

MEASURING PRODUCTIVITY

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Abstract:

Productivity may be a growth enhancement in the micro level and macro level. Disputable is how to measure productivity in the sense of variables used as proxies and the methodology used for estimation. In this paper we review methodologies used in productivity measurement. In our research we classify studies that measure productivity in: index number studies (Malmquist index and Törnqvist index), production function studies, distance function studies and DEA analysis. We conclude that the definition of variables used in the model and the estimation methodology are crucial for the results we will obtain. Also we suggest that micro-panel dataset may be helpful in solving estimation and comparison models in productivity studies.

Keywords: Productivity, index numbers, production function

Introduction:

The stakeholders in the productivity and profitability of the firm are employees, owners and the government. In theory it is sad that SME may be an engine for development. Therefore our interest is to identify measurement methodology that may be applied in measuring productivity. There are various studies that empirically test productivity. What they try to answer is what determines productivity. But still we do not have a general outcome or a framework what may lead to productivity which makes this an ongoing area of interest. We may often read that there is development, efficiency and improvement in the working of companies but what we want to research is what benefited to this improvement. Why companies in some countries show better performance than in others? Why companies in the same industry differ in productivity? Trying to answer these questions we want to determine what may affect firms' performance. We want to research what may be the sources of

diversity among firms with reference that productivity and efficiency of using their inputs leads to this diversity in the performance of the companies. Profitability or firm growth dispersion is present between firms within an industry and between industries. Why some companies grow? Why some are efficient? Why some are in the market for a long time and expand while others vanish? What makes firms differ? Is there a model they should follow?

The literature on productivity is diverse and looking at different aspects of productivity. Productivity may be discussed in the production functions using inputs such as labour and capital. An alternative way of studying productivity is looking at the cost function—the minimum cost to produce. And there is duality between approaches.

What we tempt to answer is how to define productivity, how it can be measured and how can it be practiced. Looking at the literature review we find that most of definitions of productivity use input and output or simply define productivity as a measure of translating inputs to output. This leads to another question how can we define inputs and outputs and are they always measurable? “Translating” inputs in outputs is a process so we may not get straightforward answers. Productivity is not a matter of only developing countries is a matter of any state of development.

In the process of productive translating of inputs in outputs we may be interested in technology that the company uses, the demand and the elasticity of the demand for the goods produced, the skills of the labor input and their respective learning curve. In the firm level being productive may be understood as incentivizing employees to work efficiently while in the macro level studies on productivity we may be interested in GDP and employment. While firms increase productivity there are three scenario possibilities:

- Increasing technological unemployment because of investment in technology
- Increasing the employment because of more qualitative and more costly products
- Ensure stability of employment by reacting with proportional changes

This suggest us that just being productive itself does not mean that we will be able to have straightforward benefits so any institutional change should be looked with caution. The importance of research on productivity is outlined in Mawson et al (2003) and the review of literature on productivity studies can be found on: Barteslamn and Doms (2000); Mawson et al (2003).

While defining productivity as a ratio of output and inputs sounds simple the measurement is complex. This paper is focused on definition matters respectively on measurement problems (in section 1.1) and follow up with specific methodologies used in

productivity studies such as: index number studies in 1.2; production function studies in 1.3; distance function in 1.4; DEA analysis in 1.5. We finalize the paper (section 1.6) with conclusions and some remarks for future research.

1.1 The problem of defining variables

Sink and Smith (p. 136) use the following definition “Productivity is the relationship between what comes out of the organizational system and what is consumed to create those outputs”, while “profitability measures the relationship between revenues and costs” (p.137).

Oyeranti (2000) note that misconception about productivity are made:

- when productivity is related only to labor productivity
- Productivity is not same with increase in performance.
- Cutting cost does not mean increasing productivity.

Accordingly productivity simultaneously considers effectiveness and efficiency. There is a large “menu” of alternatives in the research of productivity but this has the problem of choosing which choice is most appropriate since they provide different measures.

