Human Capital and Financial Development: Firm-Level Interactions and Macroeconomic Implications*

Lian Allub† Pedro Gomes‡ Zoë Kuehn§

CAF Birkbeck UAM

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Abstract

Capital-skill complementarity in production implies non-trivial interactions between availability of human capital and financial constraints. Firms that are constrained in their access to finance hire a lower proportion of skilled workers compared to unconstrained firms. On the other hand, a lack of human capital increases skilled wages, reducing firms' desired capital intensity and thus loosening effective financial constraints. We build a dynamic occupational-choice model to quantify how a lack of human capital and financial frictions, as well as the joint effect of both restrictions interact to explain cross-country differences in aggregate output per capita, productivity, average firm size, and college premia. We calibrate our model to US data, and we vary financial frictions and educational attainment as observed across countries. We find that the joint effect of both restrictions is up to 50 percent larger compared to the sum of the individual effects. In countries with a negligible share of tertiary educated workers, financial development has only small effects on aggregate output.

JEL Classification: O11, O40, E22, J24, E24.

Keywords: financial development, financial frictions, capital-skill complementarity, educational attainment, entrepreneurship, college premium.

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†CAF-Development Bank of Latin America, Madero 900, Torres Catalinas Plaza, Piso 14, Ciudad Autónoma de Buenos Aires, Argentina, C1106 E-mail: lallub@caf.com.

‡Birkbeck, University of London, Department of Economics, Mathematics and Statistics, Malet Street, WC1E 7HX London, United Kingdom, E-mail: p.gomes@bbk.ac.uk.

§Universidad Autónoma de Madrid, Departamento de Análisis Económico: Teoría Económica e Historia Económica, Campus de Cantoblanco 28049 Madrid, Spain. Email: zoe.kuehn@uam.es

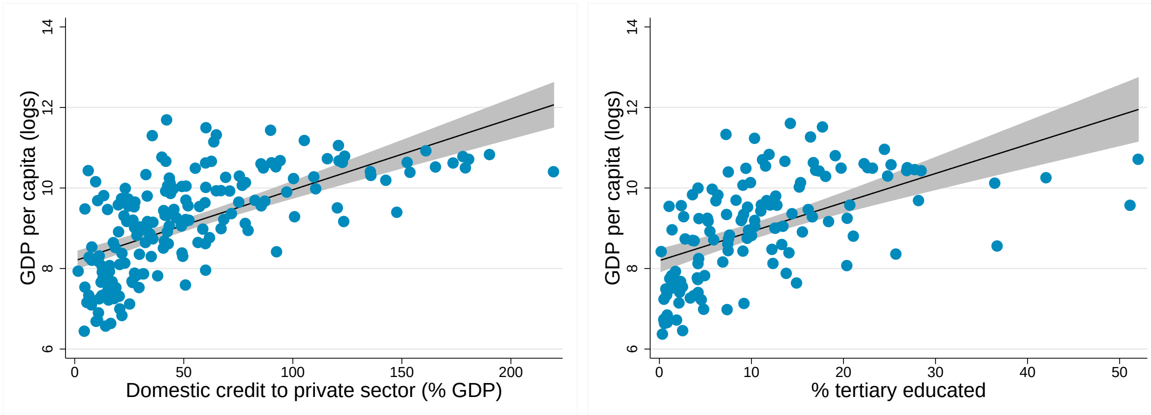
1 Introduction

The lack of physical capital and its misallocation together with a lack of human capital are among the main causes behind income disparities across countries. While the effects of the scarcity of physical capital on aggregate output were already emphasized in the classic Solow [1956] - Swan [1956] model, recent literature has suggested different micro mechanisms related to misallocation and financial development. In particular, well-functioning financial markets are found to have important effects for entrepreneurship and firm-level outcomes such as size and productivity, with significant macroeconomic implications for aggregate output. These findings point to a positive relationship between domestic credit as a measure of financial market development and countries' per capita Gross Domestic Product (GDP), as depicted in the left-hand graph of Figure 1. On the other hand, the importance of human capital for economic development has been discussed in the literature since the classical works of Lucas [1988], Barro [1991] or Mankiw *et al.* [1992]. This idea is usually illustrated with a positive correlation between countries' GDP per capita and educational attainment, shown in the right-hand graph of Figure 1.

However, the impact of financial development on countries' aggregate output has typically been analyzed separately from the impact of human capital. We argue that both sources of economic development should be analyzed jointly given the widely accepted view in macroeconomics that capital and skilled labor are complements in production (Griliches [1969]; Krusell et. al [2000]). Our analysis shows that capital-skill complementarity implies non-trivial interactions at the firm-level between the availability of human capital and financial frictions, with important macroeconomic effects and far-reaching policy implications. In particular, in our model, gains from financial development crucially depend on countries' educational attainment, which can explain why some episodes of financial deepening were more successful (e.g. East Asian countries) than others (e.g. Latin American countries). On the other hand, our model generates significantly larger output gains from education expansions when financial frictions are low.

Taking capital-skill complementarity in production as given, the current paper aims to quantify the importance of financial frictions, a lack of human capital, and the interaction of these restrictions for explaining cross-country differences in output per capita, productivity, college premia, and average firm size. To this end, we build a dynamic occupational-choice model *à la* Lucas [1978] where individuals with different levels of skills and wealth decide to set up a firm or to work. As in Allub and Erosa [2019] individuals may accumulate assets but can

Figure 1: Economic development, credit and human capital



Source: Domestic credit and GDP data from World Bank, World Development Indicators. Educational attainment of the population age 25 and above from Barro and Lee [2013], average over 1995-2005.

only borrow up to a certain fraction of their wealth. Production uses capital, skilled and unskilled labor as inputs. Under capital-skill complementarity, firms that are constrained in their access to finance hire a lower proportion of skilled labor than unconstrained firms. On the other hand, a lack of human capital increases skilled wages, reducing firms' desired capital intensity and thus loosening effective financial constraints.

