Access to the Technology Frontier: The Role of Informality

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Abstract

As well known in the growth literature, growth of TFP is the main factor behind growth for various economies. Therefore, accurately measuring TFP is crucial in understanding the constraints on economic growth. However, most of the literature and measures about TFP are only taking the formal sector into account even though the size of the informal sector is quite significant in many countries. In this paper, building upon the works of Caselli and Coleman (2002, 2006) the aim is to understand the role of the informal sector in determining countries' access to the world technology frontier as well as to their own technology frontiers. It is found that incorporating the informal economy alters the measurement of the formal TFP significantly. For 2006, the difference between TFP obtained from classical one sector model and the formal TFP obtained from the model with informality is 25%. Thus, ignoring the informality results in the underestimation of the efficiency of formal labor, especially in developing countries where informality rate is high. Both formal and informal labor efficiencies are positively related to income levels of countries. When technology frontiers of each country are investigated, it is found that access to the world technology frontier results in 38% decrease in income differences among countries.

Keywords: TFP Growth; Informal Sector; CES Production Functions

JEL Classification: J46, O17, O47

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1 Introduction

A well-known result emerging from growth literature is that Total Factor Productivity is the main source of the income differences across countries. (Prescott,1998 and Klenow et al., 1997). Accounting for production factor differences other than TFP cannot explain the big discrepancies among countries. The contribution of TFP on growth is outstanding compared to the contribution of capital and labor.

While the importance of TFP is evident, measuring it precisely is hard to accomplish. As it stands for the remaining part of the income after capital and labor are accounted, it is vulnerable to the factors that may change the measurements of the production factors and informality is one of them. In this paper, one of the aims is to obtain more accurate measures for the productivity of countries by incorporating the informal economy.

Informal economy has a substantial share in various economies. Elgin and Oztunali (2012) found that GDP-weighted informal economy size of the world is 27.9%. Also, this number is higher in the developing countries where understanding the constraints on the growth is very decisive. Thus, in order to see the real differences in productivity across countries, the informal economy should also be taken into account in calculations. As productivity patterns of the formal and the informal part of the economy are different, separating those two gives a better understanding of real productivity differences across countries.

There are several channels that are investigated in the literature which affect the productivity of a country through informality. One of the most outstanding facts about the relationship between informality and productivity is that informal firms are not as productive as formal firms (Dabla-Norris et al., 2005). One of the key reasons that may result in efficiency differences between formal and informal sectors is that informal firms cannot access to credit market which is a major determinant of the growth of a firm (Gatti & Honorati, 2007). Also, informal firms cannot benefit from government subsidies that may help their productivity to increase. In addition to this, the scale factor is a crucial determinant for informal firms to lag behind of the formal sector in terms of productivity. De Soto (1989) claims that informal firms choose to keep their size smaller in order to not to be detected by authorities. Having a smaller size prevents firms to get an advantage of economies of scale which results to operate inefficiently. La Porta et al. (2008) also states that having managers with higher education level is a prominent aspect of the formal sector which may have an effect on the productivity of those firms.

Along with lack of efficiency in the informal sector, the existence of it also alters the efficiency of the formal sector. Busso et al. (2012) claim that informality generates distortions in the labor market which result in a reduction in total factor productivity of the economy. Levya et al. (2017) find that the existence of informal labor absorbs the shocks in the economy and decrease the macroeconomic

volatility, but the cost incurred is low TFP and output levels. However, there are also opposite ideas about the effect of informality on formal sector efficiency in the literature. Although being formal is advantageous for a firm as they can access to credits easily and operate in big scales, it comes with costs also. DErasmo and Boedo (2011) explain that the firms that cannot pay the cost of being formal, that are generally less efficient firms, operates informally. Thus, the costs work as a selection mechanism which results in formal firms being more productive on average, as frictions decreases. Thus, they found that model without informality generates less TFP level than the formal sector TFP in the model with informality. Thus, the effect of informality on productivity is not assured in the literature. Ulyssea (2014) found that lower informality is not necessarily associated with high level of TFP.

The framework that Caselli and Coleman (2002, 2006) use in their paper is the building block of this paper. They use the constant elasticity of substitution production function with two types of labor to investigate the efficiency of skilled and unskilled labor with cross-country data. They also construct technology frontiers to show the choice of each country's production technology that utilizes skilled or unskilled labor more depending on their optimality in terms of labor endowments. The same structure is used for investigating the formal and informal labor efficiencies. The model introduced in this paper is also adopted by Atesagaoglu et al. (2017) in order to see how informality affects both the level as well as the growth path of the total factor productivity of Turkey in a time period of 1950-2014. They found that standard TFP calculation mostly underestimates the formal TFP compared to two labor model. One of the aims of this paper is to find whether this pattern is specific to Turkey or it can be seen in various economies.

In this paper, informality is embedded to model through labor. Different from most of the literature that model informality as a different sector, this model uses a constant elasticity of substitution production function where formal and informal labor can substitute each other but not perfectly. By using a cross-country data, each country's formal and informal labor productivity is calculated. The most outstanding finding is that classical estimation methods for total factor productivity underestimate the formal labor TFP significantly. In addition to this, it is found that richer countries use both formal and informal labor more efficiently. Also, a counterfactual analysis reveals that technology frontiers of the countries are one of the main determinants of the income differences across countries. Thus expanding the set of possible technologies for countries can improve their well-being.

