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DISCUSSION PAPER SERIES

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ABSTRACT

Gender Equity in Labor Market Opportunities and Aggregate Technical Efficiency: A Case of Equity Promoting Efficiency

This study applies a panel data stochastic frontier analysis to country data towards examining the effect of gender equity in labor market opportunities upon efficiency in the production of GDP. It finds that aggregate technical efficiency is improved by a widening of women's labor market opportunities as indicated by a rise in their share of employment, but that this effect is dampened by patriarchal cultural norms whose strength is measured by the proportion of the population tracing its ancestry to ethnic groups who adopted the plough as an agricultural implement. That aggregate technical efficiency rises in women's share of employment is consistent with improvement in the average quality of the workforce when talented women's entry to it is eased. That this effect is dampened by patriarchal cultural norms is consistent with their promoting a misallocation of employed women. Additionally, aggregate technical efficiency appears improved by democracy, the control of corruption, and trade-openness.

JEL Classification: J16

Keywords: gender equity, patriarchy, aggregate productivity, technical efficiency, stochastic frontier model

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1. Introduction

This paper employs stochastic frontier analysis to study the effect of gender equity in labor market opportunities upon efficiency in the production of GDP across countries. Since gender inequity in economic opportunities lowers the average quality of the workforce by impeding talented women's entry to it, it is expected to generate aggregate technical inefficiency. This expectation is borne out in the finding of a decrease in aggregate technical inefficiency from increase in women's share of employment, that is, greater gender equity in labor market opportunities. To our knowledge, this is the first application of stochastic frontier analysis to this research question.

In his classic *Equality and Efficiency: The Big Tradeoff* (Okun, 1975), the late Arthur Okun coined the enduring aphorism that "money must be carried from the rich to the poor in a leaky bucket.", by which it was meant that redistributive policies ran the risk of dampening economic incentives, so shrinking the resources slated for redistribution. Equity, it was held, came at the cost of efficiency.[1] However, endogenous growth theory cast doubt upon this equity-efficiency tradeoff, at least as far as a dynamic efficiency, related to economic growth, was concerned. It came to be believed that a more equitable distribution of income was favorable for economic growth, since, for example, income inequality reduced future generations' human capital accumulation. When credit markets are imperfect so that borrowing to finance education is difficult, education becomes a parental bequest. Economically disadvantaged children receive less education, in which case aggregate human capital investment would be lower, as, hence, would the rate of growth, the greater the level of income inequality (e.g., Galor and Zeira, 1993). That greater income equality caused static inefficiency, by Okun, though dynamic efficiency, that is, faster growth, according to the endogenous growth theorists, owes to the fact that the equity that concerned Okun was equity in economic *outcomes*, whose detrimental blunting of economic incentives was unquestionable, whereas the endogenous growth theorists appreciated that equity in economic outcomes in one generation translated to a beneficial equity in educational, hence economic,

[1] In what follows, when we do not specifically mention that the concept of efficiency is technical efficiency, we will be referring to efficiency in a general sense. That is, efficiency can be allocative efficiency, cost efficiency, technical efficiency, or some other type of efficiency.

opportunities for the next (Osberg, 1995). In other words, equity in opportunities has long been seen to favor efficiency.[2] This study's investigation of a connection between women's share of employment, a measure of gender equity in labor market opportunities, and aggregate technical efficiency is an attempt to further corroborate this view empirically.

The inefficient allocation of female talent takes at least two forms. Cultural norms as well as gender discrimination may discourage talented women from taking up employment. For example, restrictive cultural norms are held to be an important factor in India's persistently low female labor force participation rate even in the face of rapid economic development (Afridi, Bishnu, and Mahajan, 2019; Bernhardt et al., 2018), and less legal discrimination against women has been found to be strongly associated with higher female labor force participation across nations (Gonzalez et al., 2015). Second, women who do work may suffer occupational and industrial segregation, for example, confinement to occupations considered suitable for women (Anker, 1998; Anker, Melkas, and Korten, 2003; Borrowman and Klasen, 2020; Das and Kotikula, 2019), or barriers to professional advancement that stifle their productivity (Gjerde, 2002; Matsa and Miller, 2011). Braunstein (2008) observes that "when women are kept out of the paid labor force completely, average labor force quality will be lower than otherwise, as more productive female workers are kept from working in favor of less productive male workers", and that when there is gender-based occupational and industrial segregation, workers shall not be matched with jobs at which they are most productive. The result shall be poorer economic performance. Thus, besides an ethical case, there is a strong economic case for promoting gender equality. The World Bank notes that "Gains in women's economic opportunities lag behind those in women's capabilities", and that "this is inefficient", so that "the business case for expanding women's economic opportunities is becoming increasingly evident" (World Bank, 2006).