To discipline our model, we calibrate it to US data, following Buera and Shin [2013]. Our main application consists of varying financial frictions and educational attainment as observed across countries. This accounting exercise allows us to quantify how much of the differences in output, average firm size, and productivity with respect to the US can be attributed to differences in: i) financial frictions, ii) lack of human capital, and iii) the interaction of both restrictions. We find that the interaction effect is up to 50 percent larger compared to the sum of the individual effects. In countries with a negligible share of tertiary educated workers, financial development has only small effects on aggregate output. Running cross-country regressions of GDP and TFP on the share of tertiary educated and the ratio of domestic credit to GDP, we confirm that the positive relationships in our model are also observed in the data. Considering microdata from the World Bank Enterprise survey, we show that, controlling for several other characteristics, the fraction of skilled workers within a firm depends positively on the firm's level of assets, and that this relationship is stronger in countries with lower financial market development. Our estimated coefficients are remarkably similar to those obtained when using model-generated data.

Highlighting the mechanisms behind our findings, we first show that to depart from a unique optimal ratio of skilled to unskilled labor for all firms and to generate dispersion in this ratio, one needs a combination of two elements: financial frictions and capital-skill complementarity in production. Either one of these elements alone is not sufficient. Moreover, there are two reasons why in our model human capital of the population plays a crucial role. First, as wages of unskilled workers are lower than wages of skilled workers, more unskilled individuals decide to set up a firm. In an economy with many unskilled individuals this reduces average firm size and productivity, similarly to Gomes and Kuehn [2017]. Second, under capital-skill complementarity, human capital of the population, by affecting the desired capital intensity of firms, determines the degree to which financial constraints limit firm size. In an environment with low levels of human capital and high skilled wages, entrepreneurs who see their access to finance improve will not increase their stock of physical capital by much. Hence, financial development in a context of low educational attainment will have very little effect on average firm size, productivity, and output.

This result of our model is useful for policy makers to be able to evaluate under which circumstances financial market or educational reforms have a better chance of being successful. We consider the example of three countries: the Philippines, Mexico, and Malawi, where 21, 11, and less than 1 percent of the population hold a college degree. If financial markets in these countries were as developed as in the US, output would increase by 24 percent in the Philippines, 21 percent in Mexico but by only 9.5 percent in Malawi. In our model, financial frictions, a lack of human capital, and the interaction of both restrictions can explain up to 60 percent of the observed differences in GDP per capita between these three countries and the US.

Our mechanism focuses on the interaction of financial frictions and availability of human capital at the firm level. This is a novel mechanism that differs from the more widely studied idea that capital market imperfections limit the accumulation of human capital and generate poverty traps. For instance, recent work by Mestieri, Schauer, and Townsend [2017] studies the effect of financial constraints on both, entrepreneurship and human capital accumulation of the next generation. The authors find that financial constraints hurt individuals in the center of the income and asset distribution, and that they lead to a higher correlation of household assets and children's schooling. The authors consider that workers with different levels of schooling are perfect substitutes, and thus there is no room for capital being more complementary to skilled compared to unskilled labor in production. While our benchmark model takes the educational attainment of the population as given, in an extension we incorporate individuals' choices to acquire an education, and allow these choices to respond to changes in financial frictions.

Our study is closely related to the only four papers that we are aware of which consider the interplay between financial frictions and human capital at the firm level. Lopez and Olivella [2012] present a real business cycle model and analyze how shocks to financial frictions affect firms' optimal mix of skilled and unskilled labor. The paper by Larrain [2015] proposes a simple framework with only two types of firms to test empirically how financial development has led to more wage inequality. Berniell [2015] sets up a model of informality, occupational choice, and investments in human capital with credit frictions, but she does not perform any quantitative analysis. Finally, Fonseca and Van Doornik [2019] provide very strong empirical evidence supporting the main mechanism present in our model. The authors consider a bankruptcy reform in Brazil that led to an expansion of credit, finding that firms that were constrained before the reform, increased employment, particularly of skilled workers, relative to previously unconstrained firms.

While hence only very few papers have considered firm-level interactions between financial frictions and human capital, separately each strand of literature is quite large. Buera *et al.* [2015] provide an excellent overview of the literature on financial frictions that tends to focus on their effect on firm size (see e.g. Cabral and Mata [2003], Erosa [2001], Hsieh and Klenow [2009] or more recently Cavalcanti et al. [2019]). Closely related to the current paper is Allub and Erosa [2019] who add own-account workers to a model of occupational choice and financial frictions. In their model, reducing financial frictions leads to fewer own-account workers, more employers, and larger firms. Buera, Kaboski and Shin [2011] in an occupational choice model and Midrigan and Xu [2014] in a model of firm exit and entry *a la* Hopenhayn [1992], analyze the effects of financial frictions in an economy with two sectors. In both studies, relaxing financial frictions allows entrepreneurs to pay the fixed operating costs for the more productive sector, which increases its size, leading to gains in aggregate output. While in our one-sector model we abstract from any positive effects of financial development on the extensive margin of entrepreneurship, we contribute to the literature by generalizing the production function to include skilled and unskilled labor as inputs and to feature capital-skill complementarity.[1]

Regarding the second strand of literature, recent papers that study how human capital impacts economic development via its effects on firm size and productivity are Gennaioli *et*

[1] Our paper also relates to the broader literature on firm size distributions that has proposed other explanations as to why average firm size and productivity differ so much across countries, e.g. policy aspects (e.g. Guner *et al.* [2008]) or informality (e.g. Antunes and Cavalcanti [2007]).

al. [2013], Erosa *et al.* [2010]), Roys and Seshadri [2014], Poschke [2018], Gil *et al.* [2019], and Gomes and Kuehn [2017]. We contribute to this literature with two insights. First, we show that the magnitude of the positive effects of human capital on economic development depend crucially on how developed countries' financial markets are. In our model, a similar increase of 20 percentage points in the fraction of tertiary educated workers, raises output by 29 percent when financial frictions are small compared to only 19 percent when access to finance is more severely restricted. Second, the level of financial frictions turns out to be an important determinant of the college premium as financial development raises skilled wages more than unskilled wages.

The remainder of this paper is organized as follows: The next section presents our model. In Section 3 we discuss the calibration, and we carry out two exercises that highlight the model's mechanisms. Section 4 shows and discusses the effects of varying financial frictions and educational attainment on aggregate output, wage inequality, and average firm size. In Section 5 we present robustness checks including an open economy version of our model, a version with a Cobb-Douglas production function, and a version where we model individuals' choices of acquiring an education. Finally Section 6 concludes.

