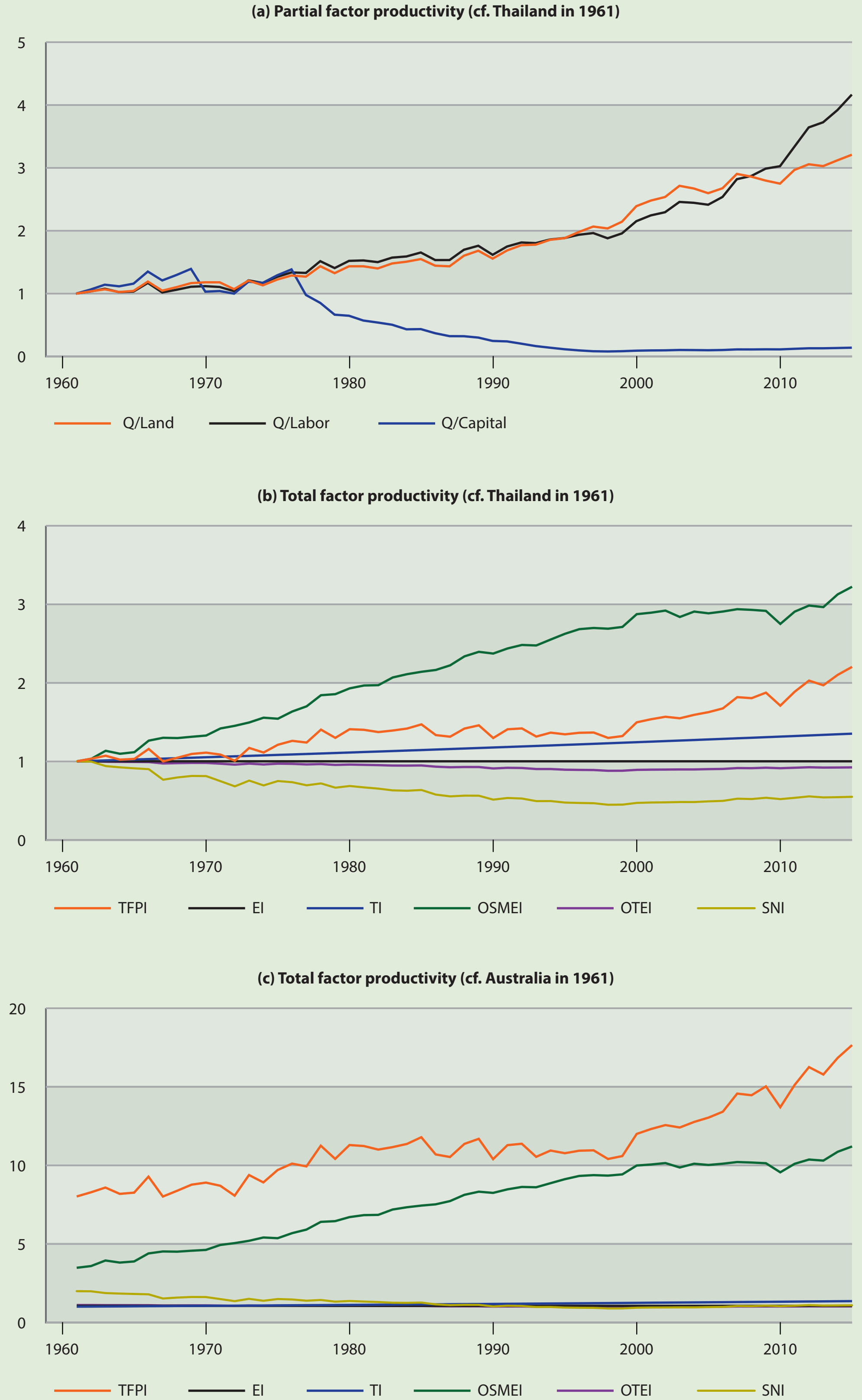


TABLE 5.20

PRODUCTIVITY CHANGE IN THAILAND (CF. THAILAND IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.035	1.034	1.064	1.033	1	1.006	1.032	1	0.996
1963	1.068	1.078	1.142	1.071	1	1.011	1.134	0.994	0.939
1964	1.025	1.024	1.116	1.021	1	1.017	1.096	0.993	0.923
1965	1.043	1.032	1.159	1.030	1	1.023	1.116	0.991	0.911
1966	1.192	1.170	1.351	1.158	1	1.028	1.263	0.990	0.900
1967	1.047	1.018	1.209	0.999	1	1.034	1.299	0.972	0.765
1968	1.103	1.062	1.297	1.045	1	1.040	1.296	0.977	0.794
1969	1.167	1.109	1.394	1.094	1	1.046	1.313	0.980	0.813
1970	1.180	1.119	1.031	1.110	1	1.052	1.328	0.979	0.812
1971	1.179	1.105	1.041	1.085	1	1.057	1.418	0.969	0.746
1972	1.071	1.039	0.999	1.006	1	1.063	1.452	0.957	0.681
1973	1.206	1.211	1.189	1.170	1	1.069	1.495	0.971	0.754
1974	1.132	1.170	1.172	1.112	1	1.075	1.555	0.960	0.693
1975	1.223	1.267	1.291	1.211	1	1.081	1.542	0.970	0.748
1976	1.288	1.337	1.386	1.261	1	1.087	1.635	0.967	0.733
1977	1.270	1.329	0.979	1.239	1	1.093	1.700	0.960	0.694
1978	1.436	1.516	0.852	1.404	1	1.100	1.842	0.965	0.719
1979	1.326	1.406	0.665	1.299	1	1.106	1.855	0.954	0.664
1980	1.435	1.521	0.648	1.409	1	1.112	1.929	0.958	0.685
1981	1.435	1.528	0.572	1.401	1	1.118	1.965	0.955	0.668
1982	1.400	1.501	0.540	1.372	1	1.124	1.970	0.951	0.652
1983	1.480	1.573	0.505	1.392	1	1.131	2.068	0.946	0.629
1984	1.508	1.591	0.432	1.417	1	1.137	2.110	0.945	0.625
1985	1.550	1.654	0.436	1.471	1	1.143	2.140	0.947	0.635
1986	1.444	1.534	0.370	1.334	1	1.150	2.164	0.931	0.576
1987	1.434	1.534	0.323	1.313	1	1.156	2.222	0.924	0.553
1988	1.603	1.698	0.322	1.417	1	1.163	2.337	0.927	0.563
1989	1.682	1.761	0.300	1.458	1	1.169	2.394	0.927	0.562
1990	1.556	1.618	0.247	1.297	1	1.176	2.373	0.909	0.511
1991	1.687	1.749	0.239	1.408	1	1.182	2.438	0.917	0.533
1992	1.771	1.814	0.203	1.419	1	1.189	2.482	0.915	0.526
1993	1.779	1.803	0.165	1.315	1	1.196	2.476	0.901	0.493
1994	1.856	1.861	0.139	1.365	1	1.202	2.551	0.902	0.493
1995	1.882	1.884	0.115	1.344	1	1.209	2.624	0.893	0.474
1996	1.981	1.937	0.097	1.363	1	1.216	2.683	0.891	0.469
1997	2.067	1.963	0.083	1.367	1	1.223	2.699	0.889	0.466
1998	2.037	1.881	0.080	1.298	1	1.229	2.689	0.879	0.447
1999	2.144	1.958	0.084	1.321	1	1.236	2.712	0.880	0.448
2000	2.391	2.152	0.092	1.497	1	1.243	2.874	0.891	0.470
2001	2.480	2.244	0.096	1.536	1	1.250	2.893	0.894	0.475
2002	2.537	2.295	0.097	1.567	1	1.257	2.920	0.895	0.477
2003	2.715	2.459	0.104	1.548	1	1.264	2.838	0.896	0.481
2004	2.673	2.445	0.102	1.592	1	1.271	2.907	0.896	0.481
2005	2.598	2.414	0.099	1.626	1	1.278	2.885	0.900	0.490
2006	2.676	2.538	0.103	1.673	1	1.286	2.908	0.903	0.496
2007	2.905	2.821	0.112	1.817	1	1.293	2.938	0.914	0.524
2008	2.861	2.871	0.112	1.804	1	1.300	2.929	0.912	0.519
2009	2.798	2.988	0.114	1.875	1	1.307	2.916	0.918	0.536
2010	2.750	3.027	0.113	1.709	1	1.315	2.750	0.912	0.518
2011	2.967	3.336	0.122	1.886	1	1.322	2.906	0.918	0.535
2012	3.058	3.644	0.130	2.028	1	1.329	2.984	0.924	0.553
2013	3.028	3.726	0.131	1.969	1	1.337	2.964	0.920	0.540
2014	3.121	3.920	0.135	2.101	1	1.344	3.127	0.921	0.543
2015	3.210	4.167	0.140	2.203	1	1.352	3.224	0.922	0.548