Yet, there is evidence of persistent, even widening, gender gaps in economic opportunities. For example, Goldin (2014) finds that, in the U.S., a gender gap in earnings endures despite decades of its narrowing, with Blau and Kahn (2017) observing that this gap actually widened at the top of the wage distribution between

[2] For example, Alesina and Rodrik (1994), Persson and Tabellini (1994), and Perotti (1996) document a positive relation between income equality and economic growth.

1980 and 2010. Such a gender gap remains common enough in the developing world, as evidenced by the finding of a persistent unexplained gender wage gap in Mexico over the years 2000 – 2017, one that technological advances seem to have exacerbated (Rodríguez Pérez and Meza González, 2021). Klasen (2018) observes that labor force participation rates of prime-aged women have "stagnated or fallen slightly in many regions, fallen substantially in South Asia (from low levels), and increased strongly only in Latin America and the Caribbean", whereas those of men have mostly held stable at high levels, making for a stubborn gender gap. In addition, Borrowman and Klasen (2020) find that gendered sectoral and occupational segregation has increased in more developing countries than in which it has decreased. The immensity of the economic damage wrought by these trends is captured in McKinsey Global Institute's, perhaps simplistic[3] (Klasen, 2018), calculation that the elimination of all gender gaps in the world's labor markets has the potential to add $28 trillion to global GDP by the year 2025, this sum being greater than the combined sizes of the US and Chinese economies (McKinsey Global Institute, 2015).

The remainder of this paper is organized as follows. Section 2 supplies a succinct review of the literature. Section 3 describes the empirical model and discusses estimation, section 4 presents the results of estimation, and section 5 a brief conclusion.

2. The Literature

A number of theoretical models demonstrate that gender equity in economic opportunities promotes dynamic efficiency in boosting the rate of economic growth. These commonly hinge upon a decline in fertility following rise in the opportunity cost of children from the widening of economic opportunities for women. A fall in fertility mechanically, even without an increase in output per worker, raises the growth rate of per capita GDP. As noted by Bloom and Williamson (1998), $Y/P = (Y/L)\times(L/P)$, where Y, L, and P denote, respectively, GDP, the workforce, and the population. In other words, per capita GDP is the product of output per worker, or labor productivity, and the ratio of the workforce to the population. This implies that the growth rate of per capita GDP is the sum of the growth rates of, respectively, output per worker and the workforce, less the

[3] The calculations are simplistic in the sense that they ignore general equilibrium effects.

population growth rate. Therefore, a fertility decline would, at least before the population aged and swathes of the workforce entered retirement, cause the workforce to grow faster than the population, so raise the growth rate of per capita GDP. Besides thus automatically raising the rate of growth, a decline in fertility may spur growth by stimulating labor productivity. For example, in Galor and Weil's (1996) model, a decline in fertility, yielding fewer household dependents, raises saving, hence capital per worker, to boost labor productivity. Similarly, in Cavalcanti and Tavares's (2016) model, labor market discrimination, as manifested in a gender pay gap, lowers female participation in employment. Not only does this reduction in the input of female labor reduce per capital output immediately, it does so in the long term as well by raising fertility, so lowering saving and hence physical capital accumulation. By the authors' calibration exercise, US per capita output would have been substantially lower had the gender pay gap been as wide as it is in some other countries. A decline in fertility from improved labor market opportunities for women may be accompanied as well by a labor productivity increasing rise in parental investment in children's human capital, that is, the fertility decline may reflect a trading-off of the quantity for the quality of children (e.g., Lagerlof, 2003). The common reasoning of the empirical literature that gender inequity in economic opportunities hurts economic performance by obstructing the participation of women from the upper reaches of the distribution of productivity, generally plays no part in these theoretical models, which typically assume that the genders are homogenous. A rare exception is the model by Hsieh et al. (2019), which considers workers, male and female, to possess heterogeneous occupational aptitudes. It predicts that a lowering of barriers to women's entry to an occupation will first usher in women with the highest aptitude for it. This is bound to raise the average level of employee aptitude in the occupation, hence productive efficiency. Indeed, by the authors' model-based simulation, between 20 and 40 percent of the growth in per capita GDP in the U.S. between 1960 and 2010 may be attributed to a reduction in gender and racial discrimination in the matching of workers to occupations.