2 Model

We build a model economy *à la* Lucas [1978] with a continuum of infinitely lived agents who differ in their skill levels as workers, their entrepreneurial abilities, and their asset holdings. Given their labor and capital income, each period individuals decide about consumption and savings. Depending on their asset holdings, entrepreneurial abilities, and skills, individuals also choose whether to become entrepreneurs or workers. As typical in these models, under perfect capital markets only skill levels and managerial abilities determine individuals' occupational choices, while under imperfect capital markets, asset holdings also play a role for whether individuals decide to become workers or entrepreneurs. Entrepreneurs produce a homogeneous good by using unskilled labor, skilled labor, capital, and their own abilities as inputs. Since we focus on steady states and for clarity of exposition, we initially omit the time subscript, t, from the description of our model.

Endowments Each individual has one unit of productive time that he supplies inelastically. Individuals differ in their skill levels as workers e, where $e = s, u$ (skilled (s) or unskilled (u)) and in their managerial abilities, z_i, distributed in $Z = [0, \overline{z}]$, and with cdf $F(z_i)$ and density $f(z_i)$.[2] Individuals hold assets a_i, which are distributed in $A = [0, \overline{a}]$, with cdf $H(a_i)$ and density $h(a_i)$. Note that the asset distribution in this model is the outcome of individuals' consumption-savings decisions and as such an endogenous object.

Production Each entrepreneur, i, has access to the same technology. He hires unskilled workers n_i^u, skilled workers n_i^s, and he rents capital k_i. Firms produce a single good according to the following CES production function

$$y_i(n_i^u, n_i^s, k_i) = z_i^{(1-\gamma)}[\mu(n_i^u)^\sigma + (1-\mu)[\lambda(k_i)^\rho + (1-\lambda)(n_i^s)^\rho]^{\frac{\sigma}{\rho}}]^{\frac{\gamma}{\sigma}}, \tag{1}$$

where ρ and σ govern the elasticities of substitution between inputs, μ is the share of unskilled labor in production, and λ is the share of capital in the composite input. The presence of decreasing returns to scale on the marketable inputs implies the existence of entrepreneurial profits that depend on managerial abilities (z_i).

Imperfect capital markets In this economy, enforcement problems of contracts limit the amount of borrowing. In particular, entrepreneurs are only able to borrow an amount equivalent to χ times their asset holdings. Parameter $\chi \in [1; \infty]$ thus represents the strength of the legal institutions in the economy, with $\chi = 1$ indicating the absence of any financial markets. On the other hand, as χ approaches ∞ we converge to an economy with perfect capital markets without any borrowing limits.

Entrepreneurs Entrepreneurs choose the number of skilled and unskilled workers, as well as the amount of capital to maximize their firms' profits. Entrepreneurs always choose strictly positive amounts of all inputs. Given wages per skill level (w^u, w^s) and a gross rental rate for capital (r), the entrepreneur's problem is given by

$$\max_{\{n_i^u, n_i^s, k_i\}} \pi(z_i, a_i) = y_i - w^u n_i^u - w^s n_i^s - r k_i, \tag{2}$$

[2]Gomes and Kuehn [2017] allow for skilled individuals to draw their managerial abilities from a different distribution than unskilled individuals, but once calibrated these distributions turn out to be quite similar. To keep our mechanism more transparent we prefer that all individuals draw their managerial ability from the same distribution, although we acknowledge that effects of education expansions might be larger if they also improve the distribution of managerial ability.

subject to the technology (Equation 1) and the following borrowing constraint: $k_i \leq \chi a_i$. The first-order conditions of the entrepreneur's problem are:

$$\frac{\partial y_i}{\partial n_i^s} = w^s \quad , \quad \frac{\partial y_i}{\partial n_i^u} = w^u \quad , \quad \frac{\partial y_i}{\partial k_i} = r_i, \tag{3}$$

where $r_i = r + \omega_i$, and with ω_i being the multiplier on the collateral constraint. In Appendix A.1 we show how combining these first-order conditions, we can derive the following expression for the entrepreneur's optimal ratio of skilled to unskilled labor:

$$\frac{n_i^s}{n_i^u} = \left[\frac{w^u}{w^s} \frac{(1-\lambda)(1-\mu)[\lambda(\frac{\lambda w^s}{(1-\lambda)r_i})^{\frac{\rho}{1-\rho}} + (1-\lambda)]^{\frac{\sigma-\rho}{\rho}}}{\mu} \right]^{1/(1-\sigma)}. \tag{4}$$

Notice that this optimal skill mix depends on r_i, which is firm-specific and depends on how closely binding the collateral constraint is. If firms are unconstrained in their access to finance then $r_i = r$, and the right-hand-side of the expression only depends on aggregate prices and parameters. For all unconstrained firms, the skilled-unskilled labor ratio is thus constant. For firms that are constrained in their access to finance on the other hand, the skill mix depends on the size of the multiplier and, in turn, on firm characteristics. Notice that while χ is an aggregate parameter, r_i reflects the multiplier on the constraint and is different for each firm. Nevertheless, firms' optimal skill mix will be affected by financial frictions as reductions in χ will tighten the collateral constraint, raising r_i for all constrained firms.

The role of capital-skill complementarity Calculating the derivative of the ratio of skilled to unskilled labor with respect to the firm-specific cost of capital r_i we obtain the following expression

$$sign\left(\frac{\partial(\frac{n_i^s}{n_i^u})}{\partial r_i}\right) = sign\left(\frac{\rho-\sigma}{(1-\rho)(1-\sigma)}\right), \tag{5}$$

where both σ and ρ are smaller than 1. In particular, the sign is negative for the case of capital-skill complementarity in production, $\rho < \sigma$. Hence, entrepreneurs who are more financially constrained and who face higher costs of capital will hire a lower ratio of skilled to unskilled labor. Notice that if $\sigma = \rho$, which includes the case of a Cobb-Douglas production function, entrepreneurs will always employ the same ratio of skilled to unskilled labor, independently of their cost of capital.

