The UNIDO World Productivity Database: An Overview

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ABSTRACT

This article introduces a new unique database, the World Productivity Database (WPD), which contains information on levels and growth of aggregate total factor productivity (TFP) for up to 112 countries, covering the period 1960 to 2000. At its core are numerous measurement methods, variations in functional forms and specifications — including schooling and health — of the production function, constant and variable returns to scale, as well as measures of technical progress and change in technical efficiency. In addition, five labour and four capital stock measures are used to derive a variety of TFP measures. Another significant feature is TFP forecasts for the period of 2001-2010.

THE PURPOSE OF THIS ARTICLE is to describe a new, unique database—the World Productivity Database (WPD) — which contains information on aggregate productivity performance, level and growth for up to 112 countries from 1960 to 2000. In addition, forecasts of TFP levels and growth are provided from 2001 to 2010. Although the WPD mainly focuses on measures of total factor productivity (TFP), it also includes partial measures, such as labour productivity (output per worker), and basic statistics, such as capital per worker and its change over time.

To a great extent, the work of the United Nations Industrial Development Organization (UNIDO) is concerned with long-term sustainable industrial development and its role in overall economic development. Sustained growth relies on productivity growth. To understand better what policies for industry and productivity growth to recommend to countries at different stages of development, UNIDO launched a project on productivity performance in 15 developing countries. Based on case studies, it examined country-specific conditions regarding productivity measurement and attendant policies along with conventional cross-country analysis.[2] The project revealed that, while many international and national organizations in industrialized countries regularly publish pro-

1 Researcher in the Research and Statistics Branch, United Nations Industrial Development Organization (UNIDO). The author thanks Tim Coelli for his advice on Data Envelopment Analysis (DEA) as well as for his generosity, without which the WPD would not have contained any Long-Memory DEA (LMDEA) results, and Chuck Hulten for excellent discussions and insights on productivity measurement. Important contributors to the database include Margarita Grushanina, Harvir Kalirai and Katarina Zigova. The World Productivity Database website (www.unido.org/data1/wpd/Index.cfm) was constructed and is maintained by Ömer Aksoycan and his contribution is gratefully acknowledged. Comments and suggestions by two anonymous referees and the editor of this journal have improved the article. The author alone assumes responsibility for any errors in the WPD and its documentation. The views expressed herein are those of the author and do not necessarily reflect the views of UNIDO. This paper is based on Isaksson (2007c) posted at http://www.unido.org. Email: a.isaksson@unido.org.

2 The countries covered were Argentina, Brazil, Chile, Mexico, China, India, Indonesia, Republic of Korea, Egypt, Morocco, Kenya, Nigeria, South Africa, Uganda and United Republic of Tanzania. Cross-country analysis of productivity and its determinants used for comparative purposes were produced by Isaksson (2007a and 2007b).

ductivity figures, this is generally not the case in developing countries. Hence, the idea of the WPD was born.[3]

By making internationally comparable productivity data available to policymakers in developing countries, the WPD enables them to track productivity performance and prospects for increased living standards, as well as track their progress relative to others. Moreover, with productivity growth at the heart of industrial and overall economic development, the WPD is also potentially useful to multilateral institutions, such as the World Bank and many United Nations organizations, as well as bilateral aid donors and non-governmental organizations (NGOs).

The WPD also provides data to academe for analysis. In particular, the WPD caters to the many existing preferences and views among researchers regarding productivity measurement. For example, TFP measures are provided based on more than ten different measurement methods, several approaches to measuring capital and labour input, measures of technical change, change in technical efficiency and scale efficiency, and various specifications of the aggregate production function, including those accounting for schooling and health. For the many researchers who link information on productivity to other issues such as poverty reduction, effects of environmental regulation, and wage determination, the WPD can considerably shorten the time needed for data collection and measurement.

Data Sources and Coverage[4]

The principal data source is Penn World Tables (PWT) version 6.1 (Heston, Summers and Aten, 2006), which provide estimates of gross domestic product (GDP) and investment, both expressed in 1996 US dollars at power purchasing parity exchange rates. Labour force data are also provided. Real investment is used to compute capital stock in international prices. The combination of output, investment and labour force data from PWT defines the maximum number of countries and years covered.