That the empirical literature is sparser is attested to by Klasen and Lamanna's (2009) observation that "A subject that has not been investigated in great detail is the impact of gender inequality in employment and pay on economic growth." As this remark intimates, most econometric studies of effect of gender inequality upon economic performance take the rate of growth to gauge the latter. Klasen (1999) finds that growth in women's share of the working-age population employed in the formal sector is positively and significantly related to the rate of economic growth over the period 1960 – 1992. Extending the analysis to the year 2000, Klasen and Lamanna (2009) estimate that women's share of the labor force is positively and significantly associated with the rate of economic growth. A rare instance in this literature of a study that measures economic performance by the level of aggregate output rather than by its rate of growth is that by Esteve-Volart (2004). It finds that the ratios of female-to-male managers and female-to-male workers as a whole are positively and significantly related to per capita output across 16 states of India over the period 1961 – 1991.[4] Analogously, our study estimates a stochastic frontier aggregate production function, describing the maximum attainable level of GDP. A nation's actual GDP may be lower due to, for example, technical inefficiency stemming from gender inequities in labor market opportunities. The radial distance between the frontier and actual GDP, the inefficiency term, will be used to calculate technical efficiency. Stochastic frontier models treat the inefficiency term as an unobservable random variable. The distribution of the inefficiency term is taken to depend on certain 'environmental variables' of which the extent of gender equity in labor market opportunities, as measured by women's share of employment, is foremost. This is the crux of the empirical strategy. Data envelopment analysis (DEA) and stochastic frontier analysis have become the standard econometric tools of efficiency analysis. DEA is a non-parametric method based on linear programming techniques. Although its conventional versions are deterministic, recent versions have managed to incorporate randomness (e,g., Kuosmanen and Kortelainen, 2012). Since DEA is a non-parametric method, statistical hypothesis tests are difficult to implement, and large problems can be computationally intensive. In contrast, stochastic frontier analysis employs econometric methods that are generally parametric, though there are non-parametric (e.g., Kumbhakar et al, 2007) or semi-parametric (e.g., Ferrara and Vidoli, 2017) versions. One of the main advantages of the parametric approach is its ability to impose and test the theoretical restrictions like monotonicity, curvature conditions, and tail thickness. This study makes use of a parametric stochastic frontier model. While stochastic frontier analysis is widely used to assess efficiency at the level of the firm, it has been employed in efficiency

[4] Other related studies focus on the effect of female leadership on firm performance. For example, using data on Italian firms, Flabbi et al (2019) find that the effect of female leadership on firm performance is an increasing function of the proportion of female workers, suggesting that female CEOs are more adept at managing female workers.

analysis at the aggregate level as well (e.g., Mastromarco and Ghosh, 2009, Méon and Weill, 2010, and Wang and Wong, 2012), though not as commonly. As demonstrated next, it easily lends itself to the research question at hand.

3. Empirical Model

Consider the stochastic production function rendered in logs as:

$$\ln Y_{it} = f(\ln L_{it}, \ln K_{it}, \ln E_{it}, t; \beta) + v_{it} - u_{it} \tag{1}$$

where Y_{it} denotes country i's real GDP at time t, L_{it} signifies aggregate employment in country i at time t, K_{it} represents country i's stock of physical capital at time t, E_{it} symbolizes country i's energy usage at time t, β is a vector of parameters, v_{it}'s are the usual independently and identically distributed two-sided error terms with normal distribution, i.e., $v_{it} \sim N(0, \sigma_v^2)$, and u_{it}'s are non-negative independently distributed (conditional on exogenous variables) random variables associated with technical-inefficiency, which we will call the inefficiency term. We assume that u_{it} has a half-normal distribution with scale parameter $\sigma_{u,it}$, i.e., $u_{it} \sim N^{+}(0, \sigma_{u,it}^2)$. We assume that $\sigma_{u,it}^2 = \exp(z_{it}^{'}\alpha)$, so that $\ln\sigma_{u,it}^2 = z_{it}^{'}\alpha$, z_{it} being a vector of explanatory variables, termed environmental variables, related to country i's aggregate technical inefficiency at time t. Technical efficiency is defined as:

$$TE_{it} = \exp(-u_{it}) \tag{2}$$

In stochastic frontier models, empirical identification of efficiency is achieved through skewness of the composed error term $\varepsilon_{it} = v_{it} - u_{it}$