The organization of the paper is as follows: In the next section, benchmark model together with the other two models used in the calculations are presented. Also, the production frontier concept is introduced and its derivation is explained. In section three, the data and the methodology of the calibration of the parameters are introduced. In section four results of both models are presented and a counterfactual analysis is given. It is concluded in section five.

2 Model

As a benchmark model, a standard neoclassical production technology is used with only formal labor. Then, to see the impact of the informality on productivity, informal labor is also added to the production technology. In order to see whether chosen production technology affects the results or not, two types of function -one level CES and two-level CES - are used in two labor model.

2.1 Model with Formal Labor

TFP levels in growth literature are mostly measured by calculating the number that explains the discrepancy between factor endowments and income. Production function that is used in the benchmark model is a constant returns to scale Cobb-Douglass production function as follows:

$$Y_t = (K_t)^{\alpha}(A_t L_t)^{1-\alpha}, \tag{1}$$

where A_t, K_t and L_t denote, respectively, the productivity, the stock of capital and the input of labor. It can be seen that production function adopt a labor augmenting productivity. It is assumed in that way because the comparison of formal and informal labor can be done conveniently.

Based on the production technology given in (1), the productivity measure A_t can be backed up from the following equation:

$$A_t = \left[\frac{Y_t}{(K_t)^{\alpha}(L_t)^{1-\alpha}}\right]^{(\frac{1}{1-\alpha})} \tag{2}$$

In this calculation, Y_t stands for only the formal output level. As this calculation is used as a benchmark, it is calculated with the standard data on the formal economy.

2.2 Models with Formal and Informal Labor

In this section, informal labor is incorporated into neoclassical production function. Following Caselli and Coleman (2002, 2006), two alternative CES production technologies are used. Those two functions are explained in detail in the following sections.

2.2.1 One Level CES Production Technology

In this model, it is assumed that the output Y_t, which is now a combination of formal and informal output, is produced according to the following CES production technology

$$Y_t = (K_t)^{\alpha}\left[(A_t^F L_t^F)^{\sigma} + (A_t^I L_t^I)^{\sigma}\right]^{\frac{1-\alpha}{\sigma}}, \tag{3}$$

where L_t^F is formal labor, L_t^I is informal labor, A_t^F is productivity level of formal labor, A_t^I is productivity level of informal labor. It can be seen that when informality becomes zero, the production function turn into the one in the benchmark model. Hence, the productivity level that is found in benchmark model is the same with A_t^F if informality is assumed to be zero. The elasticity of substitution between formal and informal labor is equal to $1/(1-\sigma)$ and it is assumed $\sigma < 1$. When $\sigma = 1$, formal and informal labor are perfect substitutes. This implies that only the formal labor, which is assumed to be more productive, is used in the production. In that case, the model again becomes same with the benchmark model.

By assuming marginal productivity levels are paid for each production factor, closed form solution of this optimal allocation problem is found. Thus, we can obtain A_t^F and A_t^I. Let w_t^F, w_t^I and r_t denote, respectively, the formal wage, informal wage and marginal productivity of capital stock. Then, the closed form solutions of A_t^F and A_t^I as follows:

$$A_t^F = \left[\frac{(Y_t)^{\frac{1}{1-\alpha}}(K_t)^{\frac{-\alpha}{1-\alpha}}}{L_t^F}\right]\left(\frac{w_t^F L_t^F}{w_t^F L_t^F + w_t^I L_t^I}\right)^{1/\sigma} \tag{4}$$

$$A_t^I = \left[\frac{(Y_t)^{\frac{1}{1-\alpha}}(K_t)^{\frac{-\alpha}{1-\alpha}}}{L_t^I}\right]\left(\frac{w_t^I L_t^I}{w_t^F L_t^F + w_t^I L_t^I}\right)^{1/\sigma} \tag{5}$$

The productivity level A^F is the measurement that is compared with the productivity level in the benchmark case.

2.2.2 Two Level CES Production Technology

In this model, it is assumed that the output Y_t, which is again a combination of formal and informal output, is produced according to the following CES production technology

$$Y_t = \{(A_t^I L_t^I)^\sigma + \left[(A_t^F L_t^F)^\rho + (A_t^K K_t)^\rho\right]^{\frac{\sigma}{\rho}}\}^{\frac{1}{\sigma}}, \tag{6}$$

where L_t^F is formal labor, L_t^I is informal labor, A_t^F is productivity level of formal labor, A_t^I is productivity level of informal labor, A_t^K is productivity level of capital, $\sigma < 1$ and $\rho < 1$. The elasticity of substitution between formal labor and capital is equal to $1/(1-\rho)$. In this model, again the elasticity of substitution between formal and informal labor, and also between capital and informal labor, is equal to $1/(1-\sigma)$.