Refined labour measures and more intricate specifications require additional data. From the Groningen Growth and Development Centre (GGDC, 2005), the Organisation for Economic Co-operation and Development (OECD, 2004) and the Asian Development Bank (ADB, various issues), data on employment and hours worked have been obtained, while unemployment rates have been collected from the International Labour Organization *Yearbook 2003* (ILO, 2003a), the ILO's Key Indicators of the Labour Market (KILM) (ILO, 2003b) and the ADB (various issues). Barro and Lee (2000) is the source for schooling data, while the health indicators of life expectancy and adult mortality rates come from the World Development Indicators (World Bank, 2005).

In cases where dubious data were encountered, they have been verified against national sources and, occasionally, adjusted. The countries included in the WPD are listed in Appendix Table 1 and are sorted on the basis of stage of development.

Output and Inputs

Output

Output is measured as chain-weighted real GDP in constant 1996 prices adjusted for purchasing power parity. For countries that did not have full coverage of output data — with typically one or a few of the end years missing — the general solution is to use information on the growth of real GDP, as obtained from the World Development Indicators (World Bank, 2005).

3 Although the project has now been completed, UNIDO's work on productivity in developing countries continues.

4 Isaksson (2007c) describes data coverage and adjustments in detail.

When GDP estimates are missing for the middle of the series (for example, Haiti in 1966), they are interpolated by taking the average of two years.

Capital input

Capital is the most difficult production factor to measure, partly because of data requirements but also due to controversies related to the computation of the initial capital stock and depreciation rates.[5] For that reason, the WPD includes TFP estimates based on four definitions of the capital stock. These differ in how the initial capital stock is computed, the rate at which capital is assumed to depreciate,[6] whether that rate is constant or varies over time, and whether the lifetime and attendant efficiency of an asset is explicitly accounted for.[7]

The perpetual inventory method provides a standard way of formulating how capital evolves. In this computation, the rate of depreciation and initial capital stock are unknowns and have to be estimated or assumed. Since the appropriate values of these two unknowns can be debated, the WPD offers capital measures based on alternative estimates or assumptions, leading to three different measures of the capital stocks called K06, K13 and Ks. Common to all three is that capital is assumed to depreciate at a constant rate over time.

For two of these, K06 and K13, it is assumed that ten years of investment serve as an adequate proxy for initial capital stock. For example, for investment data starting in 1950, investments from 1950 to 1959 are used to construct initial capital stock for 1960.

These two capital stock estimates only differ in terms of their assumed depreciation rates, which are 6 and 13.3 per cent, respectively (hence, K06 and K13). The latter measure is based on Leamer (1988) and assumes an unusually rapid depreciation rate, implying an emphasis on relatively recent investments and less impact of initial capital. It implicitly assumes an asset lifetime of 15 years. By contrast, K06 places relatively less emphasis on recent investments, with the effect of the initial year capital stock lingering longer.[8] The implied lifetime for K06 goes beyond the end of the sample period.

Another common way of computing the initial capital stock is to assume that the country is at its steady state capital-output ratio, leading to what is termed steady-state capital stock (Ks). The major advantage of this capital stock measure compared to K06 and K13 is that ten years of data are not lost in the calculation of the initial capital stock.

The steady state capital-output ratio requires estimates of steady state values of the investment rate, rate of GDP growth, and depreciation rate. The depreciation rate is set at 6 per cent. Following Easterly and Levine (2002), the GDP growth rate is a weighted average of all countries' average growth rate and world growth rate of GDP for the first ten years (1960-1969). The weights are set to 0.75 and 0.25 for the world and country growth rates, respectively, leading to country-specific estimates of the steady state

5 The flow of capital services is the preferred measure of capital input. As this measure cannot be easily obtained for many of the countries in the WPD sample, the convention that capital services are proportional to the stock of capital is assumed.

6 Depreciation should be understood in terms of the decay of productive capacity of a fixed asset and not as a reduction in the value of the asset. The former refers to the production process, while the latter is a wealth accounting concept.