The individual's problem Individuals maximize the infinite sum of discounted utilities:

$$\sum_{t=0}^{\infty} \beta^t \frac{(c_t^i)^{1-\psi}}{1-\psi}, \tag{6}$$

where c_t^i denotes consumption of individual i at time t, and $\beta \in (0,1)$ is the discount factor. The parameter ψ determines individuals' degree of risk aversion. The individual chooses consumption and savings, and the optimal occupation, in order to maximize Equation 6 subject to the individual's budget constraint:

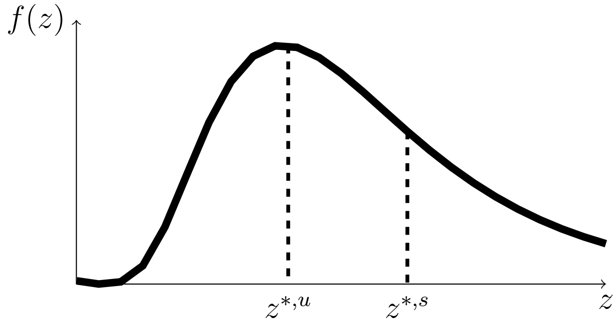
$$\begin{aligned} c_i + a_i' &= I_{z_i(a_i) < z^{*,e}(a_i)}(w^e + \tilde{r}a_i) + \\ &+ I_{z_i(a_i) \geq z^{*,e}(a_i)}(\pi(z_i, a_i) + \tilde{r} * max(0, (a_i - k_i))). \end{aligned}$$

We denote by $z^{*,e}(a_i)$ the marginal entrepreneur of skill e with asset holdings a_i. The individual's income includes wage and capital income if the individual chooses to become a worker, and it includes profits for those who choose to become entrepreneurs. The net rental rate of capital, $\tilde{r}$, in equilibrium is $\tilde{r} = r - \delta$. If entrepreneurs find it optimal to not use all their assets as capital in production, they earn an additional capital income. The solution to the individual's problem is characterized by the following condition determining the thresholds for becoming an entrepreneur for individuals of each skill level:

$$w^e + \tilde{r}a_i = \pi(z^{*,e}(a_i), a_i) + \tilde{r} * max(0, (a_i - k_i)). \tag{7}$$

This condition is somewhat similar to Lucas' [1978] condition for the "marginal" entrepreneur. Wage payments plus capital income have to equal the profits individuals of a certain skill and with a certain amount of assets expect to make as entrepreneurs. Different wages for skilled and unskilled individuals translate into different thresholds, as depicted in Figure 2. However, note that once entrepreneurial abilities are drawn and certain individuals choose to become entrepreneurs, their returns are no longer dependent on their skill levels.

Figure 2: Thresholds for becoming an entrepreneur, by skill levels



Value function for workers For an individual of skill e, managerial ability z_i and endowed with assets a_i, the value of being a worker is given by

$$V_e^{wk}(z_i, a_i) = \max_{\{a_i', c_i\}} \Bigg(U(c_i) + \beta\zeta E[I_{z_i(a_i') < z^{*,e}(a_i')} V_e^{wk}(z_i, a_i') + I_{z_i(a_i') \geq z^{*,e}(a_i')} V_e^{ent}(z_i, a_i')]$$
$$+\beta(1-\zeta)E[I_{z_i'(a_i') < z^{*,e}(a_i')} V_e^{wk}(z_i', a_i') + I_{z_i'(a_i') \geq z^{*,e}(a_i')} V_e^{ent}(z_i', a_i')] \Bigg),$$

where ζ is the probability that the individual keeps the same managerial ability z_i. With probability $1-\zeta$ individuals obtain new draws for their managerial ability.[3] Furthermore, individuals who are workers today may, as they accumulate assets, decide to become entrepreneurs in the future.

Value function for entrepreneurs The value of being an entrepreneur for an individual of skill e, managerial ability z_i and endowed with assets a_i is given by

$$V_e^{ent}(z_i, a_i) = \max_{\{a_i', c_i\}} \Bigg(U(c_i) + \beta\zeta E[V_e^{ent}(z_i, a_i')]$$
$$+\beta(1-\zeta)E[I_{z_i'(a_i') < z^{*,e}(a_i')} V_e^{wk}(z_i', a_i') + I_{z_i'(a_i') \geq z^{*,e}(a_i')} V_e^{ent}(z_i', a_i')] \Bigg).$$

Notice that individuals who are entrepreneurs today can only become workers in the future if they draw a new managerial ability z_i, which happens with probability $1-\zeta$.

[3]This is similar to Buera and Shin [2013] and needed for financial frictions to have long-run effects on output. Because if managerial ability were constant over time all entrepreneurs would accumulate enough wealth to operate on an unconstrained scale.

Equilibrium In equilibrium, all four markets must clear: the two labor markets plus the capital and goods markets. Denote the demand for skilled and unskilled labor services, and capital by an entrepreneur of managerial ability z_i by $n_i^s(z_i, w^u, w^s, r_i)$, $n_i^u(z_i, w^u, w^s, r_i)$, and $k_i(z_i, w^u, w^s, r_i)$, respectively. We assume that a fraction θ of the population is skilled. For the skilled labor market to clear, the supply of skilled workers has to equal the sum of demands for skilled labor by all entrepreneurs:

$$
\begin{aligned}
\theta \int_0^{\overline{a}} F(z^{*,s}(a_i))h(a)da &= \theta \int_0^{\overline{a}} \int_{z^{*,s}(a_i)}^{\overline{z}} n_i^s(z_i, w^u, w^s, r_i) f(z)dzh(a)da \\
&\quad + (1-\theta) \int_0^{\overline{a}} \int_{z^{*,u}(a_i)}^{\overline{z}} n_i^s(z_i, w^u, w^s, r_i) f(z)dzh(a)da.
\end{aligned}
$$

Similarly, the labor market for unskilled workers clears when:

$$
\begin{aligned}
(1-\theta) \int_0^{\overline{a}} F(z^{*,u}(a_i))h(a)da &= \theta \int_0^{\overline{a}} \int_{z^{*,s}(a_i)}^{\overline{z}} n_i^u(z_i, w^u, w^s, r_i) f(z)dzh(a)da \\
&\quad + (1-\theta) \int_0^{\overline{a}} \int_{z^{*,u}(a_i)}^{\overline{z}} n_i^u(z_i, w^u, w^s, r_i) f(z)dzh(a)da.
\end{aligned}
$$