As in one level CES function case, the closed form solutions for A_t^F, A_t^I and A_t^K can be obtained by assuming that all factors of productions are paid their marginal productivity. Let w_t^F, w_t^I and r_t denote, respectively, the formal wage, informal wage and the marginal productivity of capital stock. The closed form solutions for A_t^F, A_t^I and A_t^K as follows:

$$A_t^F = \frac{Y_t}{L_t^F}\left(1 - \frac{r_t(\frac{K_t}{Y_t})}{S_t}\right)^{1/\rho} {S_t}^{1/\sigma} \tag{7}$$

$$A_t^I = \frac{Y_t}{L_t^I}\left(1 - S_t\right)^{1/\sigma} \tag{8}$$

$$A_t^K = \left(\frac{r_t(\frac{K_t}{Y_t})^{1-\rho}}{S_t}\right)^{1/\rho} {S_t}^{1/\sigma} \tag{9}$$

where

$$S_t = \frac{\frac{w_t^F L_t^F}{w_t^I L_t^I} + r_t(\frac{K_t}{Y_t})}{\frac{w_t^F L_t^F}{w_t^I L_t^I} + 1} \tag{10}$$

In this model also the productivity level A^F is the measurement that is compared with the productivity level in the benchmark case.

2.3 Technology Frontier

In the production of the goods, it is assumed that there is no fixed production technology for each country. Instead, there are set of different technologies available for each country in which they choose the appropriate one among them conforming with their labor endowments. Those set of technologies are represented by a technology frontier. All technology bundles that are in below the frontier are dominated by the bundles on the frontier in terms of efficiency and technology bundles above the technology frontier are not feasible for the country. Thus each frontier shows the technology boundary for a country. In order to find the technology frontier, a representative firm is used. Representative firm solves profit maximization problem which is subject to a constraint that represents the boundary of efficiency level.

$$\max_{A_t^F, A_t^I} \pi_t = Y_t - w_t^F L_t^F - w_t^I L_t^I - r_t K_t \tag{11}$$

subject to

$$(A_t^F)^\omega + \gamma (A_t^I)^\omega \leq B \tag{12}$$

Every firm, so every country, chooses an efficiency bundle (A_t^F, A_t^I) from its own technology frontier. Thus, B is the main determinant for the efficicency choice and defines the boundary on technology adoptation.

3 Data and Calibration

The data used in the calculations are from 2002 to 2006. Due to data limitations, it covers 42 to 50 countries, which varies from year to year. The level of capital

stock K_t, formal labor L_t^F, and formal output Y_t^F are from Penn World Tables. The data on informal labor L_t^I and informal output Y_t^I are obtained from Elgin and Oztunali(2012).

Formal sector wages w_t^F are taken from Extended Penn World Table. Unfortunately, there is no comprehensive data for informal wage w_t^I. Gindling et al (2016) provide wage gaps in the formal and informal sector for 36 countries. In order to expand the data, a relationship between agricultural wage and informal wage is found for those 36 countries. Then by using this relationship and agricultural wage data for other countries, an informal wage data is constructed. Before choosing agricultural wage, other indicators are also experimented such as minimum wage, informality size, GDP level. However, agricultural wage turned out to be the best among those with high correlation with the informal wage.

For Model 2, the marginal productivity of capital stock, r_t, is equal to the real interest rate plus the rate of depreciation on physical capital. Real interest rate data is constructed with deposit interest rate data minus the inflation rate, both of the data from World Development Indicators and the depreciation rate δ data is taken also from Penn World Table. For the capital share parameter α, two constant values are used for two different set of countries. First countries are divided into two different income groups. For low-income countries, the capital share is taken as $1/2$ and the high-income countries it is taken as $1/3$.

As there is no estimated $1/(1-\sigma)$ values in the literature, which defines the substitution elasticity of formal and informal labor, it is calculated with the method that Bowles(1970) defines in his paper. The resulting σ level obtained from the panel-data regression is 0.88. In addition to this, it is also calculated from the survey data containing firm-level information about informal sector in Turkey. (Elgin and Sezgin, 2017) The estimation result gives the σ value as 0.7. In order to check the robustness of the results across different σ values, both of them are used in the calculation. From this robustness check, it can be said that the main results are not affected by the σ value. Results of them can be seen in the Appendix. To estimate the elasticity of substitution between capital and formal labor $1/(1-\rho)$, panel data regression is used by following the method in the Antras(2004). The obtained value for ρ is 0.27. The value of σ is bigger than ρ shows that substitution between formal labor and informal labor is higher than the substitution between formal labor and capital.