We model the deterministic part of the production function in Equation (1) by the translog function, which is a flexible functional form. An important advantage of flexible functional forms is that they do not impose prior restrictions on the Allen-Uzawa elasticities of substitution. Moreover, the translog functional form can be considered the second-degree Taylor series approximation of an unknown functional form (Caves and

Christensen, 1980).[5] Time, *t*, is included as an argument of the translog production function in a bid to flexibly incorporate technological progress. Whereas the arguments of the typical macroeconomic production function are but labor and capital, the inclusion of energy is justified upon the grounds that it is a ubiquitous input. While not all of the energy consumed is in the nature of an input in production, a very substantial portion is. For example, data from the US Energy Information Administration suggests that about 63% of the energy consumed in the United States is an input in production, the remainder being drawn by homes and, presumably household-owned, light-duty vehicles. This fraction is likely to be higher in developing countries, where household energy use is generally low. The model also includes country-specific fixed effects, which capture the time-invariant heterogeneity of countries. Greene (2005a,b) and Kutlu and McCarthy (2016) argue that heterogeneity may be confused with inefficiency if unobserved heterogeneity isn't controlled for in stochastic frontier models.[6]

The error term v_{it} may be considered to arise from mismeasurement of real GDP or random factors affecting production such as agro-climatic conditions, extreme natural events, and domestic and international political events. Hence, the function

$$\ln Y_{it}^{*} = f(\ln L_{it}, \ln K_{it}, \ln E_{it}, t; \beta) + v_{it}, \tag{3}$$

represents the *stochastic* production frontier, describing maximum attainable output at time *t*, achieved when the inefficiency term, u_{it}, is zero. The term capturing inefficiency in production, u_{it}, is non-negative since output can never exceed maximum attainable output. Given that u_{it} is half-normally distributed with scale parameter $\sigma_{u,it}$, its unconditional expectation is $\sigma_{u,it}\sqrt{2/\pi}$ and its unconditional variance $\sigma_{u,it}^{2}(1-2/\pi)$. Therefore, the environmental factors from among the elements of z_{it} that raise (lower) the unconditional variance of the inefficiency term u_{it} by increasing (decreasing) the scale parameter $\sigma_{u,it}$, also raise (lower) its unconditional mean.

[5] For alternative, yet somewhat less frequently used, flexible functional forms, see Kutlu, Liu, and Sickles (2022).

[6] See Kutlu and Tran (2019) for a brief survey of heterogeneity in stochastic frontier models.

In practice, following Jondrow et al. (1982), technical inefficiency is rather predicted by the conditional expectation $E\left(u_{it} | \varepsilon_{it} \right)$, and, following Battese and Coelli (1988), technical efficiency by the conditional expectation $E\left(\exp(-u_{it}) | \varepsilon_{it} \right)$. Kumbhakar et al. (2020) demonstrate that

$$\frac{\partial E\left(u_{it} | \varepsilon_{it} \right)}{\partial \sigma_{u,it}} \geq 0, \tag{4}$$

and that

$$\frac{\partial E\left(\exp(-u_{it}) | \varepsilon_{it} \right)}{\partial \sigma_{u,it}} \leq 0 \tag{5}$$

i.e., that the environmental factors that increase (decrease) the scale parameter $\sigma_{u,it}$ raise (lower) technical inefficiency while lowering (raising) technical efficiency.

The coefficients of the translog frontier production function $f(\ln L_{it}, \ln K_{it}, \ln E_{it}, t; \beta)$ together with the coefficients of the environmental variables, α, may be estimated by the method of maximum likelihood estimation.[7] There are at least two advantages to our using stochastic frontier analysis. First, the method supplies a *relative* measure of macroeconomic performance, in that the aggregate output produced by a quantity of inputs is compared to the maximum output that those inputs might have yielded based on production in the best-performing countries. Second, while total factor productivity too is a comparative measure of macroeconomic performance, in that it is also based on distance to a function, one describing the average relation between inputs and output, it confounds efficiency with production technology and returns to scale. For example, Calice, Kutlu, and Zeng (2021) are compelled to decompose TFP growth into returns to scale, technical progress, and technical efficiency change components.[8]

The analysis includes the following time-varying environmental variables: women's share of employment, this variable interacted with the time-invariant fraction of the population descended from ethnic groups who adopted the plough as an agricultural implement, the POLITY2 score of the Center for Systemic

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[7] For example, STATA's *frontier* routine estimates such a model.