5.21 UK

In 2014, the agriculture sector in the UK employed 1.7% (respectively 0.7%) of the male (respectively female) labor force and contributed 0.6% to the GDP. Most cropping activity is concentrated in East Anglia. Most livestock activity is concentrated in the South West. The average age of UK farmers is close to 60, as low farm incomes and high land prices have discouraged younger generations from joining the industry. Figure 5.21 reports estimated changes in agricultural productivity in the UK from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.21.

Panel (a) in Figure 5.21 indicates that land and labor productivity increased steadily over the sample period. In 2015, output per unit of land (respectively labor) was 64.2% (respectively 47.1%) higher than it had been in 1961. Capital productivity also increased steadily over the sample period. In 2015, output per unit of capital was 31.2% higher than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of the raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production fell by 2.8% (respectively increased by 8.9%) while the area of land used for agricultural production fell by 13%.

Panel (b) in Figure 5.21 indicates that TFP in UK agriculture was 39.9% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 1 \times 1.352 \times 1.063 \times 0.994 \times 0.980 \\
&= 1.399
\end{aligned}
$$

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 6.3% increase in TFP; (iv) changes in technical efficiency (the OTEI component) had a negligible impact on TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 2% fall in measured TFP.

Panel (c) in Figure 5.21 indicates that TFP in the UK in 2015 was 7.973 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

$$
\begin{aligned}
TFPI &= EI \times TI \times OSMEI \times OTEI \times SNI \\
&= 0.986 \times 1.352 \times 7.499 \times 0.954 \times 0.836 \\
&= 7.973.
\end{aligned}
$$

This decomposition indicates that (i) the production environment in the UK (wet temperate) is 1.4% less productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in the UK were 7.499 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in the U.K. were 4.6% less technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.21