As the parameters in technology frontiers are model specific, they are estimated from first order optimality conditions of the profit maximization problem. In Model 1, the equation that describes the optimal efficiency bundle is that:

$$\gamma \left(\frac{L^F}{L^I} \right)^{\sigma} = \left(\frac{A^F}{A^I} \right)^{\omega - \sigma} \tag{13}$$

when the logarithm of this equation is taken, the relation between labor ratio and efficiency ratio becomes linear. Thus ω, γ and B can be obtained with a panel data

regression by using the equation below.

$$log\left(\frac{A^F}{A^I}\right) = \frac{\sigma}{\omega-\sigma} log\left(\frac{L^F}{L^I}\right) + \frac{1}{\omega-\sigma} log(\gamma) \tag{14}$$

In model 2, the equation that describes the optimal efficiency bundle is that:

$$\gamma[(A^F L^F)^\rho + (A^K K)^\rho]^{\frac{\sigma}{\rho}-1} \frac{(A^F L^F)^\rho}{(A^I L^I)^\sigma} = \left(\frac{A^F}{A^I}\right)^\omega \tag{15}$$

when the logarithm of this equation is taken, the relation becomes linear. Thus ω, γ and B can be obtained with a panel data regression by using the equation below.

$$log\left(\frac{A^F}{A^I}\right) = \frac{1}{\omega} log\left(\gamma[(A^F L^F)^\rho + (A^K K)^\rho]^{\frac{\sigma}{\rho}-1} \frac{(A^F L^F)^\rho}{(A^I L^I)^\sigma}\right) \tag{16}$$

4 Results

4.1 Model 1

One of the aims of this paper is to find how incorporating the informal sector affects the measurement of the formal labor TFP. When TFP obtained from benchmark case A_t and the formal labor TFP obtained from one level CES model A_t^F are compared, it is found that benchmark model cannot explain the 31% of the real efficiency of formal labor on average. As it can be seen from Table 1, the difference shrinks in years. This pattern coincides with the decrease in the informality size in years.

Year	Mean	Std dev	Frequency
2002	.369	.306	44
2003	.339	.296	48
2004	.315	.279	48
2005	.301	.272	47
2006	.250	.255	52
Total	.313	.282	239

Table 1: Percent difference in formal TFP

When the countries are categorized according to their income level, the differences in formal TFP are contrasting. The unexplained part of the formal TFP is significantly higher in low-income countries which is one of the important results. This means formal part of the productivity of low-income countries are higher than they seem if the informality is taken into consideration. As in one sector TFP estimations low-income (less productive) countries, TFP levels are more underestimated than high-income (productive) countries, it can be said that productivity

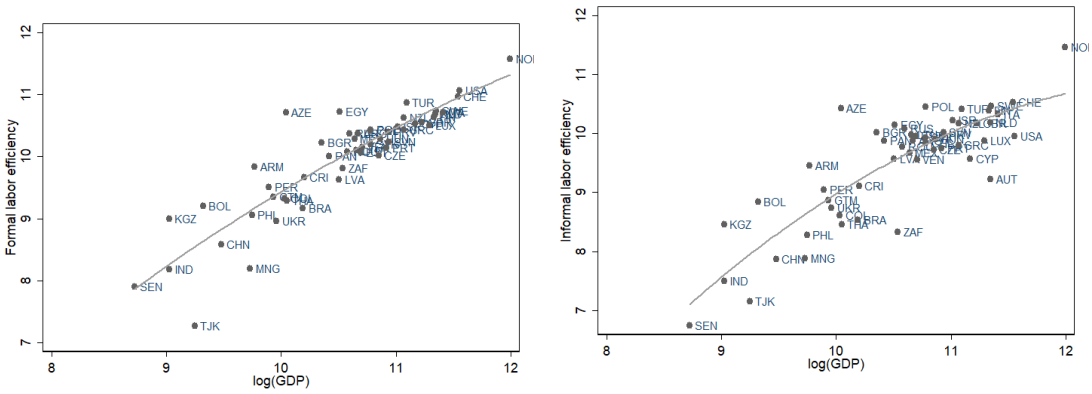
differences in the formal part of the economy among countries are less than the general thought in the literature. When logarithm of TFP level in one sector and logarithm of formal labor TFP level in Model 1 are compared the standard deviation of former is 0.97 where the latter is 0.86 for 52 countries in 2006. Thus, it can be said that one of the reasons for income differences among countries is not that some countries do not have productive sectors in their economy, but having a big share of an unproductive informal sector.

Year	2002	2003	2004	2005	2006
Low-income	.557	.546	.505	.497	.471
High-income	.098	.094	.091	.098	.111

Table 2: Percent difference in formal TFP (Year=2006)

The results of different substitution values with formal and informal labor can be found in the Appendix. When substitution between different labors become more available, two sector model yields higher formal labor productivity levels.

In line with the literature, there is a positive relationship between formal labor efficiency and GDP per capita. It is not surprising to find that when a country efficiently utilizes its formal labor, its income level boost. Norway stands out among other countries with its efficiency and income level. Although there is again a positive relationship between informal labor efficiency and income level, it is not a significant determinant of income level as formal labor efficiency. The relation between A^I and income gets weaker when income level increases.



(a) Formal Labor

(b) Informal Labor

Figure 1: GDP per worker level vs. efficiency level of labor

As is readily seen from Figure 2, formal labor efficiency and informal labor efficiency go hand in hand. It is not surprising as informal labor most of the times include some unregistered part of the workers do same jobs with the other registered

workers. Hence although their efficiency level is less than formal one for various reasons, the overall know-how in the country affect both formal and informal labor same which result in the same behavior in efficiency levels with income. However, it is important to remember that efficiency of formal and informal labor is affected by the relative wages. As in developed economies, excluding the US, the wage distribution is more egalitarian than the other countries, this may also affect the results.