7 The effect of different ways of calculating capital is most apparent when comparing TFP levels. For comparisons of TFP growth the effect is much less discernible.

8 Specific countries can have different depreciation rates due to different compositions of capital. For example, developed countries tend to have a larger share of IT-related assets, which have relatively high depreciation rates, while capital stocks in developing countries contain a relatively large share of buildings and machines, which have a slower rate of depreciation

growth rate. The average investment rate for the first ten years serves as a proxy for the steady state investment rate. Finally, the initial capital stock is computed as the initial year GDP (i.e. the 1960 value) multiplied by the steady state capital-output ratio.

A different way of measuring capital — the physical efficiency method (Keff) — is to assume a time-varying depreciation rate. This method starts from the notion that an asset's productive efficiency declines with age. The age-efficiency function is assumed to be hyperbolic in shape, which means that, at year one, the efficiency of the asset is 100 per cent and, as the asset ages, its efficiency declines at an increasing rate. After some time, the asset's lifetime is considered over or, at least, the asset's efficiency is so low that the asset is scrapped. Using this age-efficiency function, efficiency coefficients are derived and used to adjust the investment series, which leads to investment data expressed in standardized efficiency units. The perpetual inventory method is then applied to this new investment series to obtain a capital stock series (Keff).

According to Crego *et al*. (1998), when the different capital assets — which have different lifetimes — are translated into aggregate investment, the aggregate service life turns out to be 20 years.[9] The WPD adopts 20 years of service life for each year's aggregate investment. As a consequence, it also uses 20 years for the calculation of the initial capital stock for this particular capital stock. The implication is that the capital stock and TFP series based on this method only begin in 1969, compared to the standard of 1960 used elsewhere in the WPD.

Labour input[10]

The WPD offers productivity estimates based on five labour input measures: labour force, employment, derived employment, hours worked based on employment and hours worked based on derived employment. It is standard in the cross-country empirical literature to use the labour force as a proxy measure of labour input. The advantage of this labour measure is its superior availability and, possibly, quality compared to alternative labour measures. The main disadvantage is that it leads to underestimation of measured productivity levels because not everyone in the labour force is actually working (either due to unemployment or underutilization), thus overestimating labour input. The effect on productivity growth is uncertain, since labour force growth could be smaller or larger than that of other measures of labour such as employment or hours worked.

In several cases, periods of unusually rapid labour force growth were observed, possibly due to changing measurement methods or population coverage. In Argentina, for example, the average annual labour force growth rate over the sample period is 1 per cent. In 1991, it suddenly jumped to 5 per cent, a rate that lasted until 1995. Thereafter, it returned to 1 per cent. The fluctuation may reflect an administrative change in coverage, such as the inclusion of rural areas or women, which may have been previously excluded. Large increases in the growth rate of the labour force are considered unrealistic and are, therefore, smoothed out. While these adjustments do not affect TFP growth, they have implications for the TFP level. Continuing with this example, because pre-1996 labour force levels are adjusted upwards in Argentina, TFP levels are correspondingly adjusted downward.

There are two kinds of labour utilization rates for which labour force should be adjusted: variations in the number of workers employed and in the average number of hours worked by these

9 In this case, the so-called decay, or curvature, parameter is 0.70.

10 Here, labour is understood as raw or unadjusted labour. This distinguishes it from cases when adjustments are made for its quality (see the discussions on schooling and health).

workers. Employment is obtained either as a direct measure or is derived by applying unemployment rates to labour force data (derived employment). There are two reasons for using two measures of employment. First, employment figures derived from unemployment rates differ from "measured" employment. Second, compared with direct employment measures, the country coverage for derived employment differs because countries that have information on unemployment may not have data on employment, and vice versa.[11] As can be expected, employment data are more difficult to obtain than are labour force data. Consequently, the country coverage is reduced by 50 per cent compared to that for labour force. In cases where unemployment series are shorter than the employment series described above, the unemployment series are extrapolated based on growth of derived unemployment resulting from subtracting employment from labour force.