[8] For details about total factor productivity growth decompositions, see Kumbhakar and Lovell (2000).

Peace, measuring the degree of political regime authority on a 21-pont scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy), the World Bank's Control of Corruption indicator, capturing perceptions of the extent to which public power is exercised for private gain, with higher values indicating less corruption, and the share of international trade in GDP.

Women's share of employment is considered positively related to gender equity in labor market opportunities. However, the expected decrease in productive inefficiency arising from greater gender equity may be dampened by patriarchal cultural norms that promote the misallocation of employed women. There is reason to believe that such norms have agricultural origins. By combining pre-industrial ethnographic data with measures of women's present participation in economic and public life, Alesina, Giuliano, and Nunn (2013) uncover rigorous evidence supportive of Boserup's (1970) thesis that the adoption of the plough in ancient times masculinized agriculture since it was a heavy implement drawn by powerful and recalcitrant draft animals[9], leading to a sexual division of labor whereby women's work was confined to the home, which eventually gave rise to cultural norms prescribing a domestic role for women in society. Alesina, Giuliano, and Nunn (2013) find that there continues to be less female participation in economic and public life in countries in which a greater proportion of the population is descended from ethnic groups who adopted the plough. There is precedent, thus, for the measurement of the strength of patriarchal cultural norms as the fraction of the population whose ancestors adopted the plough. It is plausible that, besides constituting a cultural barrier to women's participation in employment, these norms also govern *employed* women's work lives, by, for example, prescribing their confinement to occupations deemed suitable for women, such as school teaching or nursing, or to less productive roles within any occupation. In other words, patriarchal cultural norms may promote a misallocation of employed women that dampens the increase in productive efficiency from more women entering employment.

Given Acemoglu, Naidu, Restrepo, and Robinson's (2019) finding that democracy boosts economic performance, democracy is expected to be negatively associated with productive inefficiency. Since corruption

[9] This is as opposed to light tools readily deployed by women, such as the hoe and the digging stick, in agro-ecological regions of shifting cultivation.

has long been estimated to hurt economic performance (Mauro, 1995; Olson, Sarna, and Swamy, 2000), the World Bank's Control of Corruption indicator too is expected to be negatively related to productive inefficiency. By Hicks's Quiet Life hypothesis (Hicks, 1935), managers of firms with market power are likelier to pursue the quiet life than strive to reap monopolistic rents. In other words, the lack of market competition likely promotes inefficiencies. International trade typically heightens market competition. Firms whose preserve was the domestic market must compete against imports, and exporting firms must compete abroad. Besides, it has been argued that more open economies are better able to absorb technological advances generated in countries at the leading edge of invention and innovation (e.g., Romer, 1992). This too would likely reduce inefficiency. Hence, productive inefficiency is expected to be negatively related to trade openness as measured by the sum of exports and imports as a share of GDP, especially in light of the evidence of a positive relation between trade exposure and dynamic efficiency as measured by the rate of economic growth (e.g., Edwards, 1998).

4. Results

The analysis is conducted upon an unbalanced panel of 116 countries over the years 1996, 1998, 2000, and 2002 – 2015. The discontinuities in the time series are dictated by the World Bank's originally discontinuous reporting of its Control of Corruption data. Table 1 presents the sample means of a selection of the variables employed in the analysis. These pertain to the levels of the variables employed in logs in the analysis. The level of employment by gender is calculated from the World Bank's unemployment rate and labor force data as the labor force × (100 - unemployment rate) / 100. Aggregate employment is calculated as the sum of male and female employment, and women's share of employment as simply female employment as a percentage of aggregate employment. That the mean of women's share of employment is substantially less than half attests to gender inequity in labor market opportunities globally. Aggregate energy consumption is calculated as the product of per capita energy consumption and the population, these data obtained from the World Bank.