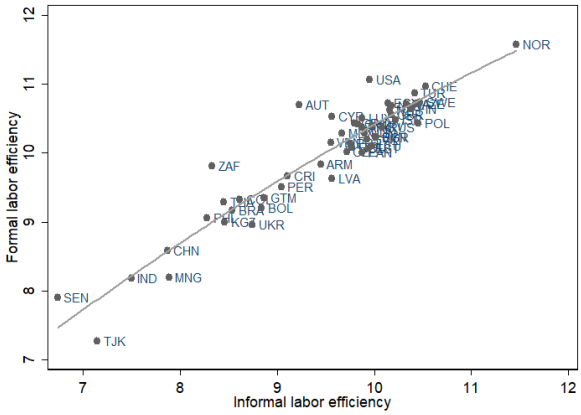


Figure 2: Efficiency level of formal labor vs. informal labor (Year=2006)

One of the interesting questions is that how productivity ratios of two types of labor changes with the income level of the countries. If one country starts to use one of its labor more efficiently when it grows, it is said that there is a biased technology change. If it uses formal labor more efficiently than informal labor then it is formal-biased technology change and if it uses informal labor more efficiently than formal labor then it is informal-biased technology change. When we plot the efficiency ratios with income level, we see that it is almost a flat line. Thus, when a country upgrade its technology both formal and informal labor can utilize the new technology with the same rate of efficiency.

As it is mentioned before, in the model countries choose their production technology according to their formal and informal labor endowments. The technology frontier of each country represents the possible choices for production technology. Figure 4 shows technology frontiers of US, Turkey, and Mexico as an example. The countries having relatively more informal labor choose an efficiency bundle that utilizes informal labor more. Hence, they are placed in the part of their frontier that is near x-axis. As it can be seen countries with less income such as Mexico has a frontier that is inside of the frontiers of richer countries such as Switzerland, Norway, and the USA. This shows the efficiency boundary on income levels of the countries. In section 4.3, how those boundaries affect the income dispersions among countries is investigated with a counterfactual analysis. The outer frontiers have higher B levels which can be seen as the overall efficiency of a country. Norway has

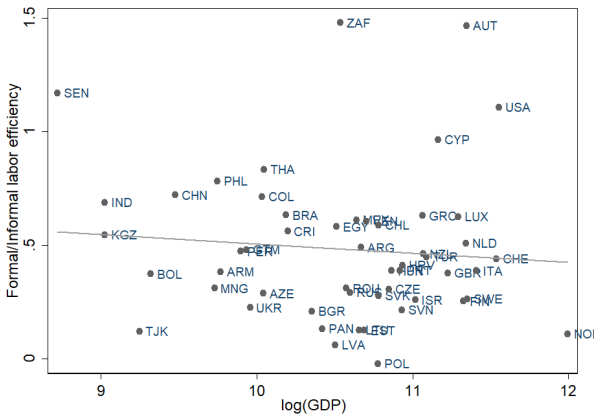


Figure 3: Formal/Informal TFP Ratios vs. GDP per-capita (Year=2006)

the outermost frontier, thus it represents the world technology frontier.

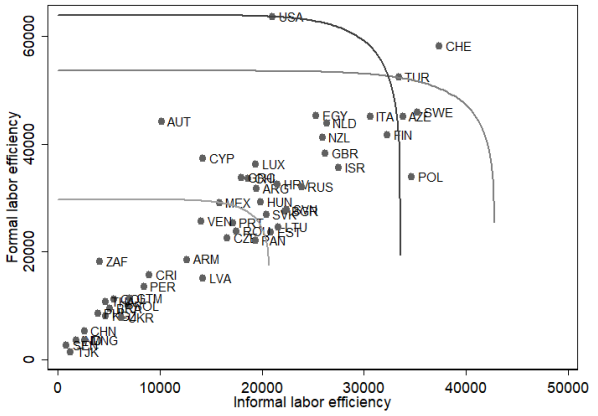
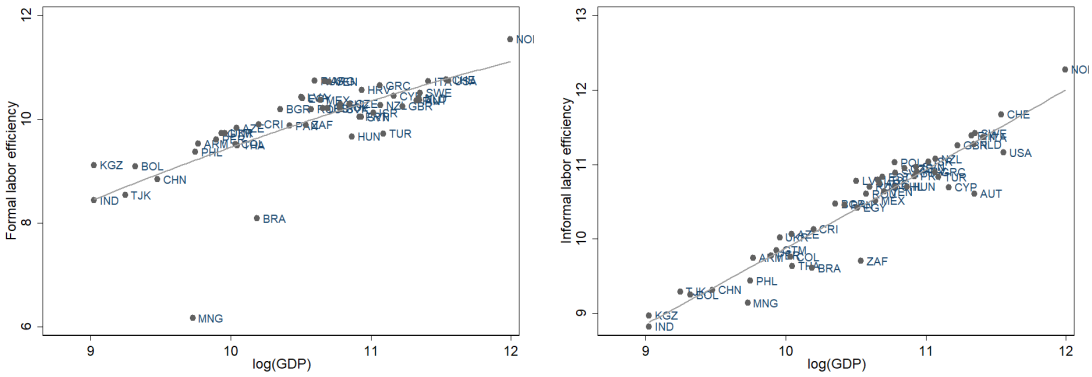


Figure 4: Technology Frontiers of USA, TUR, and MEX (Year=2006)

4.2 Model 2

In this model, there is a substitutability in both between formal labor and informal labor and also between capital and formal labor. One of the noteworthy results that differ from the one level CES model is the relationship between formal labor efficiency and income level. Although there is still a positive correlation between them it is not as significant as in the Model 1. This may result from that in Model 1 efficiency of capital is explained by the efficiency of formal labor as they are the substitute to each other to some extent. However as there is no substitution between informal labor and capital, results of informal labor efficiency are not affected by the change in the model construction.