The market clearing condition for capital is given by:

$$
\begin{aligned}
K \equiv \int_0^{\overline{a}} a_i h(a)da &= \theta \int_0^{\overline{a}} \int_{z^{*,s}(a_i)}^{\overline{z}} k_i(z_i, w^u, w^s, r_i) f(z)dzh(a)da \\
&\quad + (1-\theta) \int_0^{\overline{a}} \int_{z^{*,u}(a_i)}^{\overline{z}} k_i(z_i, w^u, w^s, r_i) f(z)dzh(a)da.
\end{aligned}
$$

With $y_i(z_i, w^u, w^s, r_i)$ being the supply of goods by any entrepreneur of ability z_i, for market clearing in the goods market, we require

$$
\begin{aligned}
C + \delta K &= \theta \int_0^{\overline{a}} \int_{z^{*,s}(a_i)}^{\overline{z}} y_i(z_i, w^u, w^s, r_i) f(z)dzh(a)da \\
&\quad + (1-\theta) \int_0^{\overline{a}} \int_{z^{*,u}(a_i)}^{\overline{z}} y_i(z_i, w^u, w^s, r_i) f(z)dzh(a)da.
\end{aligned}
$$

3 Calibration

We calibrate our model to data from the United States. Some parameters are set exogenously based on outside information or as normalizations, while the remaining parameters are calibrated to match US statistics for 2000-2010. Table 1 displays our chosen parameter values. We take several parameters from Buera and Shin [2013]. In particular, we fix the depreciation rate at 6 percent per year, and we set the risk aversion parameter to 1.5. We also choose a probability of drawing a new managerial ability in each period of 0.106. The fraction of skilled individuals is set to 0.31, equal to the share of the US population above 25 with completed tertiary education according to Barro and Lee [2013]. As it is common in the literature, the United States is considered to have perfect capital markets, and hence χ the parameter governing the tightness of financial frictions is set to a large enough number such that no firm is financially constrained. For the parameters governing the elasticities of substitution between capital, skilled and unskilled labor ρ and σ, we use values of -0.495 and 0.401 respectively as estimated by Krusell et al [2000].

We are left with six parameters that are calibrated to match six targets. The parameter γ that determines decreasing returns at the firm level is set to 0.87 to match a ratio of

Table 1: Baseline calibration

Parameters set exogenously	**Value**	**Source**
Depreciation rate (δ)	0.060	Buera and Shin [2013]
Risk aversion (ψ)	1.5	Buera and Shin [2013]
Prob. of drawing a new ability (ζ)	0.106	Buera and Shin [2013]
Fraction of skilled individuals (θ)	0.31	Barro and Lee [2013]
Tightness of financial frictions (χ)	∞	normalization
<u>Production function</u>		
Substitutability		
Capital and skilled labor (σ)	0.401	Krusell et al. [2000]
Capital and unskilled labor (ρ)	-0.495	Krusell et al. [2000]
Calibrated parameters	**Value**	**Target**
Span-of-Control (γ)	0.87	Profits to GDP ratio
Discount factor (β)	0.929	Real interest rate
<u>Production function</u>		
Weights		
Unskilled labor in production (μ)	0.439	College premium
Capital in Production (λ)	0.619	Capital-output ratio
<u>Distribution of ability</u>		
Shape parameter (α)	1.047	Mean establishment size
Scale parameter (ξ)	0.426	Relative size establishment unskilled-skilled manager

profits to GDP of 0.13. As in Buera and Shin [2013], the value for the discount factor β targets an annual real interest rate of 4.5 percent. Turning to the parameters of the production function, the weight of capital in production, λ, is set to 0.64 to target a private capital-output ratio of 2, as established for the United States by Kamps [2006]. According to Goldin and Katz [2009], the college premium in the 2000 US Census was 61%. To match this number, μ is calibrated to a value of 0.439. Finally, we consider a Pareto distribution for managerial ability which can be characterized by two parameters α and ξ. Both skilled and unskilled individuals are assumed to draw their managerial abilities from the same distribution. The parameters of this distribution are chosen to target two statistics on average firm size. According to the Business Dynamic Statistics of the US Census, mean establishment size was 17.5. The Survey of Business Owners (SBO 2007) has information about firm size and the education of managers. We restrict our sample to firms with managers who are majority owners. The average size of establishments with primary and secondary educated entrepreneurs was equal to 70% of mean establishment size. We set scale parameter ξ to 0.426 and shape parameter α to 1.047 to target these numbers.

Table 2 displays our calibration targets next to the model's statistics. We also show some additional moments that were not targeted. Our model matches the data well, including several non-targeted moments. The model matches several statistics from the Business

Table 2: Calibration targets and model values, baseline model

Targeted moments	**Source**	**Data**	**Model**
Profits to GDP ratio	BEA	0.13	0.13
Real interest rate	Buera and Shin [2013]	0.045	0.045
Mean establishment size	US Census	17.46	17.49
Relative size establishment skilled manager	SBO(2007)	0.70	0.70
Capital-output-ratio	Kamps [2006]	2.00	2.00
College Premium 2000	Goldin and Katz [2009]	0.63	0.63
Non-targeted moments	**Source**	**Data**	**Model**
Establishment share, < 10 employees	US Census	0.70	0.54
Establishment share, $10 - 19$ employees	US Census	0.14	0.23
Establishment share, $20 - 99$ employees	US Census	0.13	0.23
Establishment share, > 100 employees	US Census	0.03	0.01
Employment share, < 10 employees	US Census	0.15	0.20
Employment share, $10 - 19$ employees	US Census	0.10	0.16
Employment share, $20 - 99$ employees	US Census	0.30	0.39
Employment share, > 100 employees	US Census	0.45	0.24
Domestic credit to GDP ratio	WDI (2000)	1.62	1.56
Labor share	BEA	0.63	0.66
Self-employment rate	OECD	0.07	0.05

Dynamic Statistics of the US Census, regarding establishment and employment shares by firm size. The dimension with the worst performance is the employment share of large firms which is only 24 percent in the model, compared to 45 percent in the data.[4] Regarding aggregate statistics, the model slightly underestimates the US ratio of domestic credit to GDP of 1.62, and generates a labor share that is slightly higher than the 0.63 found in the data. In our model once we target average firm size, the self-employment rate is determined. In particular, targeting an average establishment size of 17.5 fixes the entrepreneurship rate in our model at 5% ($\frac{1-e}{e} = 17.5$; $e = 0.054$). The model thus underestimates the share of self-employed in the US labor force of 7% as reported by the OECD.[5]