Hours worked are computed based on employment and derived employment. In addition to correcting labour input for variations in the number employed, hours worked also adjust labour for the intensity with which employees work (for example, part-time and overtime). Intensity, here, refers to the number of total hours worked per worker, rather than the level of effort within a specific number of hours. Hour worked thus account for two adjustment mechanisms available to employers in case of shifts in demand: changing the number of workers or changing the number of hours worked by each worker. Again, the number of countries reporting hours worked for a sufficient time period is relatively smaller, with coverage largely confined to OECD countries.

Schooling and Health

In addition to the primary inputs used in production functions, the WPD includes schooling as one of two additional secondary inputs. Schooling is measured using educational attainments levels for the population 15 years and older, as obtained from Barro and Lee (2000). Economists differ in how they include schooling in the production function. The WPD offers two approaches: as a separate regressor or as an increase to labour input (Hall and Jones, 1999). In the latter case, it is assumed that returns to schooling differ according to the stage of development, such that, in less advanced countries, returns to education are higher.

Another characteristic of labour quality is health, which is only included together with schooling. Following the work of Weil (2001), it is hypothesized that differing levels of nutrition and health have a significant impact on the capacity to work across countries. The WPD employs two measures of health, both from the World Development Indicators (World Bank, 2005). Life expectancy is used when health enters the production function as a separate input, because it has very good country coverage. However, adult mortality rate (AMR) — the fraction of current 15 year-olds expected to die before the age of 60 — is the preferred measure when labour is adjusted for health (Weil, 2001). In any case, the correlation between life expectancy and AMR is very high.

Mankiw, Romer and Weil (1992) estimate the output elasticity to human capital, as measured by schooling, to be one-third. This value becomes useful when attempting to account for health in growth accounting calculations for which, otherwise, no obvious income share is available. In the WPD, an income share of a third is assumed for the composite of schooling and health.[12] The, admittedly, ad hoc solution used in the WPD to make health operational in growth accounting — while maintaining that it can only enter the production function with

11 This concerns Costa Rica, Ghana, Kenya and Malawi.

12 The income share of raw labour is reduced by the same amount.

schooling — is, first, to estimate statistically a relationship (non-linear, as it turns out) between schooling and health and, then, use it as a broad measure of human capital.[13] The reason for undertaking this operation is that schooling, in terms of scale, is only 10 per cent of life expectancy in terms of years in our sample. For example, if life expectancy in a country is 70 years, the years of schooling turn out to be approximately seven on average. To add simply schooling and health would not do justice to schooling, since variation in the composite would almost entirely be due to variations in health.

Measuring Total Factor Productivity

TFP levels

TFP measurement at the total economy level — implicitly or explicitly — starts from the notion of an aggregate production function. Such an assumption is almost unavoidable when measuring TFP.[14] However, it is only a parable, since it is unlikely that the true shape and properties of such a function can be accurately established. Yet, it is justified as a means to organize data in a way that makes economic sense, as well as a framework for interpreting empirical results. The WPD, therefore, makes use of the notion of the aggregate production function.

For TFP level measurement, a standard constant returns to scale Cobb-Douglas production function with Hick-neutral technical change is assumed, and then computed relative to the TFP level of the United States. The respective weights of capital and labour are the capital's and labour's income shares in output, which, when perfect competition in factor markets prevails, equal the respective marginal products. Table 1 shows the top and bottom ten countries in terms of TFP levels.

This way of ranking countries by relative TFP levels is only possible because income shares are assumed to be country- and time-invariant. If income shares vary across countries or over time, TFP ranking should be based on the formula provided by Caves, Christensen and Diewert (1982).

In the literature, income shares are often assumed to approximate, respectively, one-third and two-thirds. This practice is adopted here because the true income shares for most of the countries in the WPD are unknown. Table 2 shows how sensitive productivity measurement is to the choice of income shares. In the table, 'conventional' refers to the one-third/two-thirds rule, 'United Nations' to calculations based on United Nations National Accounts data, while 'Rodriguez-Ortega' is a third source of income shares.[15]

As the concept of TFP is not universally accepted, the WPD also offers simple output per worker, relative to the United States, and capital per worker measures. Although they serve as reasonable starting points for productivity analysis, they should not be seen as equivalent alternatives to TFP.