The micro longitudinal data have helped to improve empirical problems. Barteslamn and Doms (2000) discuss the aggregation problem for input and input in longitudinal data and simple measures cannot be used. The data on output use deflators which when do not capture quality may result in downward bias for productivity. Researches use as measure of output: physical output or gross production. Vector of outputs and inputs may be used to measure TFP. Estimation of a cost function and factor demand is another method of computing productivity index. They review Olley and Pakes (1996) method : “ by inverting the investment function, one can estimate the unobserved productivity component semi-parametrically as a function of investment” (p.10). They mention problems of no ideal dataset, problems of measuring inputs and outputs and the quality of data obtained is unknown. In their literature review they note some stylized facts on productivity:

1. There is heterogeneity between firms and establishments in productivity. Measuring the degree of dispersion in productivity: how much reflects differences among firms and how much is measurement error
2. Theoretical models and assumptions underlying them vary
3. changes in distribution over time have been estimated using parametric and nonparametric methods
4. the variance of productivity increases once they allow entry and exit
5. whether productivity moves procyclically with output

Authors and researchers address productivity in micro and macro aspect. Mainly they use a production function which combines inputs such as labor and capital in producing outputs. Most of macroeconomic studies finish noting the limitations on macroeconomic studies and suggesting micro studies to capture the channels to which business climate enhances growth (Durlauf et al. 2008; Straub (2008); Pande and Udry (2005).

There are different measures of productivity but we should be careful when choosing the measure according to the question we are interested in to answer. Another measurement issue that needs to be clarified is whether we are using level productivity or growth of productivity. If we are measuring growth accounting we are decomposing the growth of output in its potential components. Going back again at the productivity definition we know that the first thing for measurement issue is how to measure output and input. The problem that may arise with output is when output is not homogenous and this brings the question of how to aggregate the data. Regarded to input most commonly inputs used are labor and capital, the latter may be more problematic to measure. Even after we solve all these issues still remains the problem of choosing the econometric method for modeling and estimating an issue which is not the focus of this part.

“ Broadly, productivity measures can be classified as single factor productivity measures (relating a measure of output to a single measure of input) or multi-factor productivity measures (relating a measure of output to a bundle of inputs)” Schreyer 2001, OECD (p.38.).

Nordhaus (2000) provide data for measuring productivity using the income side instead of using output side. They introduce the well measured output instead of GDP. Comparing the BEA-output side and BLS- income side they both show increase in labor productivity.

Chambers (1998) review mathematically input, output indicators. His indicators are translation invariant and not homogenous of degree zero as Malmquist indexes. On the other hand Dethier et al (2008) propose a mathematical model for estimating TFP which results in line with Schumpeterian view on productivity dispersion. Crespi et al (2006) add that output data are important for productivity data but the problem is their adjustment.

Bernard and Jones (1996) measure labor productivity¹ and total factor productivity and suggest that less productive countries catch up more productive countries respectively countries in the 70s and 80s converge.

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Diewert (2008) revise measurement problems. In the input output model they note that we need information on the outputs produced, but revenues should not include any commodity taxes imposed on the industry whereas input costs should include taxes imposed. Reasoning is since tax on revenues is not received from the firm as well taxes on inputs are paid by companies. They note that this system misses information on contracted labor and rented capital. They also note the problem of labor inputs since hours worked differ, also workers skills differ therefore using the number of employees it's not accurate. They claim that there are difficulties in measuring productivity.

Steindel and Stiroh (2001) review measures of labor productivity and total factor productivity or the overall efficiency of transforming inputs in outputs. They draw the difference between two concepts of output: value added (Gros- inputs (sales and input should be deflated by price index) and gross output (Total value of sales; productivity measured as sales per worker). Traditional source of productivity analysis is a production function that relates labor productivity to capital, labor quality and total factor productivity.

We have seen the diversity in measurement and still we are questioning the causes for heterogeneity of the firms. What are the impediments and what sources are opportunities for firms? Maybe the answer will depend of the measures we are using and the measurement methodology we are using. In the following section we will look at different methodologies.

1.2 Index numbers

Diewert (1995) note that the competing approaches to index number are the test approach and the economic approach. They show mathematically whether Selvanathan and Prasada Rao new stochastic approach yield estimator of variance of Paasche and Laspeyeres

¹ Output per worker measure

index. Thus this would tell us how precise these indexes are. He criticize the test and economic approach and concludes that they “ give a false sense of precision” (p. 29).