3.1 Interaction between financial frictions and occupational choice

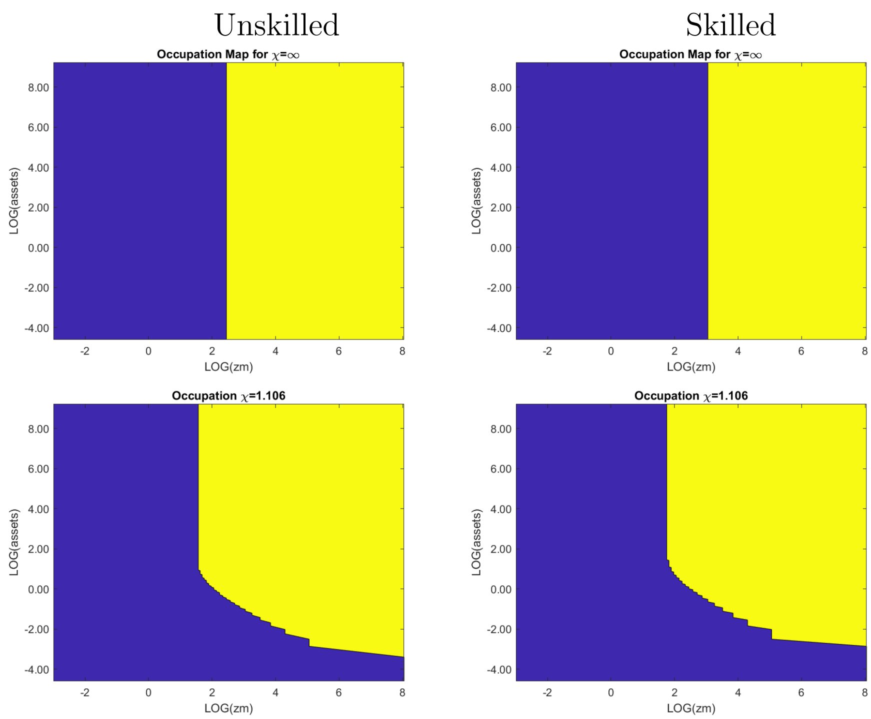
Given our calibration, we solve the model for economies with different shares of skilled individuals (θ) and different levels of financial frictions (χ). Figure 3 shows the occupational maps for the choice to become an entrepreneur (light) or a worker (dark), depending on individuals' assets and managerial abilities. To illustrate the interaction between financial frictions and occupational choice, we consider two different economies, one with fully developed financial markets ($\chi = \infty$), shown in the top panels, and another one with financial frictions ($\chi = 1.106$), shown in the bottom panels. On the left hand side, we show occupational maps for unskilled individuals while those for skilled individuals are displayed on the right hand side.

Without financial frictions the choice to become an entrepreneur or a worker only depends on individuals' managerial abilities and not on their assets. The vertical line separating the two occupations in both top panels indicates this. Note that this line lies below the value of 3 for unskilled individuals but above the value of 3 for skilled individuals. Endowed with the same managerial ability, skilled and unskilled individuals would obtain the same profits as entrepreneurs, but their outside options as workers are different. Unskilled individuals with relatively low managerial abilities choose to become entrepreneurs because they would obtain lower wages as workers.

[4] A commonly used approach for fixing this issue is to add an extra tail to the distribution of managerial ability. However, given that our focus is not on replicating the US firm size distribution, and in order to keep the model simple, we abstain from doing so.

[5] The OECD statistic is also similar to the fraction of unincorporated self-employed over total employment in the US of 6-7% as reported in Hipple [2010]. As the author points out, many data sources tend to count incorporated self-employed as employees, potentially also our source for average establishment size. In this case the most comparable rate to our model statistic is the fraction of unincorporated self-employed.

Figure 3: Occupational maps for economies with and without financial frictions



Notes: Light color indicates entrepreneurs, dark color workers. Top panels for an economy without financial frictions ($\chi = \infty$)*, bottom panels for an economy with financial frictions* ($\chi = 1.106$)*.*

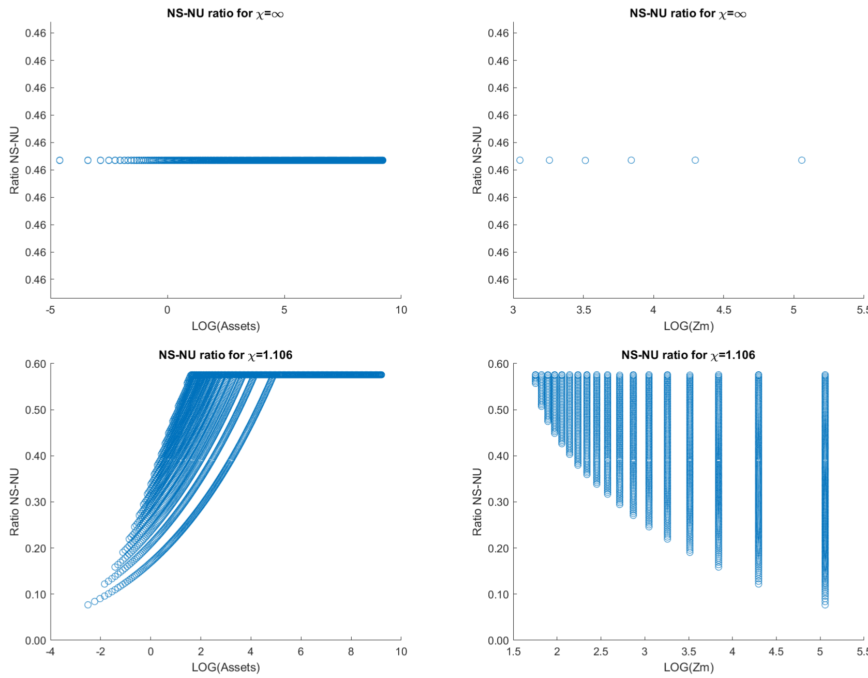
With financial frictions on the other hand, occupational choices depend on individuals' assets. Even individuals with very high managerial abilities choose to become workers if they do not have any assets. On the other hand, in particular unskilled individuals with very low managerial abilities but large amounts of assets decide to become entrepreneurs.