PRODUCTIVITY CHANGE IN UK

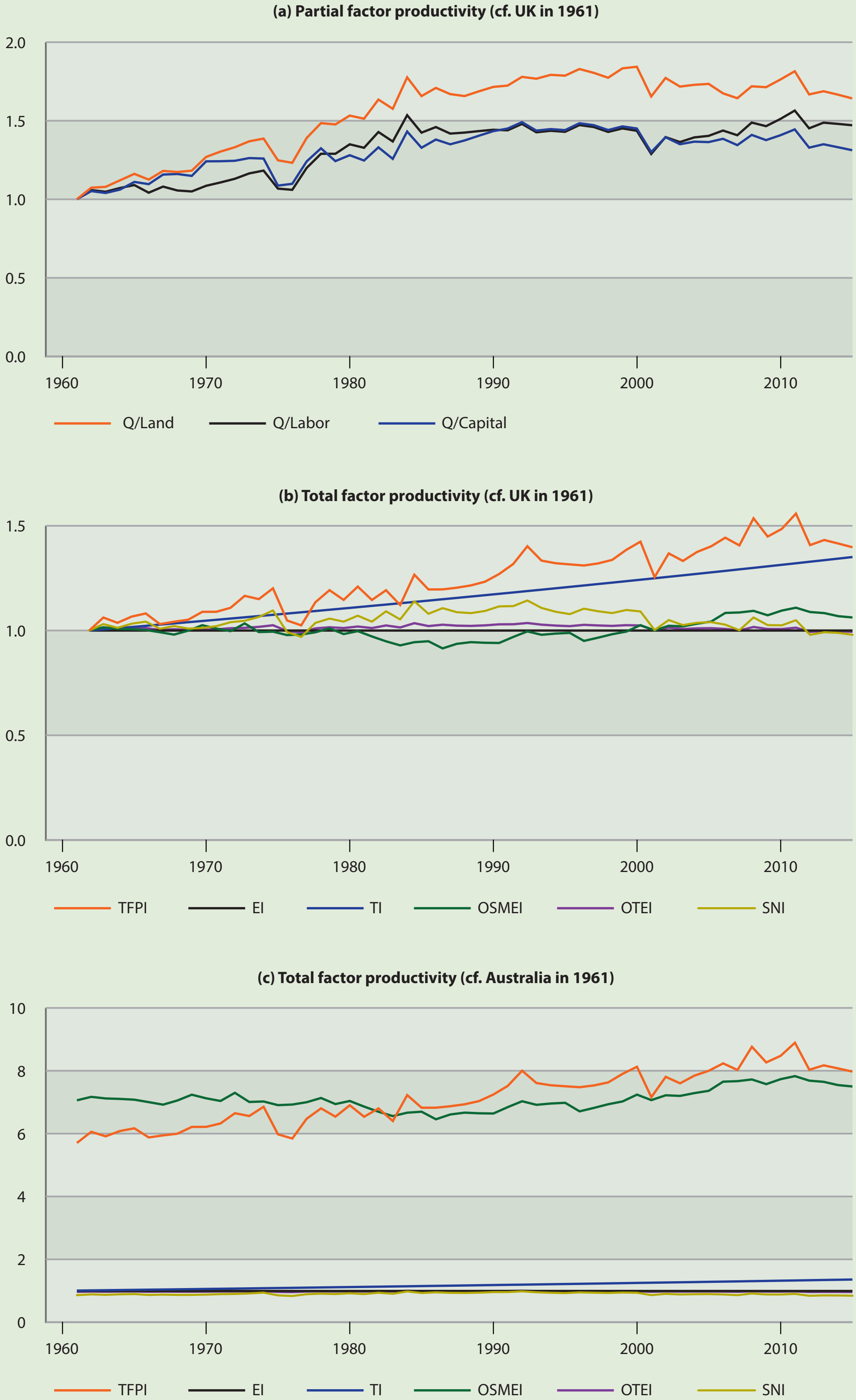


TABLE 5.21

PRODUCTIVITY CHANGE IN UK (CF. UK IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.073	1.058	1.051	1.062	1	1.006	1.016	1.009	1.031
1963	1.079	1.047	1.039	1.037	1	1.011	1.009	1.004	1.013
1964	1.120	1.071	1.061	1.067	1	1.017	1.007	1.009	1.033
1965	1.161	1.090	1.110	1.082	1	1.023	1.003	1.012	1.043
1966	1.125	1.041	1.096	1.031	1	1.028	0.992	1.002	1.008
1967	1.180	1.080	1.157	1.042	1	1.034	0.981	1.006	1.022
1968	1.173	1.055	1.160	1.052	1	1.040	0.999	1.003	1.009
1969	1.182	1.049	1.148	1.090	1	1.046	1.026	1.004	1.012
1970	1.269	1.085	1.241	1.090	1	1.052	1.009	1.006	1.021
1971	1.303	1.107	1.242	1.109	1	1.057	0.997	1.011	1.040
1972	1.331	1.130	1.245	1.166	1	1.063	1.034	1.013	1.047
1973	1.369	1.164	1.262	1.150	1	1.069	0.993	1.018	1.065
1974	1.386	1.182	1.259	1.202	1	1.075	0.995	1.025	1.096
1975	1.248	1.067	1.086	1.048	1	1.081	0.978	0.998	0.993
1976	1.232	1.060	1.098	1.025	1	1.087	0.981	0.991	0.970
1977	1.390	1.199	1.240	1.135	1	1.093	0.992	1.010	1.037
1978	1.485	1.289	1.324	1.193	1	1.100	1.011	1.016	1.057
1979	1.476	1.289	1.242	1.147	1	1.106	0.983	1.012	1.042
1980	1.532	1.350	1.280	1.210	1	1.112	0.997	1.019	1.071
1981	1.513	1.328	1.246	1.146	1	1.118	0.972	1.012	1.042
1982	1.635	1.428	1.330	1.193	1	1.124	0.948	1.024	1.092
1983	1.576	1.367	1.257	1.122	1	1.131	0.929	1.015	1.053
1984	1.776	1.535	1.431	1.267	1	1.137	0.944	1.035	1.140
1985	1.657	1.424	1.328	1.197	1	1.143	0.949	1.021	1.080
1986	1.709	1.460	1.380	1.197	1	1.150	0.915	1.028	1.107
1987	1.669	1.418	1.350	1.205	1	1.156	0.936	1.023	1.088
1988	1.657	1.424	1.374	1.216	1	1.163	0.944	1.022	1.083
1989	1.687	1.434	1.404	1.234	1	1.169	0.942	1.025	1.094
1990	1.715	1.442	1.433	1.271	1	1.176	0.941	1.030	1.116
1991	1.724	1.439	1.450	1.319	1	1.182	0.969	1.030	1.117
1992	1.779	1.480	1.491	1.404	1	1.189	0.996	1.036	1.144
1993	1.767	1.426	1.437	1.335	1	1.196	0.980	1.028	1.108
1994	1.792	1.436	1.446	1.322	1	1.202	0.986	1.024	1.090
1995	1.787	1.429	1.440	1.317	1	1.209	0.989	1.021	1.079
1996	1.829	1.472	1.484	1.311	1	1.216	0.950	1.027	1.105
1997	1.805	1.460	1.471	1.321	1	1.223	0.966	1.024	1.092
1998	1.774	1.428	1.441	1.338	1	1.229	0.983	1.022	1.084
1999	1.834	1.451	1.464	1.386	1	1.236	0.995	1.026	1.098
2000	1.844	1.436	1.450	1.425	1	1.243	1.026	1.024	1.091
2001	1.654	1.288	1.300	1.256	1	1.250	1.001	1.001	1.003
2002	1.772	1.396	1.395	1.369	1	1.257	1.023	1.014	1.050
2003	1.717	1.364	1.350	1.333	1	1.264	1.020	1.007	1.026
2004	1.728	1.393	1.366	1.376	1	1.271	1.033	1.010	1.037
2005	1.735	1.403	1.364	1.403	1	1.278	1.043	1.011	1.040
2006	1.674	1.437	1.385	1.445	1	1.286	1.084	1.008	1.028
2007	1.643	1.407	1.344	1.407	1	1.293	1.087	1.000	1.001
2008	1.719	1.488	1.410	1.537	1	1.300	1.094	1.017	1.063
2009	1.713	1.465	1.376	1.450	1	1.307	1.073	1.007	1.026
2010	1.762	1.511	1.407	1.487	1	1.315	1.096	1.007	1.025
2011	1.815	1.564	1.445	1.560	1	1.322	1.109	1.014	1.049
2012	1.667	1.451	1.328	1.409	1	1.329	1.089	0.994	0.979
2013	1.688	1.487	1.350	1.433	1	1.337	1.083	0.998	0.992
2014	1.666	1.480	1.331	1.416	1	1.344	1.069	0.997	0.989
2015	1.642	1.471	1.312	1.399	1	1.352	1.063	0.994	0.980

5.22 USA

Agriculture is an important industry in the USA. In 2014, the sector employed 2.1% (respectively 0.8%) of the male (respectively female) labor force and contributed 1.2% to the GDP. Most agricultural activity is concentrated in the Great Plains (in the center) and the Corn Belt (around the Great Lakes). Major crops include corn, soybeans, wheat, potatoes, and sugar beets. Figure 5.22 reports estimated changes in agricultural productivity in the USA from 1961 to 2015. The index numbers used to construct panels (a) and (b) in this figure are reported in Table 5.22.

Panel (a) in Figure 5.22 indicates that land and labor productivity increased steadily over the sample period: in 2015, output per unit of land (respectively labor) was 2.599 (respectively 2.224) times higher than it had been in 1961. Capital productivity also increased steadily over the sample period. In 2015, output per unit of capital was 2.185 times higher than it had been in 1961. Taken together, these results indicate that labor per hectare and capital per hectare both increased over the sample period. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by 6.6% (respectively 8.5%) while the area of land used for agricultural production fell by 8.8%.

Panel (b) in Figure 5.22 indicates that TFP in USA agriculture was 82.5% higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 1.193 × 1.021 × 1.108
= 1.825

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) led to a 19.3% increase in TFP; (iv) higher technical efficiency (the OTEI component) led to a 2.1% increase in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 10.8% increase in measured TFP.

Panel (c) in Figure 5.22 indicates that TFP in the USA in 2015 was 11.19 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

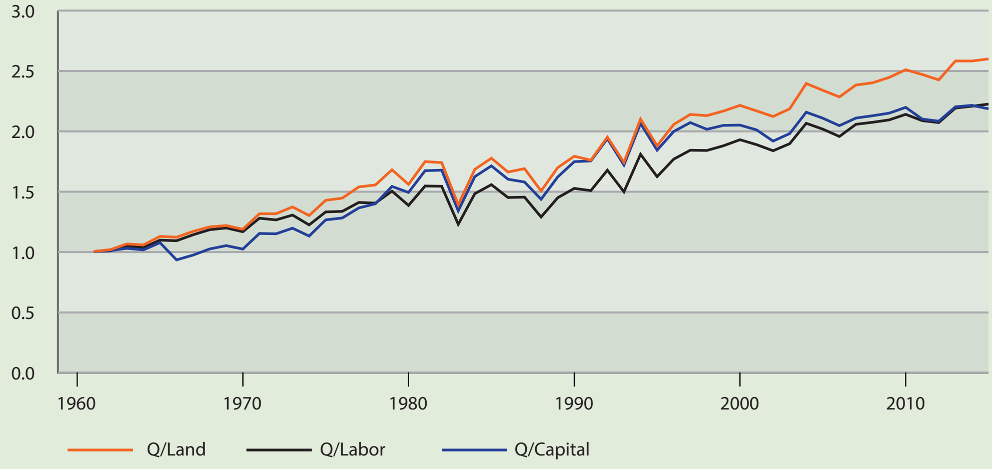
TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 7.068 × 1.027 × 1.14
= 11.19.