Balk (2008) conclude that Fisher index though is ideal is not perfect and is inconsistent in aggregation. “ The Fisher quantity index is an average of a Laspeyres index, which values the quantity change for the i th item at p_{i0} , and a Paasche index, which values its quantity change at price p_{i1} ” (Marshall B. Reinsdorf, W. Erwin Diewert & Christian Ehemann, 2000; p.4).

The theoretical grounds of the Malmquist index originate from 1953 from Sten Malmquist who introduced this productivity index after whom is also named. The Malmquist index is often referred as productivity index has to do with the production function or a function of maximum possible production using inputs (labour and capital). The Malmquist index was introduced by Caves et al. (1982). They assume that each firm operates in the production function. They want to introduce a productivity index that will allow us to compare two different firms either operating at the same year or in different time periods.

Fare et al (1994) applied the theory of Malmquist index and they decomposed it in efficiency change and technological change. The Malmquist index assumes constants returns to scale. Grosskopf (2002) proposes that decomposition of Malmquist index depends on the question we are asking.

Camanho and Dyson (2006) compare branches of Portuguese banks using the Malmquist index while Dong-hyun Oh (2010) note that Malmquist-Luenberger is used for measuring evaluation environment sensitive productivity growth at micro and macro level and propose another index called global Malmquist-Luenberger index for measuring productivity in 26 OECD countries for the time period 1990-2003.

The Törnqvist index is used for calculating multifactor productivity and it is measured as the geometric mean of growth of rates of inputs used. When calculating the Törnqvist index the assumptions are that the firm operates under constant returns to scale and the input factor are paid their marginal product. The geometric mean of Laspeyres and Pasches index is Fischer index.

“The Törnqvist index is a kind of geometric mean (or “log change”) index”(Marshall B. Reinsdorf, W. Erwin Diewert & Christian Ehemann, 2000; p.7). Resendorf et al (2002) provide formulas for decomposition of the contribution of individual changes to the Fischer index and Törnqvist index.

1.3 Production function

Solow (1957) represents the production function: the output as a function of labor and capital inputs and time that allows technical change. He aggregates all the changes in the production function in the notion technical change. He assumes that inputs are rewarded the marginal products. As a measure of output he uses GNP. He uses Glodsmith calculation of capital but notes that the measurement of capital is arguable since what matters in the production function is the capital in use not the capital in place. Their result show that there is increase in GNP and only 1/7 part is attributable to increased capital intensity while the other part to technical efficiency. He refers to the major part of increased GNP as a result of increased productivity. He assumes a linear production function and constant returns to scale. They try to fit their data and find that the Cobb-Douglas and semi logarithmic form are a bit better than others. He segregates the shifts in the production function and movements along the production function. On his data on American economy he concludes that technical change was neutral on average, there was an upward shift in the production function and the increase was attributable to technical change (87.5%) and increase in capital input (12.5%).

Fernandes (2008) use a sample of 575 firms in Bangladesh. They estimate a Cobb Douglass production function using OLS which may result with simultaneity bias. They measure output as ration of nominal sales or material costs and corresponding firm specific deflators, capital stock is calculated using the perpetual inventory method formula, labor is measured by the number of workers while workforce human capital by share of skilled workers.

Grimes et al (2011) in their literature review note that previous research does not treat micro data and looking at internet connection as a boast for productivity. They are testing whether firms with faster internet connection are more productive relative to firms with slower internet connection. They use a production function and their dependent variable is (log of) firm i's labor productivity relative to the industry average. Die'go Legros and Fabrice Galia (2011) acknowledge that many studies use R&D expenditure as a proxy for knowledge mainly in Cobb Douglas production function.

Griliches and Mairesse (1995) note the critics of Cobb Douglas production function is that input variables cannot be treated as independent and the model cannot be run by OLS since they will be biased. The critics say that there may be correlation between inputs and error term. They introduce that in the anatomy of the error there is a part known by the producer but not by the econometrician and a part that is only econometrician's problem

(error of measurement, data collection and computational procedures). Thus this anatomy leads to simultaneity problem. As a result of the critics there are used panel industrial micro-data. They discuss simultaneity, selectivity, lack of information on quality problems. These problems made researcher to use thinner slices of data to solve for simultaneity but that lead to other problems such as misspecifications.