Adding capital-formal labor complementarity into the model changes the relationship between the efficiency of formal and informal labor. Although it does not



(a) Formal Labor (b) Informal Labor

Figure 5: GDP per worker level vs. efficiency level of labor

change the direction of the relationship, we have a humped pattern in this case where it is linear in Model 1. When we examine the Figure 5b, we can see that formal efficiency of countries converges to each other when income level increases. Thus the differences among formal TFP in Model 1 can be attributed to capital efficiency, which means income differences between rich countries depend on how they utilize their capital more than their formal labor.

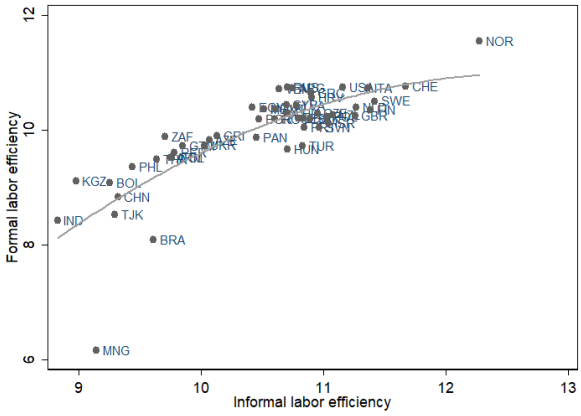


Figure 6: Efficiency level of formal labor vs. informal labor (Year=2006)

The most striking difference between the results of two models is that adding capital-formal labor complementarity to model changes the biasedness of the technology change. When a country increases its technology level, the informal labor utilizes the new technology better than the formal one.

4.3 Counterfactual Analysis

One of the aims of this paper is to see how the boundaries of technology affect the productivity, so the income level, of the countries. Hence a counterfactual analysis

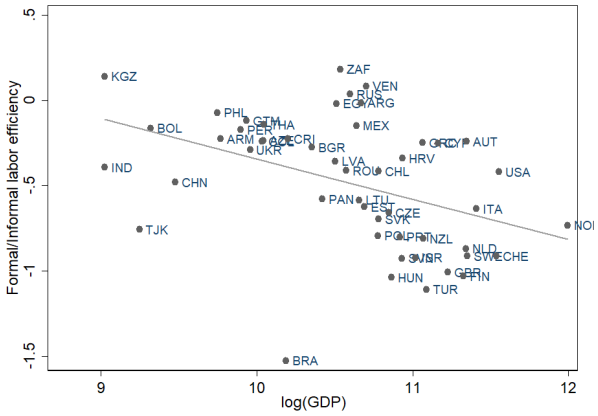


Figure 7: Formal/Informal TFP Ratios vs. GDP per-capita (Year=2006)

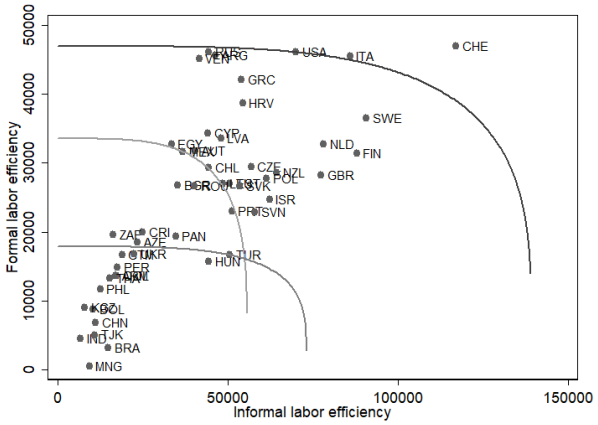


Figure 8: Technology Frontiers of USA, TUR, and MEX (Year=2006)

is conducted to find the income gain of removal of the barriers. By having each countries frontiers, world technology frontier can be identified as the outermost frontier at hand. The technology frontier of Norway specifies the world technology frontier in all cases and all years. It is assumed that all countries can have access to the world technology frontier, thus they can choose the most appropriate technology pair from that production frontier to maximize their output levels. If all countries reached the outermost frontier and chose efficiency pair from this frontier, it is obvious that income levels of all countries, except the one whose frontier is the outermost one, would increase. The gain from removing the barriers are higher when barriers are more restrictive for a country. Figure 9 shows the gain that results from removing the barriers on technology. As it can be seen from the graph, the income level of a low-income country like Tajikistan can augment its output by almost nine-fold.