3.2 Interaction between financial frictions and skill composition at the firm level

To highlight the interactions between financial frictions and capital-skill complementarity at the firm level, in Figure 4 we plot the skill composition of employment chosen by entrepreneurs as a function of their assets and managerial abilities. The top panels show the skilled-to-unskilled labor ratio chosen by entrepreneurs in an economy without financial frictions ($\chi = \infty$), while the bottom panels show the same ratio for an economy with financial frictions ($\chi = 1.106$).

In an environment with perfect capital markets, all entrepreneurs choose the exact same

Figure 4: Skilled-unskilled labor ratio at the firm level



Notes: Top panels for an economy without financial frictions ($\chi = \infty$), bottom panels for an economy with financial frictions ($\chi = 1.106$). Left hand side for skilled-unskilled labor ratios as a function of entrepreneurs' assets, right hand side for same ratios as a function of managerial ability.

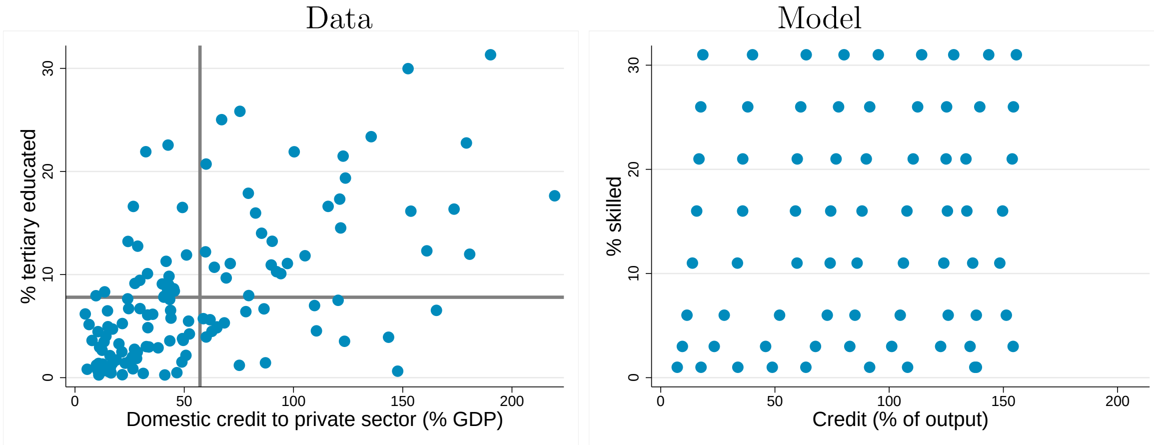
ratio of skilled to unskilled labor, independently of their assets or managerial abilities. With financial frictions on the other hand there is substantial dispersion in the skilled to unskilled labor ratio at the firm level, depending on entrepreneurs' assets and managerial abilities. Note that this dispersion in the skilled-to-unskilled labor ratio can be interpreted as a measure of financial constraints. The more financially constrained entrepreneurs are, the lower their chosen capital stock relative to the optimal one. And as a consequence of capital-skill complementarity, more financially constrained entrepreneurs will also hire relatively fewer skilled workers. Misallocation of capital thus translates into misallocation of skills.

4 Analysis

4.1 Effects of financial development and education on output

Our main exercise consist of varying financial frictions and educational attainment as observed in the data. The left hand graph of Figure 5 plots ratios of domestic credit to GDP

Figure 5: Domestic credit to GDP and educational attainment: data and model



Notes: For each country, data is averaged over 2004-2016. Sources: Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013]. The right hand graph shows the grid for which the model was simulated. Top right grid point is the US benchmark.

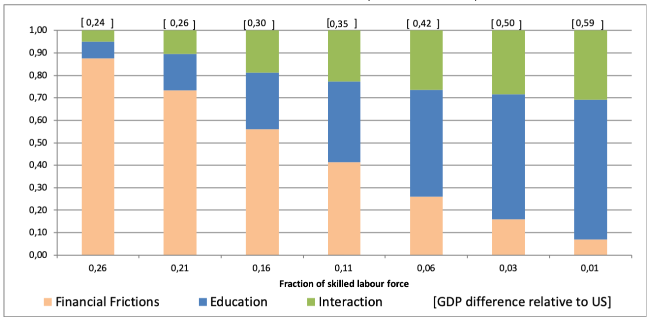
against the percentage of individuals with completed tertiary education across a range of 131 countries. We observe quite some variation in the data. Several countries are characterized by high educational attainment but low credit to GDP ratios, while others display high credit to GDP ratios but low educational attainment. We use these statistics to assign a realistic range to both χ and θ, simulating in total 72 economies, as shown in the right hand graph. In Figure A.1 in Appendix A, for these 131 countries we display relative GDP per capita with respect to US GDP, and compare these numbers to the values generated by our model. On average, within the framework of our model, the two dimensions – share of tertiary educated and domestic credit to GDP – can explain 50 to 60 percent of countries' observed GDP per capita gap relative to the US.

To provide a better understanding of the relative contribution of educational attainment and financial frictions as well as of their interactions, we conduct the following two exercises. First, for economies with a low level of financial development ($\chi = 1.1$) and different levels of educational attainment, we consider two reforms: full financial development ($\chi = \infty$) and an education expansion that increases the supply of skilled labor to the US level ($\theta = 0.31$). We then consider a third scenario where both reforms are carried out simultaneously. The second exercise considers the same reforms carried out in economies with initially low levels of educational attainment ($\theta = 0.01$) and different levels of financial market development.