This decomposition indicates that (i) the production environment in the USA is the same as the production environment in Australia (dry temperate); (ii) the agricultural pro- duction technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in the USA were 7.068 times more scale and mix efficient in 2015 than Australian farmers had been in 1961, (iv) farmers in the USA were 2.7% more technically efficient in 2015 than Australian farmers had been in 1961.

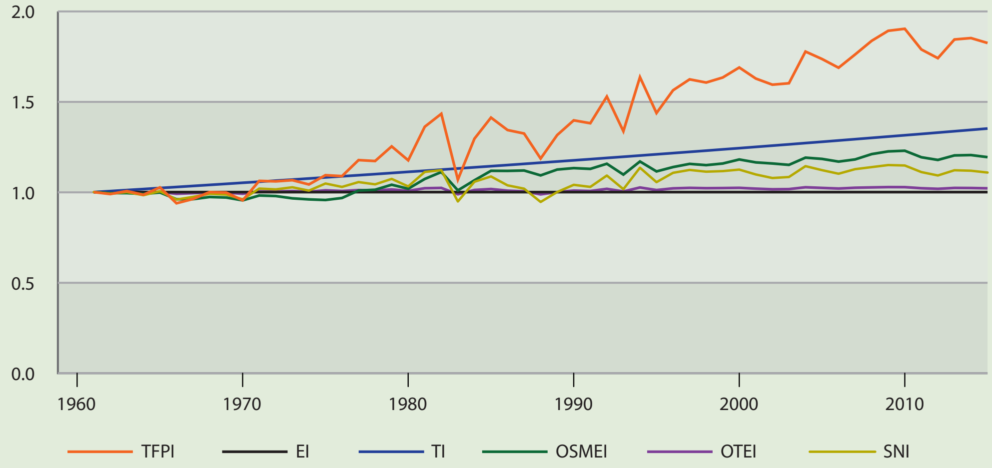
FIGURE 5.22

PRODUCTIVITY CHANGE IN USA

(a) Partial factor productivity (cf. USA in 1961)



(b) Total factor productivity (cf. USA in 1961)



(c) Total factor productivity (cf. Australia in 1961)

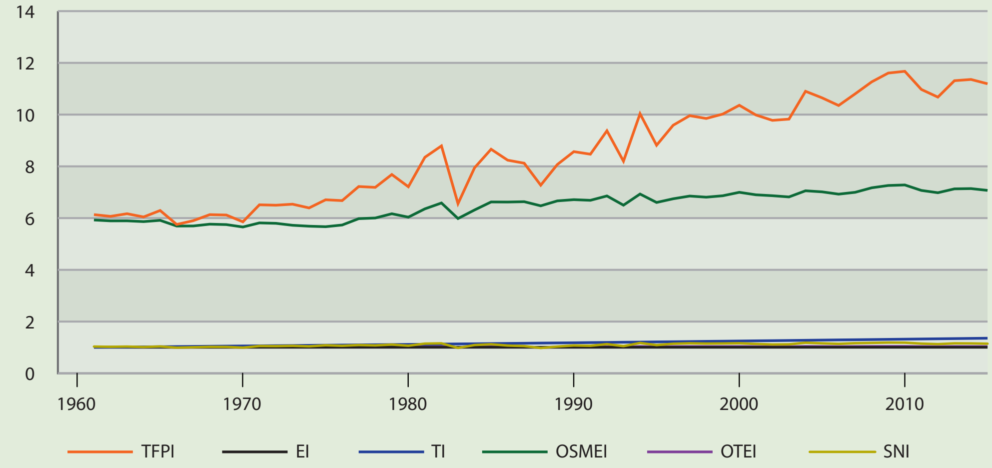


TABLE 5.22

PRODUCTIVITY CHANGE IN USA (CF. USA IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.015	1.005	1.007	0.989	1	1.006	0.994	0.998	0.991
1963	1.062	1.045	1.026	1.006	1	1.011	0.994	1.000	1.000
1964	1.054	1.031	1.013	0.985	1	1.017	0.990	0.996	0.983
1965	1.124	1.094	1.072	1.026	1	1.023	0.998	1.001	1.005
1966	1.118	1.088	0.930	0.938	1	1.028	0.960	0.991	0.959
1967	1.166	1.138	0.970	0.962	1	1.034	0.961	0.994	0.974
1968	1.204	1.180	1.020	1.000	1	1.040	0.973	0.998	0.990
1969	1.215	1.195	1.048	0.998	1	1.046	0.970	0.997	0.986
1970	1.184	1.163	1.019	0.955	1	1.052	0.954	0.991	0.960
1971	1.313	1.275	1.149	1.062	1	1.057	0.981	1.004	1.019
1972	1.313	1.262	1.146	1.059	1	1.063	0.978	1.003	1.015
1973	1.370	1.302	1.193	1.066	1	1.069	0.965	1.006	1.027
1974	1.298	1.220	1.128	1.042	1	1.075	0.960	1.002	1.008
1975	1.425	1.328	1.262	1.094	1	1.081	0.956	1.010	1.047
1976	1.442	1.333	1.278	1.088	1	1.087	0.967	1.006	1.029
1977	1.536	1.407	1.361	1.177	1	1.093	1.009	1.011	1.055
1978	1.552	1.401	1.396	1.172	1	1.100	1.013	1.009	1.043
1979	1.678	1.501	1.540	1.253	1	1.106	1.041	1.015	1.073
1980	1.557	1.382	1.490	1.176	1	1.112	1.018	1.007	1.031
1981	1.746	1.543	1.670	1.362	1	1.118	1.073	1.022	1.111
1982	1.737	1.541	1.675	1.434	1	1.124	1.111	1.023	1.121
1983	1.387	1.225	1.337	1.069	1	1.131	1.010	0.988	0.948
1984	1.682	1.480	1.621	1.296	1	1.137	1.065	1.012	1.057
1985	1.774	1.554	1.710	1.412	1	1.143	1.118	1.017	1.087
1986	1.659	1.448	1.600	1.343	1	1.150	1.117	1.008	1.037
1987	1.687	1.451	1.576	1.324	1	1.156	1.120	1.004	1.019
1988	1.502	1.286	1.433	1.186	1	1.163	1.092	0.987	0.945
1989	1.696	1.446	1.618	1.316	1	1.169	1.125	1.000	1.000
1990	1.790	1.524	1.745	1.397	1	1.176	1.133	1.008	1.040
1991	1.758	1.505	1.751	1.381	1	1.182	1.128	1.006	1.029
1992	1.950	1.674	1.936	1.529	1	1.189	1.157	1.018	1.092
1993	1.740	1.495	1.717	1.337	1	1.196	1.097	1.003	1.016
1994	2.099	1.807	2.063	1.636	1	1.202	1.170	1.025	1.135
1995	1.877	1.621	1.841	1.438	1	1.209	1.114	1.011	1.055
1996	2.054	1.766	1.996	1.564	1	1.216	1.139	1.021	1.107
1997	2.138	1.840	2.070	1.624	1	1.223	1.156	1.023	1.123
1998	2.128	1.838	2.014	1.607	1	1.229	1.149	1.022	1.113
1999	2.166	1.877	2.047	1.634	1	1.236	1.158	1.022	1.116
2000	2.213	1.928	2.049	1.690	1	1.243	1.181	1.024	1.124
2001	2.167	1.887	2.009	1.629	1	1.250	1.165	1.019	1.098
2002	2.121	1.836	1.917	1.595	1	1.257	1.159	1.016	1.078
2003	2.185	1.895	1.979	1.602	1	1.264	1.151	1.017	1.084
2004	2.395	2.064	2.156	1.778	1	1.271	1.191	1.027	1.144
2005	2.338	2.015	2.106	1.737	1	1.278	1.184	1.023	1.121
2006	2.283	1.955	2.044	1.688	1	1.286	1.169	1.020	1.102
2007	2.382	2.056	2.108	1.762	1	1.293	1.181	1.024	1.127
2008	2.401	2.072	2.127	1.837	1	1.300	1.210	1.026	1.138
2009	2.445	2.092	2.148	1.893	1	1.307	1.225	1.028	1.150
2010	2.509	2.138	2.196	1.904	1	1.315	1.229	1.027	1.147
2011	2.469	2.086	2.099	1.790	1	1.322	1.193	1.021	1.111
2012	2.425	2.070	2.082	1.741	1	1.329	1.178	1.018	1.092
2013	2.582	2.191	2.201	1.845	1	1.337	1.203	1.023	1.121
2014	2.581	2.206	2.213	1.853	1	1.344	1.205	1.023	1.118
2015	2.599	2.224	2.185	1.825	1	1.352	1.193	1.021	1.108