1.4 Distance function

Conceição et al (2006) use a geometric distance function where they put input and output vectors while assuming that they know the efficient input and output levels according to the efficient Pareto-frontier. So they use target outputs. They calculate the ratio geometric average of inputs towards geometric average to outputs which will tend to show the inefficiencies in the production under the assumption that the target is Pareto efficient. Their GDF measure is used for calculating TFP measure and finding the sources of inefficiencies. What TFP measures is the ratio of ratios of input and outputs in different time periods. In multiple input- output case there is a need for aggregation and use of index numbers (Laspeyres, Paasche and Fisher). They suggest that GDF measure has advantages since it does not impose any assumptions on technology. David et al (2007) also uses an input distance function.

1.5 DEA

Feng-Cheng Fu et al (2007) use data for state owned enterprise to measure for productivity. They use the DEA method and linear programming model in an output oriented model with the assumption of CRS for China enterprises. They also use the malmquist productivity indicator (MPI) and decompose it in technological change and efficiency change. With DEA they calculate production frontiers. They use value added as a proxy for output and in a separate model they use taxable profits as a proxy for output. The definition of taxable profits is total sales minus cost of goods sold. Their research is on the industrial sector for financially independent companies for the time period 1986-2003. They calculate DEA efficiency for Panel data and Cross section data. According to their results efficiency in state owned enterprises in china grew in the 80's, declined in the 90's and then steadily progressed from 2000. They suggest that favourable reform contributed to the increased efficiency. Thus they classify the economy in three stages: the first one is reforms on the 80s, the market oriented on the 90s and after 2000 the period of privatization. They find that a

favourable macroeconomic indicator may lead to productivity though they admit it is a long term determinant of productivity.

Andries (2011) suggest that studying banking productivity is important because increased productivity may lead to better performance. He provides comparative analysis of CEE countries for efficiency in banks. He uses Stochastic Frontier Analysis which allows the error term and Data Envelopment Analysis (DEA) which assumes that all deviation in efficiency are caused by firm characteristics and does not account elements that also affects the performance. He calculates Malmquist productivity index. With the DEA method you can identify the inefficiency and what should be done to improve it. Whether DEA is input oriented or output oriented will lead to different efficiency scores. The general form of production function is:

$$y_{it} = x_{it}\beta + v_{it} - u_i$$

Where v is random error, u truncated error variable, y output vector, x input vector and it can be estimated using Maximum likelihood estimation, least squares dummy variable approach and the generalized least square. They calculate Malmquist index using DEA- linear programming method. According to the studies the efficiency in banks differs in time and among banks and this is due to internal and external factors that banks face. They use two stage estimation, first they estimate the level of efficiency and then they use the estimation as a dependent variable. When the dependent variable is DEAS efficiency scores OLS cannot be used but the two tails TOBIT to analyze efficiency with other variables. Their dataset consist of 112 banks in 8 CEE countries in the period 2004-2008. They find that the average efficiency increased. The analysis uses the hypothesis of constant returns to scale. According to them private banks are more efficient while in terms of productivity state owned banks show a larger increase. When size is controlled they find that medium sized banks seem to be more productive and small banks are more efficient. They apply OLS with efficiency as a dependent variable and find that it is influenced by variables such as: bank capital structure, size of the bank, total asset of banking system, annual inflation rate, asset share of state owned banks, asset share of foreign owned banks, ownership form of the bank, the level of concentration in the banks in system; percentage of the asset owned by the 5 largest banks in the system, the banking reform and interest rate liberalization level, deposit rate and lending rate.

Conclusion:

Studies on productivity have as stakeholders the employees, owners and the government. On our literature review on studies on productivity we find that different measures of productivity, input, output are used to study the nature and the determinants of productivity. We note that researches should be cautious when proposing policies depending on the measurement of individual variables used in the estimation process. We conclude that the definition of variables used in the model and the estimation methodology are crucial for the results we will obtain. There is a large “menu” of methodologies used in productivity studies but we are looking at the most common used methodologies such as Index Numbers, Production Function, Distance Function and DEA analysis. The problem of availability of data for large samples and longer time periods is a limitation for conducting studies on productivity. Therefore we suggest that micro- panel dataset may be helpful in solving estimation and comparison models in productivity studies.

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