TFP growth

The many measurement methods for TFP growth included in the WPD are, generally, variants of each other. In attempting to measure TFP growth, they relax restrictions or estimate what another method might simply assume.

The first choice is *how* the user wishes to measure TFP growth. In other words, a measurement method needs to be selected. In principle,

13 Hence, a broader concept of human capital than that often found in the literature is applied here. The definition of human capital is generally reduced to education. The user should be aware of the slightly different view applied in the WPD.

14 Isaksson (2009) provides a survey of methods for measuring TFP.

15 For a more thorough discussion on income shares, see Hulten and Isaksson (2007), who explore the implications of this not-so-innocuous assumption and discuss different possibilities as to how more accurate income shares can be acquired.

Table 1
TFP Levels, Relative to the United States, 2000

Ranking	Country	Level (United States = 100)
1	Luxembourg	139
2	Ireland	112
3	United States	100
4	Belgium	86
5	Hong Kong, SAR of China	83
6	Netherlands	83
7	Italy	83
8	Canada	83
9	Taiwan, Province of China	83
10	Australia	82
103	Togo	13
104	Chad	12
105	Burkina Faso	12
106	Malawi	12
107	Zambia	11
108	Nigeria	9
109	Burundi	8
110	Guinea-Bissau	8
111	United Republic of Tanzania	6
112	Congo, Democratic Republic of the	3

Note: Functional form is Cobb-Douglas, while inputs are labour force and capital stock (K06).
Source: Isaksson (2007a).

Table 2
Income Shares and Sources of Growth Analysis, 1970-2000
(average annual growth rate, %)

		Conventional		United Nations		Rodriguez-Ortega	
Meta Country	**Y/L**	**K/L**	**TFP**	**K/L**	**TFP**	**K/L**	**TFP**
Low Income	0.17	0.25	-0.07	0.52	-0.35	0.38	-0.20
Lower-Mid Income	1.01	0.61	0.40	1.17	-0.16	0.79	0.22
Upper-Mid Income	0.99	0.59	0.40	1.05	-0.06	0.68	0.31
New Tigers	3.79	1.70	2.09	3.53	0.26	2.49	1.31
Old Tigers	4.89	2.37	2.52	3.92	0.97	2.67	2.23
High Income	1.95	1.00	0.95	1.36	0.58	1.00	0.95

Note: Y/L = Output per Worker, K/L = Capital per Worker and TFP = Total Factor Productivity. Meta Country = groups of countries belonging to a certain income bracket. Old Tigers refer to the first-generation Asian fast-growers, while New Tigers consists of second-generation Asian fast-growers.
Source: Hulten and Isaksson, 2007.

the different measurement methods can be divided into three main groups: growth accounting, regression analysis, and frontier analysis. Within these groups there are several methods from which to select.

If a parametric measurement method (i.e. one based on regression analysis) is selected, two functional forms are available, namely Cobb-Douglas and Translog, where the former is a restricted version of the latter.[16] Within para-

16 Statistical tests undertaken invariably show a preference for the Translog functional form. However, because there are many observations, statistical tests may have a tendency to over-reject the null hypothesis of Cobb-Douglas.

metric measurement methods, TFP growth can be measured based on production functions with and without time trend (or time dummy variables).[17] The main reason for offering this option is that some users might be particularly interested in isolating technical change from overall TFP growth.

For all methods but growth accounting, TFP growth estimates are available based on both constant (restricted) and variable (unrestricted) returns to scale, the default assumption being that of constant returns to scale. However, the user may have good reason to believe in non-constant returns to scale.[18] Under variable returns to scale, TFP growth is calculated as the residual plus the scale effect. However, one can also see this as a distinction between scale effects and technology. Since the scale component is provided, the user can subtract it from TFP growth.

The default production function specification contains one output and two inputs, capital and labour. As alluded to above, however, the WPD allows for the inclusion of schooling and health, in addition to capital and labour. It also allows the user to compare the impact on TFP of how capital and labour are measured.