5.23 Vietnam

In 2014, the agriculture sector in Vietnam employed 44.7% (respectively 48.1%) of the male (respectively female) labor force and contributed 18.1% to the GDP. Agricultural commodities account for approximately one third of all exports from Vietnam. Vietnam is the world's second largest exporter of rice. Figure 5.23 reports estimated changes in agricultural productivity in Vietnam from 1961 to 2015. The index numbers used to construct panels and (b) in this figure are reported in Table 5.23.

Panel (a) in Figure 5.23 indicates that land and labor productivity increased steadily since the end of the Vietnam war in 1975. In 2015, output per unit of land (respectively labor) was 3.841 (respectively 4.142) times higher than it had been in 1975. On the other hand, capital productivity fell significantly since the end of the war. I 2015, output per unit of capital was 89.5% lower than it had been in 1975. Taken together, these results indicate that labor per hectare fell and capital per hectare increased significantly after the war. An inspection of raw data reveals that this was because the amount of labor (respectively capital) used in agricultural production increased by a factor of 1.553 (respectively 61.87) while the area of land used for agricultural production increased by a factor of 1.674.

Panel (b) in Figure 5.23 indicates that TFP in Vietnamese agriculture was 2.347 times higher in 2015 than it had been in 1961. The breakdown of this increase is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1 × 1.352 × 2.364 × 0.952 × 0.771
= 2.347

This decomposition indicates that, over the sample period, (i) changes in the production environment (the EI component) had no impact on TFP; (ii) technical progress (the TI component) led to a 35.2% increase in TFP; (iii) improvements in scale and mix efficiency (the OSMEI component) increased TFP by a factor of 2.364; (iv) lower technical efficiency (the OTEI component) led to a 4.8% fall in TFP; and (v) changes in omitted variables and other sources of statistical noise (the SNI component) accounted for a 22.9% fall in measured TFP.

Panel (c) in Figure 5.23 indicates that TFP in Vietnam in 2015 was 12.215 times higher than TFP had been in Australia in 1961. The breakdown is as follows:

TFPI = EI × TI × OSMEI × OTEI × SNI
= 1.053 × 1.352 × 8.55 × 1.001 × 1.003
= 12.215.

This decomposition indicates that (i) the production environment in Vietnam (wet tropical/subtropical) is 5.3% more productive than the production environment in Australia (dry temperate); (ii) the agricultural production technologies available in 2015 were 35.2% more productive than the technologies available in 1961; (iii) farmers in Vietnam were 8.55 times more scale and mix efficient in 2015 than Australian farmers had been in 1961; and (iv) farmers in Vietnam were less than 1% more technically efficient in 2015 than Australian farmers had been in 1961.

FIGURE 5.23

PRODUCTIVITY CHANGE IN VIETNAM

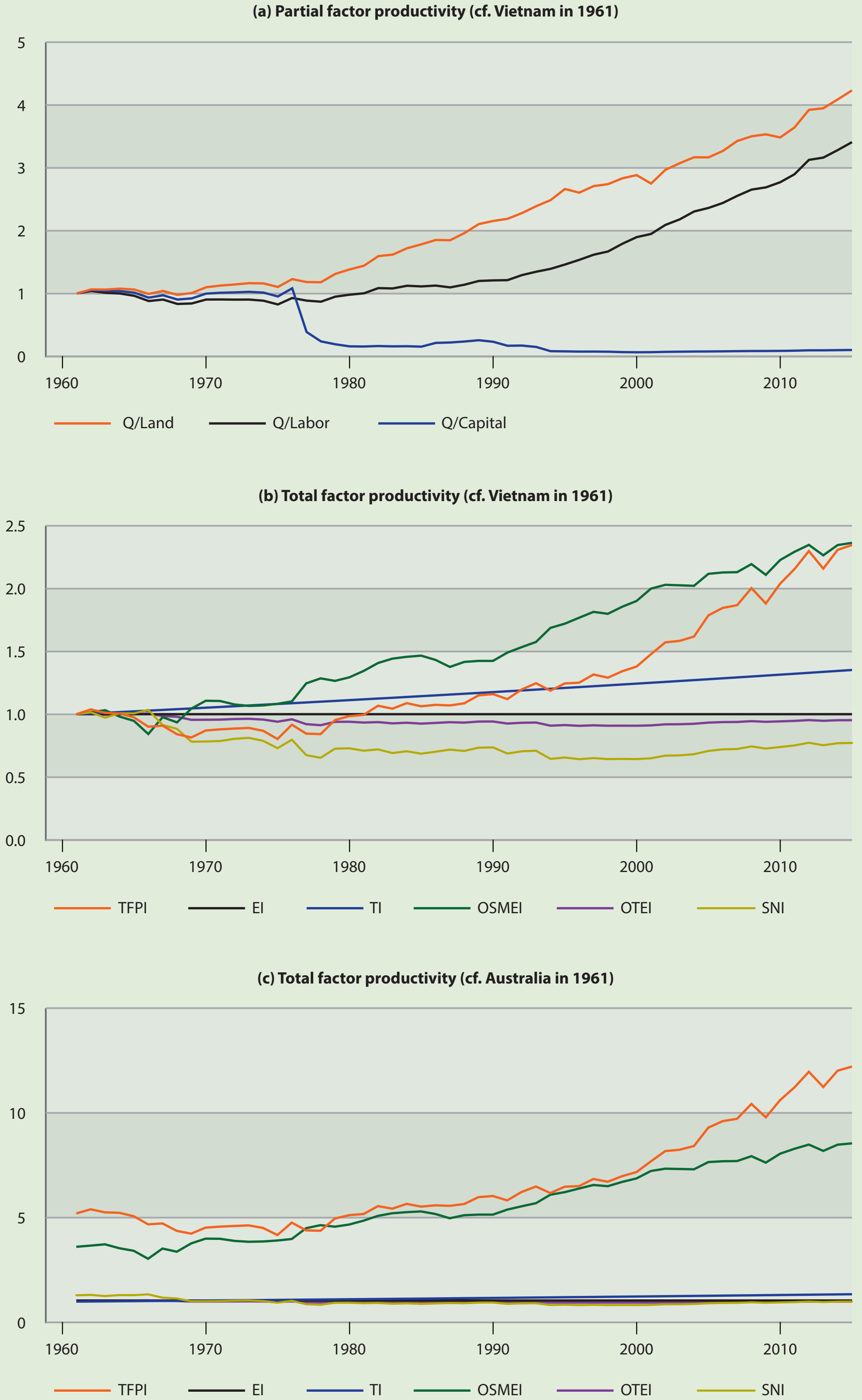


TABLE 5.23

PRODUCTIVITY CHANGE IN VIETNAM (CF. VIETNAM IN 1961)