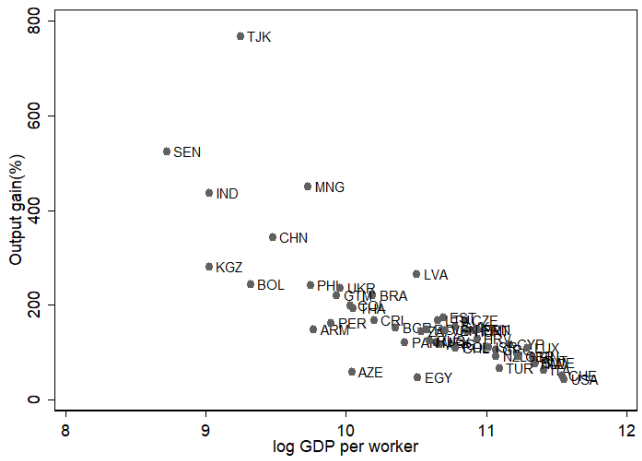


Figure 9: Output gain from reaching outermost frontier (Year=2006)

By calculating the gain, it is aimed to figure out how much of the income differences among countries are resulting from the efficiency barriers. In the data standard deviation of the log of GDP per capita is 0.73, which indicates the income discrepancies among countries. Removing the efficiency barriers this number declines to 0.45. Thus, 38% of the income differences among countries results from the efficiency disparity while the other 62% results from endowment differences.

5 Conclusion

Understanding the underlying reasons for income differences among countries is one of the most crucial efforts in growth literature. This paper investigates two overlooked factors in the literature. First one is that TFP calculations are based on the formal economy, while most of the developing economies include a considerable size of informality. As the efficiency of formal and informal labor differ significantly, separating those two will give more accurate measures on real productivity levels of countries. The results show that incorporating this fact changes TFP calculations of formal sector nearly by 25% in 2006. Thus, ignoring the informality results in an underestimation of productivity levels. It is seen that both formal and informal labor productivity increases jointly with the income level of the country. This outcome may result from the fact that higher productivity of formal labor may trigger an increase in productivity of informal labor especially the ones that are in the same workplace.

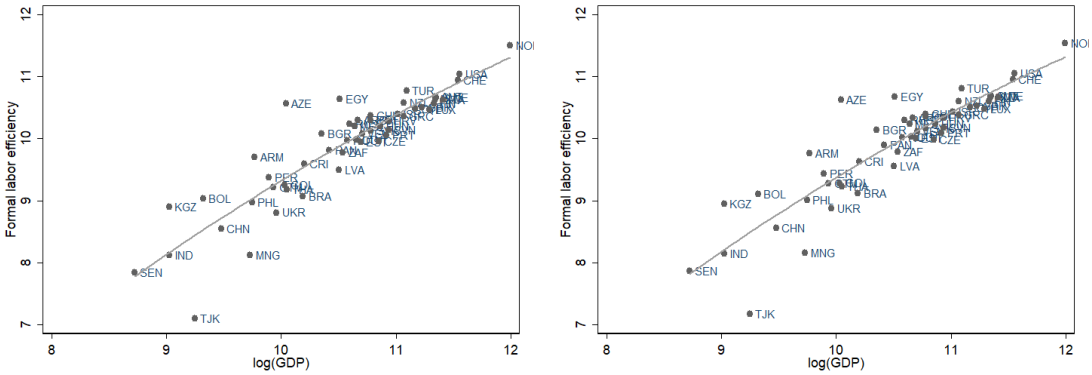
The other factor which changes the understanding of technology differences among countries is appropriate technologies. Most of the growth literature stand on the belief that if the technology owned by high-income countries can be achieved by low-income countries, the efficiency level of low-income countries will increase. However, a production technology can be efficiently used only if it is appropriate to

be used with that particular country's endowment. Thus it is suggested in this paper that countries choose their technology level on a feasible technology set conforming to their endowment level and those sets are the main determinant for income differences among countries. When technology frontiers are obtained by using productivity of formal and informal labor, it is seen that countries with higher income are located in the outer part of the frontiers of countries with lower income. When a counterfactual analysis is practiced, it is found that by abolishing the barriers to efficiency, income differences can be decreased by 38%.

The main results are independent of the production technology used in the model. Findings from both one-level and two-level CES production function behave similarly. The main difference is that as there is a substitutability between formal labor and capital in Model 2 relationship between formal labor efficiency and income is less significant. The reason of that may be that formal labor efficiency in Model 1 also includes some part of capital efficiency. When those are separated the part that explained by formal labor efficiency shrinks.