Growth accounting

Four growth accounting measurement methods are available:

- Growth Accounting with Hicks-Neutral Technical Change;
- Growth Accounting with Harrod-Neutral Technical Change;
- Dynamic Growth Accounting with Hicks-Neutral Technical Change; and
- Dynamic Growth Accounting with Harrod-Neutral Technical Change

In all cases, income shares are the conventional 2/3 and 1/3 for labour and capital input, respectively, irrespective of country and time period. As is customary, TFP growth is calculated as the residual, in other words, as the difference between output and weighted input growth. The four growth accounting methods differ in their assumptions regarding the type of technical change and whether endogeneity of capital accumulation with respect to TFP growth is taken into consideration. Although it is, in principle, possible to include a term to represent increasing returns to scale, this is seldom done in growth accounting.[19] In the WPD, only growth accounting under the assumption of constant returns to scale is provided.

The standard Hicksian growth accounting approach allows for a proportional shift of the production function, with TFP growth occurring along a constant capital-labour ratio. Output growth is decomposed into growth of the capital-labour ratio and TFP growth. This standard approach can be extended to allow for labour-augmenting, or labour-saving, technical change, implying a disproportionate shift of the production function. In this case, technical change is said to be Harrod-neutral, with the production function shifting along a constant capital-output ratio, instead of a constant capital-labour ratio. This means that output growth is decomposed into TFP growth and change in the capital-output ratio.

Another issue with growth accounting is that it neglects induced capital accumulation due to TFP growth. In other words, there may be

17 The advantage of using time dummy variables is that technical change can be allowed to evolve over time, whereas, when using a time trend only, the annual average technical change over the entire period is obtained. However, both ways of estimating technical change are period-average when estimated across countries. This was relaxed in the case of random-effects stochastic frontier estimation, where country- and year-specific technical change were obtained by including interaction terms between country and time dummy variables.

18 Statistical tests carried out tend to favour non-constant returns to scale.

19 See, for example, Hall (1988) for a case where this is done.

important dynamic effects for which to account. Failing to do so could lead to understatement (overstatement) of the role of TFP growth (capital accumulation). Hulten (1979) has explored this matter and developed a method that accounts for such effects, in the WPD called dynamic growth accounting. The method derives a dynamic residual, which is a weighted sum of the standard growth accounting residual over a period of T consecutive years and an expansion of the intertemporal production possibilities frontier. TFP growth measured this way can be expressed in terms of both Hick and Harrod-neutral technical change. To underscore the difference between standard and dynamic growth accounting, the standard residual is understood as the average rate at which the production function shifts, while the dynamic residual measures the importance of TFP change for output growth.

Regression analysis

Actual income shares may in reality differ from the aforementioned standard assumption. Regression analysis offers a partial resolution as it allows the estimation of income shares based on the country's stage of development. In addition, the assumption of constant returns to scale can be relaxed. On the negative side, parametric estimation introduces thorny issues such as the choice of functional form and uncertainties about statistical properties.

Regression analysis broadly includes:

- Pooled regression analysis
- Fixed-effects regression analysis

where the regression's residual represents the measure of TFP growth.

In pooled regression analysis, cross-sectional heterogeneity is omitted, which means that the estimated parameter may be biased, with TFP growth, likewise, biased. The WPD, therefore, also supplies TFP growth measures based on the fixed-effects estimator. Panel-data fixed-effects estimators allow the analyst to account directly for country-specific effects, while maintaining the statistical advantages of a large sample. Country-specific effects imply that each country has its own intercept, but assumes that the slope parameters are the same for all countries.

There are two ways to account for country-specific effects. One is to include country dummy variables, while the other is to transform the data (so-called 'within transformation'). Although the former reduces the statistical advantage of having a large sample and, thus, may produce larger standard errors, thanks to the large dataset it is the solution chosen. The main reason for choosing country dummies is that they can be used to obtain country-specific technical change by way of interaction terms between such dummies and a trend variable.

Although income shares are estimated, only one value for the entire sample can be obtained in this manner. Ideally, income shares should be country-specific. While this has not yet been accomplished — individual country regressions produced results with little confidence — steps have been taken to let those shares vary, according to the development stage of the country and its geographical location.