Year	Q/Land	Q/Lab.	Q/Cap.	TFPI	EI	TI	OSMEI	OTEI	SNI
1961	1	1	1	1	1	1	1	1	1
1962	1.063	1.037	1.052	1.038	1	1.006	1.015	1.002	1.014
1963	1.061	1.009	1.038	1.010	1	1.011	1.032	0.996	0.972
1964	1.075	0.998	1.036	1.006	1	1.017	0.981	1.001	1.007
1965	1.060	0.961	1.011	0.975	1	1.023	0.947	1.001	1.006
1966	0.991	0.878	0.932	0.900	1	1.028	0.842	1.005	1.035
1967	1.039	0.902	0.970	0.909	1	1.034	0.976	0.985	0.914
1968	0.977	0.831	0.902	0.840	1	1.040	0.935	0.979	0.883
1969	1.005	0.839	0.920	0.815	1	1.046	1.044	0.955	0.781
1970	1.097	0.902	0.996	0.870	1	1.052	1.107	0.956	0.782
1971	1.124	0.903	1.010	0.879	1	1.057	1.105	0.957	0.786
1972	1.142	0.900	1.016	0.885	1	1.063	1.077	0.961	0.804
1973	1.162	0.901	1.025	0.891	1	1.069	1.066	0.963	0.811
1974	1.158	0.883	1.012	0.867	1	1.075	1.070	0.957	0.788
1975	1.102	0.823	0.951	0.803	1	1.081	1.083	0.940	0.729
1976	1.227	0.927	1.081	0.916	1	1.087	1.102	0.959	0.797
1977	1.180	0.885	0.385	0.845	1	1.093	1.246	0.921	0.674
1978	1.177	0.868	0.236	0.841	1	1.100	1.285	0.912	0.653
1979	1.310	0.948	0.189	0.953	1	1.106	1.265	0.939	0.726
1980	1.381	0.979	0.156	0.984	1	1.112	1.293	0.940	0.728
1981	1.440	1.001	0.154	0.995	1	1.118	1.344	0.933	0.709
1982	1.593	1.084	0.162	1.067	1	1.124	1.408	0.937	0.720
1983	1.617	1.078	0.156	1.044	1	1.131	1.442	0.927	0.691
1984	1.719	1.122	0.158	1.088	1	1.137	1.457	0.932	0.705
1985	1.782	1.111	0.151	1.063	1	1.143	1.466	0.925	0.685
1986	1.850	1.124	0.211	1.075	1	1.150	1.432	0.931	0.701
1987	1.846	1.095	0.218	1.070	1	1.156	1.376	0.936	0.718
1988	1.960	1.138	0.233	1.086	1	1.163	1.416	0.933	0.707
1989	2.104	1.198	0.254	1.150	1	1.169	1.424	0.941	0.733
1990	2.153	1.207	0.229	1.160	1	1.176	1.424	0.942	0.735
1991	2.188	1.211	0.166	1.120	1	1.182	1.490	0.925	0.687
1992	2.278	1.291	0.169	1.197	1	1.189	1.534	0.932	0.704
1993	2.389	1.345	0.147	1.247	1	1.196	1.575	0.933	0.709
1994	2.485	1.390	0.079	1.187	1	1.202	1.687	0.909	0.644
1995	2.662	1.459	0.077	1.245	1	1.209	1.720	0.913	0.655
1996	2.604	1.534	0.073	1.251	1	1.216	1.768	0.907	0.641
1997	2.708	1.616	0.073	1.316	1	1.223	1.815	0.911	0.651
1998	2.740	1.667	0.071	1.291	1	1.229	1.799	0.908	0.643
1999	2.832	1.790	0.065	1.342	1	1.236	1.856	0.908	0.644
2000	2.883	1.896	0.062	1.379	1	1.243	1.901	0.908	0.643
2001	2.748	1.946	0.064	1.477	1	1.250	1.999	0.911	0.649
2002	2.967	2.090	0.068	1.572	1	1.257	2.030	0.919	0.670
2003	3.073	2.179	0.071	1.584	1	1.264	2.026	0.920	0.672
2004	3.168	2.304	0.074	1.618	1	1.271	2.022	0.924	0.682
2005	3.166	2.360	0.075	1.787	1	1.278	2.118	0.933	0.708
2006	3.268	2.440	0.077	1.846	1	1.286	2.128	0.937	0.720
2007	3.426	2.552	0.080	1.867	1	1.293	2.131	0.938	0.723
2008	3.501	2.653	0.082	2.004	1	1.300	2.195	0.944	0.743
2009	3.532	2.688	0.082	1.881	1	1.307	2.110	0.939	0.726
2010	3.483	2.770	0.084	2.039	1	1.315	2.228	0.943	0.738
2011	3.643	2.898	0.087	2.156	1	1.322	2.293	0.947	0.751
2012	3.922	3.126	0.093	2.299	1	1.329	2.348	0.953	0.773
2013	3.948	3.162	0.093	2.159	1	1.337	2.265	0.947	0.753
2014	4.088	3.281	0.096	2.308	1	1.344	2.346	0.952	0.769
2015	4.233	3.409	0.099	2.347	1	1.352	2.364	0.952	0.771

5.24 Summary

The main results are summarized in Figure 5.24. This figure presents a snapshot of agricultural productivity in 23 countries in 2015. The index numbers used to construct this figure are reported in Table 5.24. These index numbers have been discussed previously. For example, the index numbers reported in the first (respectively last) row of Table 5.24 were reported and discussed at the end of Section 5.1 (respectively 5.23).

Panel (a) in Figure 5.24 indicates that, in 2015, the most productive farmers were in Thailand (on average, these farmers were 17.657 times more productive than farmers in Australia had been in 1961), Malaysia (17.088 times more productive), IR Iran (16.865 times more productive), and the Lao PDR (16.697 times more productive). The least productive farmers were in Mongolia (only 37.9% as productive as farmers in Australia had been in 1961) and Australia (only 3.846 times more productive than they had been in 1961).

Panel (b) in Figure 5.24 indicates that farmers in India and IR Iran operated in a dry tropical/subtropical production environment that was 45.3% less productive than the dry temperate production environment in Australia. On the other hand, farmers in Bangladesh, Cambodia, Indonesia, the Lao PDR, Malaysia, the Philippines, the ROC, Sri Lanka, Thailand, and Vietnam operated in a wet tropical/subtropical production environment that was 5.3% more productive than the production environment in Australia.

Panel (c) in Figure 5.24 indicates that, between 1961 and 2015, technical progress provided for a 35.2% increase in agricultural productivity in every country.

Panel (d) in Figure 5.24 indicates that, in 2015, the most scale and mix efficient farmers were in IR Iran (on average, these farmers were 11.822 times more scale and mix efficient than farmers in Australia had been in 1961), Thailand (11.201 times more scale and mix efficient), Malaysia (10.637 times more scale and mix efficient) and the ROC (10.516 times more scale and mix efficient). The least scale and mix efficient farmers were in Mongolia (only 58.8% as scale and mix efficient as farmers in Australia had been in 1961) and Australia (only 1.722 times more scale and mix efficient than they had been in 1961). Observe that the pattern of variation in panel (d) is similar to the pattern of variation in panel (a). This indicates that scale and mix efficiency change has been the main driver of cross-sectional variations in agricultural productivity.