Table 1 is about here

Table 2 presents maximum-likelihood coefficient estimates of the most parsimonious version of the empirical model.[10] To control for static country-specific influences upon maximum attainable output and the inefficiency term, country dummy variables are included as arguments of both the deterministic portion of the stochastic frontier production function as well as the function describing the log of the variance of the inefficiency term. Recall that inefficiency (efficiency) decreases (increases) in the environmental variables negatively related to the variance of the inefficiency term. Hence, by these estimates, aggregate inefficiency decreases in women's share of employment. In other words, it appears that greater equity in women's labor market opportunities makes for a more technical efficient economy. It is notable as well that a decrease in corruption, as measured by a higher Control of Corruption score, increases technical efficiency, as does greater democracy as measured by a higher POLITY2 score. The mean of observation-level estimates of efficiency for this model is 92.00%, which is reasonable. When women's share of employment increases by one percentage point, the median predicted change in efficiency is 0.51 percentage points. When the Control of Corruption score increases by 1 standard deviation, the median predicted change in efficiency is 3.43 percentage points. When the POLITY2 score increases by 1 standard deviation, the median predicted change in efficiency is 1.26 percentage points.[11] Analogous figures for our other models are very similar.

Table 2 is about here

Table 3 reports estimates pertaining to a version of the model in which patriarchal cultural norms moderate the effect of gender equity in labor market opportunities upon aggregate technical efficiency. While, as before, greater gender equity in labor market opportunities increases technical efficiency, the increase is smaller the greater the fraction of the population that is descended from ethnic groups who adopted the plough

[10] Due to the translog functional form's connection with the Taylor series approximation, it is customary to multiply the squared variables by 0.5. This rescaling does not have any qualitative effect upon the results.

[11] When calculating the predicted marginal effects of environmental variables on efficiency, we predicted the derivative of u_{it} by the derivative of $E[u_{it}] = s_{u,it}\sqrt{2/p}$ with respect to the relevant environmental variable.

as an agricultural implement. This is consistent with the hypothesis that, while greater employment opportunities for women makes aggregate production more efficient by bringing talented women into the workforce, patriarchal cultural norms partly dissipate this benefit by promoting the misallocation of employed women, for example, their confinement to occupations considered suitable for women or to less productive roles within any occupation. Once again, a decrease in corruption and a strengthening of democracy make for a more productively efficient economy.

Table 3 is about here

Table 4 presents estimates ensuing from an alternate measure of the input of labor in the frontier production function, one that accounts for human capital as measured by the average years of schooling among 15 – 64 year olds. These schooling data are reported by Barro and Lee (2010) in five-year intervals spanning the years 1950 – 2010. A synthetic measure of average schooling for the years omitted by Barro and Lee is obtained by interpolation and extrapolation. Aggregate employment is then multiplied by these filled-in average years of schooling to yield an alternative measure of the input of labor as worker-years of schooling. The results remain qualitatively unchanged.

Table 4 is about here

Table 5 reports estimates that result from inclusion among the environmental variables of the share of international trade in GDP. This entails the loss of some observations on account of missing data. By these estimates as well, aggregate technical efficiency increases in women's share of employment, with the benefit dampened by a legacy of the use of the plough. As before, a decrease in corruption and a strengthening of democracy serve to reduce inefficiency. Expectedly, technical efficiency increases in trade openness. In sum, a positive relation between gender equity in labor market opportunities and efficiency in the production of GDP remains strongly supported.

Table 5 is about here

The hypothesis that patriarchal cultural norms promote a misallocation of employed women that weakens the efficiency gains from greater gender equity in labor market opportunities, merits further investigation. For example, is a legacy of plough use associated with misallocation in the form of the greater occupational segregation of the genders? There are a number of ways of measuring occupational segregation, of which the Duncan Index (Duncan and Duncan, 1955) is widely employed. It is calculated as:

$$DI = \frac{1}{2}\sum_i \left[\frac{M_i}{M} - \frac{F_i}{F}\right], \tag{6}$$

where M_i and F_i are, respectively, the numbers of men and women in occupation *i*, and M and F are, respectively, the total number of men and women in the labor force. Greater occupational segregation of the genders leads to higher values of the Duncan Index. Using data from the International Labor Organization, Das and Kotikula (2019) compute a Duncan Index for 80 developed and developing countries. For 75 of these, a legacy of plough use is quantifiable. Table 6 presents OLS coefficient estimates of regressions of the Duncan Index of the occupational segregation of the genders against, among other variables, the fraction of the population descended from ethnic groups who adopted the plough. These do not indicate that a legacy of plough use increases the occupational segregation of the genders. Thus, if patriarchal cultural norms promote a misallocation of employed women, it likely takes forms other than women's confinement to occupations deemed suitable for women. Perhaps patriarchy erects barriers to working women's professional advancement in any occupation, to the detriment of their productivity.