To this end, TFP growth has been computed based on the residual obtained from pooled and fixed-effects estimations on industrialized, developing and least developed countries, on the one hand, and industrialized,[20] Latin America, Asia and the Pacific, North Africa and Middle East and sub-Saharan Africa, on the other. For example, income shares in OECD countries are likely to differ from those in least developed countries, with return to capital being higher in relatively poor countries. While the geographic distinction is possible for all measures of the capital stock, among the labour measures the country coverage is sufficient only in the case of

20 It did not seem plausible to group, for example, Australia with Fiji and Bangladesh.

the labour force. For other labour measures, the samples are too small to obtain reasonable estimation results. In the case of the development stage distinction, TFP growth based on employment and derived employment is possible for industrialized countries and developing countries. Few least developed countries have employment or unemployment data.

Frontier analysis

So far, it has been assumed that countries are technically efficient and that TFP growth primarily is driven by technical change. Perhaps, a more realistic picture is that of allowing for technical inefficiency, defined as falling short of best practice. This benchmark of best practice can be seen as a technology frontier, and even as a world technology frontier if all industrialized countries are part of the sample. Both parametric and non-parametric methods can be used to estimate the technology frontier and the distance to it. As in the case of regression analysis, frontier methods estimate, rather than assume, the income shares.

Frontier analysis does not directly deliver measures of TFP growth but primarily exists to measure technical efficiency. However, with panel data, frontier analysis produces the necessary components for computing TFP growth. Under constant returns to scale, change in technical efficiency and technical change can be derived and combined into an index that measures TFP growth. The Malmquist TFP index (Malmquist, 1953) is such an index and is used in the WPD. Under variable returns to scale, change in technical efficiency can be further decomposed into change in scale efficiency and change in pure technical efficiency.

Popular methods for frontier analysis include both parametric and non-parametric tools. On the parametric side, the WPD offers the random-effects Stochastic Frontier Analysis (SFA) estimator due to Battese and Coelli (1992), while in the case of non-parametric estimation Data Envelopment Analysis (DEA) and Long-Memory DEA (LMDEA) estimators are provided (Forstner and Isaksson, 2002).[21] The difference between DEA and LMDEA is that the latter is constrained not to accept technical regress.[22] All other methods previously discussed allow for technical regress.

Although it is useful to be able to account for technical inefficiency, frontier analysis has its own problems. In the case of SFA, previous issues discussed under regression analysis apply. In addition, distributional assumptions of the error term are crucial, as they can have profound effects on the outcome. Non-parametric methods are free of these problems, but, because they are deterministic in nature, they are sensitive to outliers and measurement problems of output and inputs. Because SFA is stochastic, it does not share these problems. Coupled with the fact that standard errors can be obtained and hypotheses tested, these are SFA's main advantages over non-parametric frontiers. The advantage of DEA and LMDEA is that no distributional assumptions or functional form have to be assumed regarding the "production function". Generally, compared to other parametric methods, they are very flexible.

Forecasting TFP

The WPD has endeavoured to tackle the complicated challenge of forecasting TFP levels and growth. Such forecasting can be approached in two broad ways. Either the individual compo-

21 DEA and LMDEA present TFP growth in index form, which means that a score of 1.00 implies no TFP growth, 1.01 a one per cent TFP growth and 0.99 a negative growth of one per cent. To convert these into percentage form, subtract 1 and multiply by 100, e.g., (1.01-1)*100.

22 The first to question technical regress in a DEA framework were Tulkens and Vanden Eeckaut (1995). Other empirical applications using macro data include Timmer and Los (2005).

nents of TFP — outputs and inputs — are forecast separately and TFP is calculated based on those, or forecasts are derived directly from the TFP series. As it is simpler to forecast one series than three or more — for example, output, capital and labour — WPD forecasts are based directly on TFP growth series.

The WPD offers ten-year forecasts (2001-2010) for TFP growth based on: the capital input variable K06; the labour input variable based on the labour force; LMDEA; and constant returns to scale. Forecasts are available for the following specifications: labour and capital; labour, capital and schooling; labour, capital, schooling and health; capital and labour adjusted for schooling; and capital and labour adjusted for schooling and health. These forecasts are, in turn, extended to measures of TFP growth based on the other capital stock measures (Keff, K13 and Ks). Forecasts of TFP growth are, then, used to forecast TFP levels, based on labour force and the four capital stocks. For a technical description of how the forecasts were carried out, see Isaksson (2007c).