Panel (e) in Figure 5.24 indicates that, in 2015, the most technically efficient farmers were in the Lao PDR (on average, these farmers were 11.6% more technically efficient than farmers in Australia had been in 1961), IR Iran (9.2% more technically efficient) and Australia (7.5% more technically efficient). The least technically efficient farmers were in Sri Lanka (only 80.8% as technically efficient as farmers in Australia had been in 1961), and Mongolia (only 82.3% as technically efficient).

Panel (f) in Figure 5.24 indicates that, in some cases, significant differences in agricultural productivity can be attributed to omitted variables and other sources of statistical noise. The problem is most apparent in the Lao PDR, IR Iran, Sri Lanka, Mongolia, and Pakistan.

FIGURE 5.24

PRODUCTIVITY IN SELECTED COUNTRIES IN 2015 (CF. AUSTRALIA IN 1961)

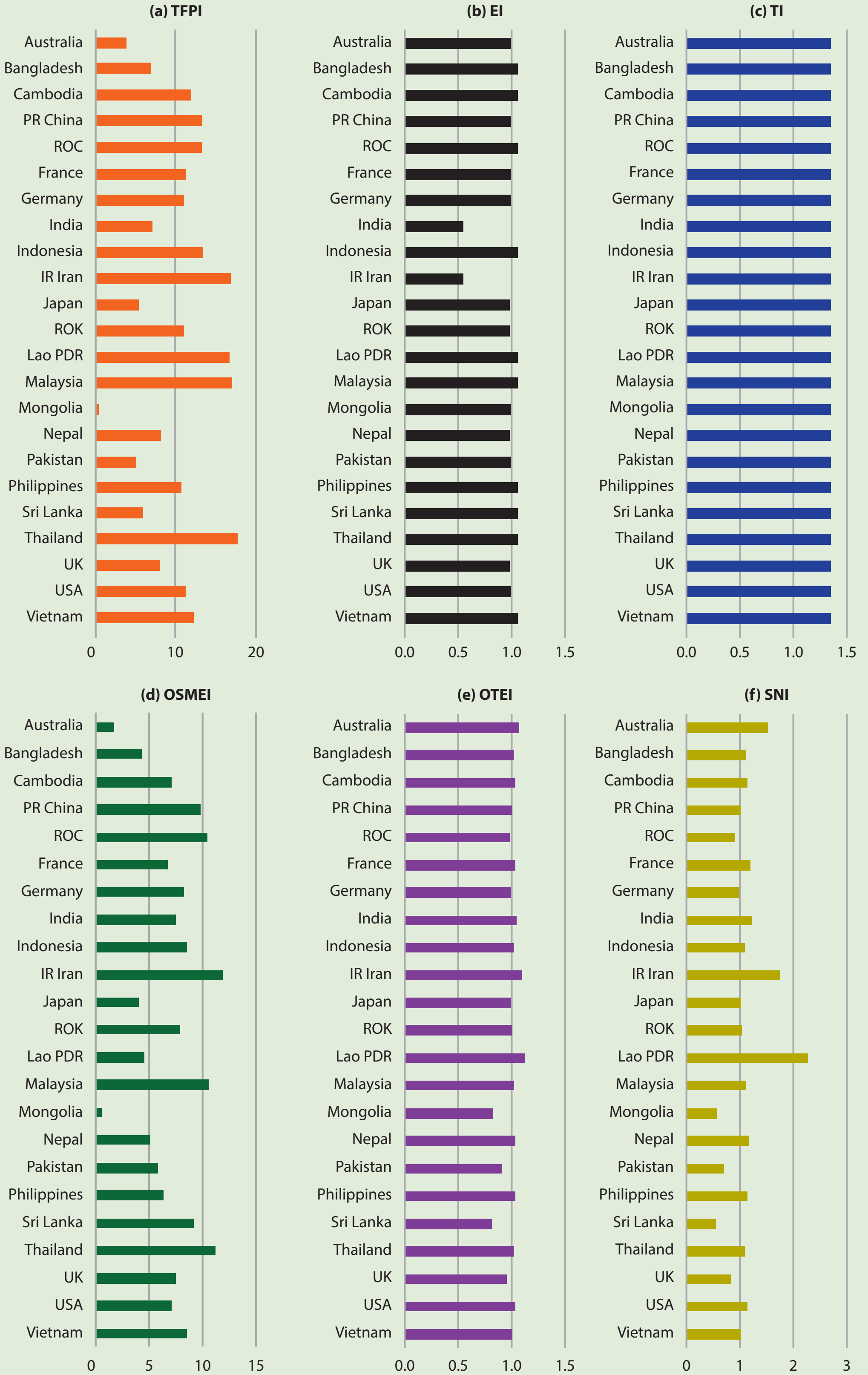


TABLE 5.24

PRODUCTIVITY IN SELECTED COUNTRIES IN 2015 (CF. AUSTRALIA IN 1961)

Year	TFPI	EI	TI	OSMEI	OTEI	SNI
Australia	3.846	1	1.352	1.722	1.075	1.537
Bangladesh	6.888	1.053	1.352	4.269	1.022	1.109
Cambodia	11.928	1.053	1.352	7.171	1.027	1.138
PR China	13.330	1	1.352	9.789	1.001	1.006
ROC	13.319	1.053	1.352	10.516	0.977	0.911
France	11.275	1	1.352	6.682	1.037	1.203
Germany	11.070	1	1.352	8.277	0.998	0.991
India	7.060	0.547	1.352	7.526	1.040	1.221
Indonesia	13.424	1.053	1.352	8.589	1.017	1.080
IR Iran	16.865	0.547	1.352	11.822	1.092	1.768
Japan	5.351	0.986	1.352	4.008	1.000	1.001
ROK	11.037	0.986	1.352	7.841	1.010	1.046
Lao PDR	16.697	1.053	1.352	4.613	1.116	2.279
Malaysia	17.088	1.053	1.352	10.637	1.021	1.105
Mongolia	0.379	1	1.352	0.588	0.823	0.580
Nepal	8.043	0.986	1.352	5.066	1.030	1.156
Pakistan	5.015	1	1.352	5.884	0.898	0.702
Philippines	10.630	1.053	1.352	6.313	1.029	1.150
Sri Lanka	5.877	1.053	1.352	9.129	0.808	0.560
Thailand	17.657	1.053	1.352	11.201	1.018	1.088
UK	7.973	0.986	1.352	7.499	0.954	0.836
USA	11.190	1	1.352	7.068	1.027	1.140
Vietnam	12.215	1.053	1.352	8.550	1.001	1.003

CHAPTER 6

MONITORING AGRICULTURAL PRODUCTIVITY CHANGE IN ASIA

This section discusses some of the issues and challenges involved in monitoring agricultural productivity change in general. It also makes some specific recommendations aimed at improving agricultural productivity measurement and analysis in Asia.

6.1 Issues and Challenges

Monitoring agricultural productivity change is a matter of measuring output and input change. The main challenge to measuring output and input change (and therefore productivity change) is the collection of accurate data. Not only must data be accurate, they must be collected at a level that is useful for policymaking. The FAO data used in this project is generally too inaccurate and highly aggregated for good farm-level policy work. Before collecting data, analysts must be careful to define the following:

1. **The level of analysis:** Productivity measurement is ultimately aimed at measuring the performance of specific decisionmakers (e.g., farm managers, or government ministers). Decisionmakers at different levels (e.g., farm level, sector level) make decisions about different variables (e.g., farm managers make decisions concerning farm-level inputs of seed and pesticides, while government minsters make decisions about fertilizer subsidies and the building of dams). Arguably the most useful data for monitoring and analyzing agricultural productivity change is farm-level data.