Table 6 is about here

5. Conclusion

Whereas a tradeoff between equity and efficiency continues to loom large in the imaginations of economists and policymakers, this paper finds that there is no equity-efficiency tradeoff when the concerned equity is gender equity in labor market opportunities. Indeed, it finds that, far from lowering efficiency, greater gender equity in employment opportunities improves it. While a positive relation between gender equity in labor market opportunities and aggregate economic performance has been posited by a sizeable theoretical literature, it has not been sufficiently empirically verified. This paper's findings contribute to the remedying of this deficit. Its other contribution is its novel use of stochastic frontier analysis towards this end.

The paper also contributes to the economic-anthropological literature on the persistent effects of cultural norms formed in the distant past. Patriarchal cultural norms with roots in the ancient adoption of the plough as an agricultural implement are believed to hinder women's participation in economic and public life (Alesina, Giuliano, and Nunn, 2013). This study's findings suggest that these norms govern employed women's work lives as well. The finding that the gain in efficiency from greater gender equity in employment opportunities is dampened by a legacy of the use of the plough is consistent with patriarchal cultural norms promoting a misallocation of employed women, for example, their confinement to less productive roles at work. The study's findings also confirm that aggregate technical efficiency is improved by greater democracy, less corruption, and more economic openness.

Table 1
Sample Means of Selected Variables

Variable	Source	Obs.	Mean	SD
GDP (billions of 2011 international dollars)	IMF	1,835	696.61	1,862.33
employment (millions of workers)	World Bank (constructed)	1,835	22.81	79.19
employment × average years of schooling	World Bank + Barro & Lee (2010)	1,835	190.00	626.96
capital stock (billions of 2011 international dollars)	IMF	1,835	1,505.04	4,085.16
energy consumption (millions of tons of oil equivalent)	World Bank (constructed)	1,835	97.43	304.22
women's share of employment (%)	World Bank (constructed)	1,835	39.57	10.27
women's share of employment × fraction of population descended from ethnic groups who adopted the plough	World Bank + Alesina, Giuliano, & Nunn (2013)	1,835	24.10	19.76
Control of Corruption indicator (higher values => less corruption)	World Bank	1,835	0.11	1.07
POLITY2 (higher values => greater democracy)	Center for Systemic Peace	1,835	4.98	6.01
share of international trade in GDP (%)	World Bank	1,785	85.48	50.83

Notes: variables employed in logs in the analysis expressed in (rescaled) levels

Table 2
Technical Inefficiency and Women's Share of Employment

Variable	**Coeff.**	**SE**
Estimates of translog frontier production function		
constant	3.273***	0.034
log employment – l	0.285***	0.022
log capital stock – k	0.303***	0.015
log energy consumption – e	0.180***	0.018
time – t	0.016***	0.001
$0.5 \times l^2$	–0.098***	0.017
$0.5 \times k^2$	–0.119***	0.014
$0.5 \times e^2$	0.037***	0.012
$0.5 \times t^2$	–0.00006	0.00007
$l \times k$	0.088***	0.012
$l \times e$	–0.050***	0.014
$l \times t$	0.003***	0.000
$k \times e$	0.050***	0.015
$k \times t$	–0.003***	0.001
$e \times t$	0.001	0.001
country fixed-effects	yes	
Determinants of log variance of technical inefficiency		
constant	5.881***	2.042
women's share of employment	–0.186***	0.040
Control of Corruption indicator	–1.165***	0.255
POLITY2	–0.076***	0.026
country fixed-effects	yes	
mean efficiency	92.00%	
log-likelihood	2,939.9762	
number of observations	1,835	