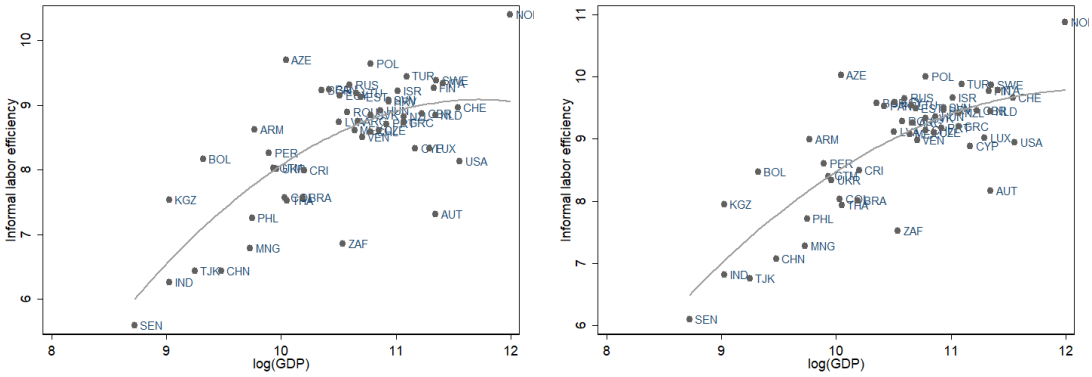
Although this research gives plausible explanations about TFP differences, there is room for improvement for future research. First, data constraints bound the analysis for only 52 countries. By using broader data, one can obtain the regional frontiers to see the spatial aspects of efficiency barriers as well. Second, in this research, technology frontiers are investigated for a cross-section of countries for specific years. However, the evolution of the frontiers in time can also be informative about the income differences among countries and how they evolve in time. Next step will be adding a time dimension to analysis and investigate changes in technology frontiers of countries. It will be informative to see whether frontiers are converging to each other or not.

6 Appendix



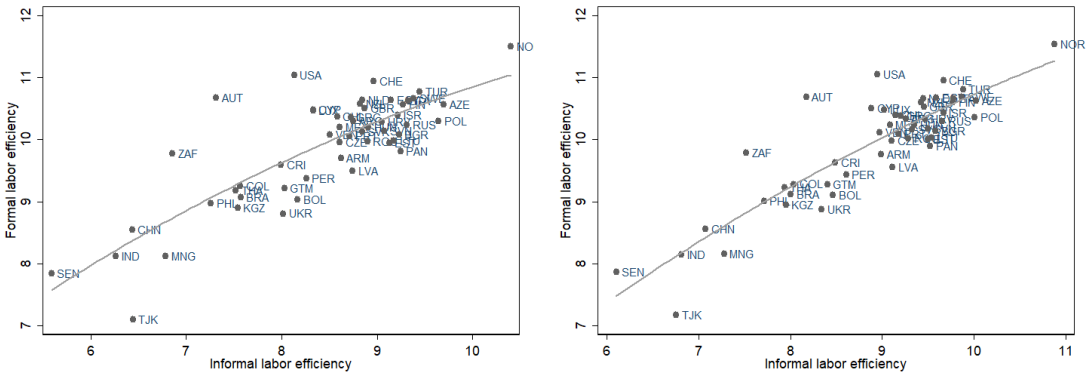
(a) σ=0.6 (b) σ=0.7

Figure 10: GDP per capita level vs. efficiency level of formal labor (Year=2006)



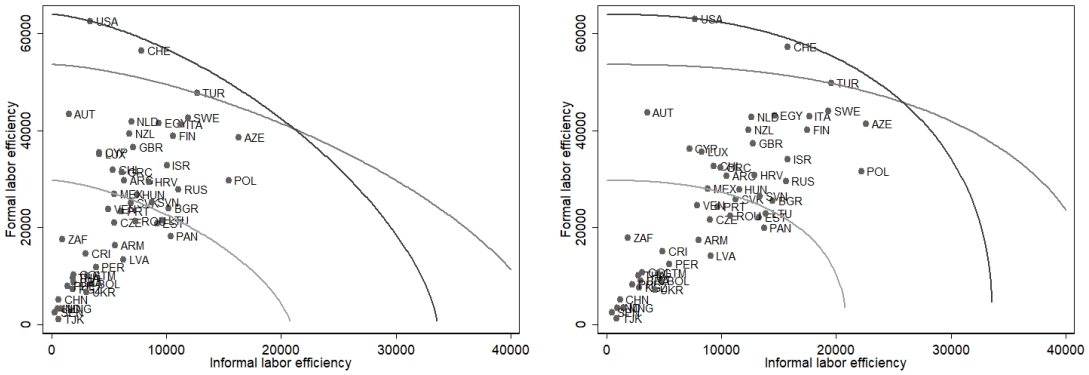
(a) σ=0.6 (b) σ=0.7

Figure 11: GDP per capita level vs. efficiency level of informal labor (Year=2006)



(a) σ=0.6 (b) σ=0.7

Figure 12: Efficiency level of formal labor vs. efficiency level of informal labor (Year=2006)



(a) σ=0.6 (b) σ=0.7

Figure 13: Technology Frontiers of USA, TUR, and MEX (Year=2006)

Table 3: Percent difference in formal TFP when σ=0.6

Year	Mean	Std. Dev.	Freq.
2002	0.256	0.254	44
2003	0.226	0.250	48
2004	0.205	0.234	48
2005	0.193	0.230	47
2006	0.140	0.218	52
Total	0.202	0.238	239

Table 4: Percent difference in formal TFP when σ=0.7

Year	Mean	Std. Dev.	Freq.
2002	0.305	0.276	44
2003	0.275	0.268	48
2004	0.253	0.252	48
2005	0.240	0.247	47
2006	0.188	0.233	52
Total	0.250	0.256	239

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