2. **The variables involved in agriculture:** It is generally possible to divide the variables involved in the agricultural production process into those that are chosen by managers and those that are not. Variables that are chosen by managers can be further subdivided into inputs and outputs. Those that are never chosen by managers should be viewed as environmental variables (e.g., rainfall). Monitoring agricultural productivity change requires data on outputs and inputs. Analyzing agricultural productivity change also requires data on environmental variables. Analyzing agricultural productivity change may also require data on other variables that affect farmers' decision-making (e.g., prices, and government policy).

3. **The variables of interest:** Productivity is a measure of output volume (or quantity) divided by a measure of input volume. However, in the business literature, the term 'productivity' is sometimes used to refer to measures of output value (e.g., revenue, and value added) divided by measures of input value (e.g., cost). On the other hand, in productivity literature, the term 'productivity' is often used to refer to a combination of technical progress and technical efficiency improvement (e.g., [3]). All of these variables (i.e., revenue, value added, cost, technical progress, and technical efficiency) are of interest to policymakers. However, except in restrictive special cases, they are not measures of productivity. Indeed, increases in some of these variables (e.g., revenue) may

be associated with decreases in productivity. Monitoring productivity change must be preceded by a very clear definition of the term productivity.

6.2 Recommendations

To improve agricultural productivity measurement and analysis in the Asian region, the research team recommends that the APO should do the following:

1. Work with experienced statistical agencies (e.g., the Economic Research Service of the U.S. Department of Agriculture, and the Australian Bureau of Agricultural and Resource Economics and Sciences) to develop a survey questionnaire that can be used to collect farm-level data for purposes of agricultural productivity analysis. First priority should be given to collecting volume (i.e., quantity) data on all variables that are physically involved in the production process (i.e., inputs, outputs, and characteristics of the production environment). Second priority should be given to collecting data on output and input prices or values (prices can be obtained by dividing values by volumes). Third priority should be given to collecting data on technologies (i.e., the techniques that farmers use to transform inputs into outputs), the personal characteristics of farm managers (e.g., age, education, and gender) and any government initiatives that are likely to have influenced the farmers' decision-making (e.g., new regulations governing the use of pesticides).

2. Work with appropriate statistical agencies in APO member countries to conduct a comprehensive farm-level survey in each country on a regular basis (e.g., once every three years). Care should be taken to minimize both non-sampling and sampling errors. Non-sampling errors can be minimized by working with local producer groups; and by using a good questionnaire, well-trained interviewers, and an up-to-date sampling frame. Sampling errors can be reduced by increasing the sample size and by using an appropriate sampling design (e.g., stratified random sampling, and cluster sampling).

3. Use primary and secondary data to measure and analyze measures of partial and total factor productivity at the farm level. The primary aim of the analysis should be to identify (a) the effects of changes in climate, public infrastructure, and other environmental variables on plot- and/or farm-level productivity; (b) the effects of research and development expenditure on the discovery of new commodity- and environment- specific production technologies (e.g., new techniques for producing almonds in a dry temperate climate); (c) the effects of government extension and training programs on the adoption and implementation of new technologies; (d) returns to scale and substitution in agricultural production and input usage (e.g., the increases in productivity associated with substituting capital for labor, or the reduction in profits associated with producing commodities that have a relatively small environmental footprint);and (e) the way that commodity prices and/or government policies may have influenced farmer output and/or input choices (e.g., the way fertilizer subsidies may have led to an increase in fertilizer usage).

REFERENCES

[1] Aigner D., Lovell C., Schmidt P. Formulation and estimation of stochastic frontier production function models. Journal of Econometrics 1977; 6: 21–37.

[2] Coelli T., Rao D. Total factor productivity growth in agriculture: a Malmquist index analysis of 93 countries, 1980–2000. Agricultural Economics 2005; 32(s1): 115–34.

[3] Fa¨re R., Grosskopf S., Norris M., et al. Productivity growth, technical progress, and efficiency change in industrialized countries. The American Economic Review 1994; 84(1): 66–83.

[4] Farrell M. The measurement of productive efficiency. Journal of the Royal Statistical Society, Series A (General) 1957; 120(3): 253–90.

[5] Hadley D., Fleming E., Villano R. Is input mix inefficiency neglected in agriculture? a case study of pig-based farming systems in England and Wales. Journal of Agricultural Economics 2013; 64(2): 505–15.

[6] Holden S., Deininger K., Ghebru H. Impacts of low-cost land certification on investment and productivity. American Journal of Agricultural Economics 2009; 91(2): 359–73.

[7] Kumbhakar S. A farm-level study of labor use and efficiency wages in Indian agriculture. Journal of Econometrics 1996; 72(1–2): 177–95.

[9] Meeusen W., van den Broeck J. Efficiency estimation from Cobb-Douglas production functions with composed error. International Economic Review 1977; 18(2): 435–44.

[10] Mullen J. Productivity growth and the returns from public investment in R&D in Australian broadacre agriculture. The Australian Journal of Agricultural and Resource Economics 2007; 51: 359–84.

[11] O'Donnell C. Nonparametric estimates of the components of productivity and profitability change in U.S. agriculture. American Journal of Agricultural Economics 2012; 94(4): 873–90.

[12] O'Donnell C. Using information about technologies, markets and firm behaviour to decompose a proper productivity index. Journal of Econometrics 2016; 190(2): 328–40.

[13] O'Donnell C. Productivity and Efficiency Analysis: An Economic Approach to Measuring and Explaining Managerial Performance. Springer. Singapore; 2018.

[14] O'Donnell C., Fallah-Fini S., Triantis K. Measuring and analysing productivity change in a metafrontier framework. Journal of Productivity Analysis 2017; 47(2): 117–28.

[15] Wikipedia. https://en.wikipedia.org/wiki/Economy of Taiwan#Agriculture.

LIST OF ACRONYMS

APO	Asian Productivity Organization
CCD	Caves-Christensen-Diewert
CRS	Constant returns to scale
DEA	Data envelopment analysis
DRS	Decreasing returns to scale
EI	Environment index
EKS	Elteto-Koves-Szulc
ETI	Environment and technology index
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GY	Geometric Young
HM	Hicks-Moorsteen
ILO	International Labour Organization
IRS	Increasing returns to scale
ISIC	International Standard Industrial Classification
LP	Linear program
ODF	Output distance function
OETSMEI	Output-oriented environment, technology, and scale and mix efficiency index
OSME	Output-oriented scale and mix efficiency
OSMEI	Output-oriented scale and mix efficiency index
OTE	Output-oriented technical efficiency
OTEI	Output-oriented technical efficiency index
PDR	People's Democratic Republic
PFP	Partial factor productivity
ROC	Republic of China
ROK	Republic of Korea
SFA	Stochastic frontier analysis
SFM	Stochastic frontier model
SNI	Statistical noise index
TFP	Total factor productivity
TI	Technology index
TSME	Technical, scale and mix efficiency
TSMEI	Technical, scale and mix efficiency index
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture

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SUSTAINABLE PRODUCTIVITY

THE NEW FRONTIER FOR PRODUCTIVITY

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Japan

Republic of Korea

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