*, **, and *** denote, respectively, significance at the 10%, 5%, and 1% levels

Table 3
The Role of Patriarchy

Variable	**Coeff.**	**SE**
Estimates of translog frontier production function		
constant	3.275***	0.035
log employment – l	0.280***	0.023
log capital stock – k	0.310***	0.014
log energy consumption – e	0.169***	0.018
time – t	0.017***	0.002
$0.5 \times l^2$	–0.097***	0.017
$0.5 \times k^2$	–0.122***	0.015
$0.5 \times e^2$	0.032***	0.012
$0.5 \times t^2$	–0.00008	0.00008
$l \times k$	0.085***	0.013
$l \times e$	–0.046***	0.014
$l \times t$	0.003***	0.000
$k \times e$	0.054***	0.015
$k \times t$	–0.003***	0.001
$e \times t$	0.001	0.001
country fixed-effects	yes	
Determinants of log variance of productive inefficiency		
constant	15.183***	4.176
women's share of employment	–0.371***	0.082
women's share of employment × fraction of the population descended from ethic groups who adopted the plough	0.240**	0.095
Control of Corruption indicator	–1.172***	0.270
POLITY2	–0.078***	0.028
country fixed-effects	yes	
mean efficiency	92.02%	
log-likelihood	2,943.4721	
number of observations	1,835	

*, **, and *** denote, respectively, significance at the 10%, 5%, and 1% levels

Table 4
Robustness: Employment Measured as Worker-Years of Schooling

Variable	Coeff.	SE
Estimates of translog frontier production function		
constant	3.362***	0.034
log [employment × average years of schooling] – l	0.087***	0.018
log capital stock – k	0.356***	0.014
log energy consumption – e	0.207***	0.018
time – t	0.019***	0.001
0.5 × l^2	–0.104***	0.017
0.5 × k^2	–0.094***	0.016
0.5 × e^2	0.039***	0.013
0.5 × t^2	–0.00020***	0.00008
l × k	0.069***	0.014
l × e	–0.011	0.017
l × t	0.004***	0.001
k × e	0.023*	0.012
k × t	–0.004***	0.001
e × t	–0.0003	0.001
country fixed-effects	yes	
Determinants of log variance of productive inefficiency		
constant	3.947	3.345
women's share of employment	–0.141**	0.066
women's share of employment × fraction of the population descended from ethic groups who adopted the plough	0.128*	0.077
Control of Corruption indicator	–1.011***	0.245
POLITY2	–0.075***	0.025
country fixed-effects	yes	
mean efficiency	91.90%	
log-likelihood	2,904.2692	
number of observations	1,835	

*, **, and *** denote, respectively, significance at the 10%, 5%, and 1% levels

Table 5
Robustness: Trade Openness and Inefficiency

Variable	**Coeff.**	**SE**
Estimates of translog frontier production function		
constant	3.254***	0.033
log employment – l	0.288***	0.023
log capital stock – k	0.300***	0.015
log energy consumption – e	0.177***	0.019
time – t	0.016***	0.001
$0.5 \times l^2$	–0.086***	0.016
$0.5 \times k^2$	–0.094***	0.016
$0.5 \times e^2$	0.062**	0.025
$0.5 \times t^2$	–0.00007	0.00007
$l \times k$	0.080***	0.012
$l \times e$	–0.047***	0.015
$l \times t$	0.003***	0.000
$k \times e$	0.030	0.019
$k \times t$	–0.003***	0.001
$e \times t$	0.0002	0.001
country fixed-effects	yes	
Determinants of log variance of productive inefficiency		
constant	10.525**	4.306
women's share of employment	–0.252***	0.084
women's share of employment × fraction of the population descended from ethic groups who adopted the plough	0.280***	0.108
Control of Corruption indicator	–1.220***	0.319
POLITY2	–0.084**	0.033
share of international trade in GDP	–0.017***	0.003
country fixed-effects	yes	
mean efficiency	92.20%	
log-likelihood	2,901.2428	
number of observations	1,785	

*, **, and *** denote, respectively, significance at the 10%, 5%, and 1% levels

Table 6
Ancestral Plough Use and Occupational Segregation
Dependent Variable = Duncan Index of Occupational Segregation by Gender

Variable	**OLS Coefficient Estimates**		
	(1)	(2)	(3)
constant	0.439*** (0.030)	0.116 (0.099)	0.505*** (0.151)
fraction of the population descended from ethnic groups who adopted the plough	–0.002 (0.037)	–0.057 (0.038)	–0.029 (0.055)
log nominal per capita income		0.039*** (0.011)	0.023** (0.011)
continent dummies with Africa divided into North and Sub-Saharan Africa			yes
number of observations	75	75	75
Adj. R^2	-0.0137	0.1149	0.3806

*, **, and *** denote, respectively, significance at the 10%, 5%, and 1% levels

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