Next Steps

Several extensions to the WPD are planned. First, to date, only productivity measures at the aggregate economy level have been calculated. The next step is to estimate manufacturing TFP for a large number of countries. Thus far, a database for aggregate manufacturing TFP has been estimated and will shortly be uploaded to the WPD website for general access. Once that has been accomplished, estimation of TFP at sub-sectoral manufacturing levels, e.g. food, textile and electronics, will be undertaken.

Second, to date, only countries with data spanning long time periods have been included . In addition, the most recent version of PWT includes more countries than version 6.1. The plan is to include those additional countries, as well as countries for which data are limited over time. The next version of the WPD will, thus, feature, for example, Germany and all of Eastern Europe, as well as other transition economies.

Third, whereas land as an input has become relatively unimportant for most industrialized countries — with agriculture no longer a major contributing sector to aggregate GDP — the contrary holds true for many developing countries. Because many countries in the sample are developing countries, the next version of the WPD will expand specifications to include land.

Fourth, in the current version, labour input has been adjusted for two quality measures, schooling and health. For a subset of countries, it has also been corrected for utilization, in terms of both unemployment and hours worked. However, no such correction has been made to capital. Ideally, in the future, the WPD will account for changes in capital utilization.

Fifth, in addition to the Cobb-Douglas and Translog functional forms, the CES function is popular and will be added to the database. With respect to estimators, the plan is to make use of dynamic panel methods in order to improve the statistical properties of WPD estimations.

Sixth, only one SFA version is currently provided. The aim is to implement more alternatives in the next version of the WPD.

Finally, the issue of country- and time-specific income shares will be addressed by applying income shares supplied by Rodriguez and Ortega (2006) and the United Nations National Accounts Database, in addition to the conventional one-third/two-thirds assumption. Table 2 already gave a first hint of what such an application will bring.

The next version of the WPD will contain TFP measures to at least 2006, with forecasts to at least 2015. These updates are planned for the summer of 2009. The WPD data are a public good. As such they can be freely downloaded from www.unido.org.

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Appendix Table 1
List of Countries by Country Group

Industrialized (24 countries)	Developing (45 countries)	Least Developed (43 countries)
Australia	Algeria	Angola
Austria	Argentina	Bangladesh
Belgium	Barbados	Benin
Canada	Botswana	Bolivia
Cyprus	Brazil	Burkina Faso
Denmark	Cape Verde	Burundi
Finland	Chile	Cameroon
France	China	Central African Republic
Greece	Colombia	Chad
Iceland	Costa Rica	Comoros
Ireland	Dominican Republic	Congo
Israel	Ecuador	Cote d'Ivoire
Italy	Egypt	DR Congo
Japan	El Salvador	Ethiopia
Luxembourg	Equatorial Guinea	Fiji
Netherlands	Gabon	Gambia
New Zealand	Guatemala	Ghana
Norway	Honduras	Guinea
Portugal	Hong Kong, SAR of China	Guinea-Bissau
Spain	India	Guyana
Sweden	Indonesia	Haiti
Switzerland	Iran	Kenya
United Kingdom	Jamaica	Lesotho
United States	Jordan	Madagascar
	Korea, Republic of	Malawi
	Malaysia	Mali
	Mauritius	Mauritania
	Mexico	Mozambique
	Morocco	Nepal
	Namibia	Nicaragua
	Nigeria	Niger
	Pakistan	Papua New Guinea
	Panama	Peru
	Paraguay	Rwanda
	Philippines	Senegal
	Singapore	Seychelles
	South Africa	Sierra Leone
	Syria	Sri Lanka
	Taiwan, Province of China	Tanzania, United Republic of
	Thailand	Togo
	Trinidad and Tobago	Uganda
	Tunisia	Zambia
	Turkey	Zimbabwe
	Uruguay	
	Venezuela	