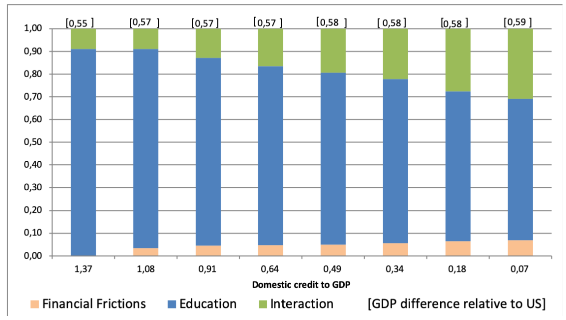
Figure 6 displays the results from these exercises and shows how each reform and their interactions contributes to the increase in output. For each scenario, relative GDP per

Figure 6: Effects of financial frictions and educational attainment on output

Low financial development ($\chi = 1.1$)



Low educational attainment ($\theta = 0.01$)



Notes: Based on model simulations. The graphs plot the contribution of each factor (financial frictions, educational attainment and their interaction) to explain differences in GDP relative to the US. The left hand graph starts at $\chi = 1.1$ *with different values of* θ*. The right hand graph starts at* $\theta = 0.01$ *with different values of* χ*. Numbers in brackets indicate GDP difference relative to the US. The last columns of the two graphs coincide.*

capita with respect to the US is shown in brackets above each column. The right hand graph corresponds to the second exercise. For very low levels of educational attainment, financial market development contributes very little to economic development. This is reflected by the fact that financial market development alone increases GDP per capita by at most 8 percent. Considering the results from the first exercise displayed in the left hand graph, we find that the impact of removing financial frictions depends crucially on the level of countries' educational attainment. As seen before, the effect is negligible for very low levels of human capital. However, when at least 15% of the population is skilled, improved access to finance becomes the main driver for economic development. Of particular interest are the interaction effects between the two reforms. When carried out jointly, the effects on output are larger than the sum of the individual effects (for a close-up see Figure A.2 in Appendix A). In particular, in a scenario where initially financial frictions are high and educational attainment is low, the interaction effect amounts to almost 50 percent of the sum of the individual effects.

4.1.1 Three case studies

We now focus on three specific case studies: Mexico, the Philippines, and Malawi. The Mexico-US comparison has sparked much interest in the literature. How much of the income difference between these two countries can be explained by differences in human capital and financial frictions? What would be the output gains for Mexico of increasing educational

Table 3: Three case studies

	Mexico	Philippines	Malawi
Share of college educated	$\theta = 0.11$	$\theta = 0.21$	$\theta^s = 0.01$
Financial frictions	$\chi = 1.18$	$\chi = 1.21$	$\chi = 1.16$
Output model	0.478	0.544	0.299
Output with $\theta = 0.31$	0.571	0.575	0.569
Output with $\chi = \infty$	0.576	0.672	0.327
Gains from education expansion	**19.3 %**	**5.7 %**	**90.3 %**
Gains from financial development	**20.5 %**	**23.5 %**	**9.5 %**
Sum of both reforms	**39.8 %**	**29.3 %**	**99.8 %**
Output model US	0.723	0.723	0.723
Both reforms jointly	**51.1 %**	**32.9 %**	**141.7 %**
Output relative to US data	**0.32**	**0.11**	**0.02**
Output relative to US model	**0.66**	**0.75**	**0.41**

attainment and financial market development to US levels? In our model this requires increasing $\theta = 0.11$ to $\theta = 0.31$ and $\chi = 1.18$ (a domestic credit to GDP ratio of 24 percent) to $\chi = \infty$. We choose the other two countries for our case study because of their different levels of educational attainment. In the Philippines around 21 percent of the population has completed tertiary education, while in Malawi this number is below 1 percent. Both countries have relatively low levels of domestic credit to GDP ratios of 32 and 11 percent respectively. For these two countries we also increase educational attainment and financial market development to the US level.

Table 3 displays the results for the three case studies. Differences in financial development and educational attainment in our model can generate approximately 50% of the difference in output between Mexico and the US. If Mexico's labor force was as skilled as the US labor force, but Mexico maintained its level of financial market development, output would increase by 19.3%. If on the other hand, Mexico had financial markets that were as developed as those in the US but kept its lower share of skilled individuals, output would increase by 20.5%. Finally, if simultaneously Mexico increased its share of skilled individuals and eliminated all frictions in its financial markets, output would increase by 51%.

The Philippines with a relatively high share of college graduates would benefit the most from adopting a policy to achieve the US level of financial market development, even though compared to the other two countries its financial markets are already more developed. Output would increase by 23.5 percent. An education expansion in the Philippines on the other hand would only have modest effects, increasing output by 5.7%.

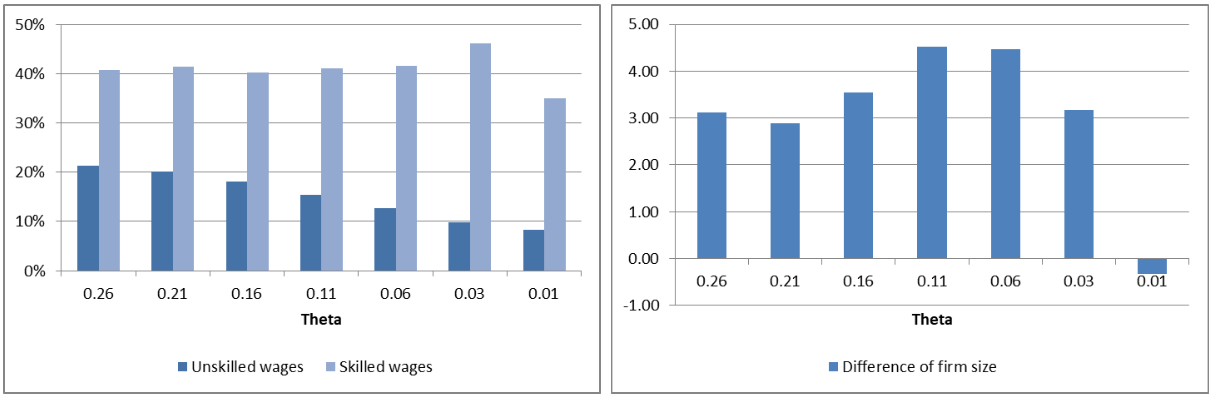
Finally, Malawi is an interesting case. During the late 1980s and early 1990s the country implemented several reforms to liberalize financial markets, following structural adjustment programs sponsored by the International Monetary Fund and the World Bank. These reforms do not seem to have spurred domestic credit which is only 11 percent of GDP. Our model suggests that given the country's low educational attainment, financial development in Malawi has only limited effects on output (an increase of less than 10 percent). This becomes especially evident when compared to the output effects of reforms that increase the educational attainment of the population. Our results are in line with the conclusions in Kabango and Paloni [2010] and Chirwa [2001]. Both papers study the effects of financial market liberalizations in Malawi. The former find an increase in industrial concentration and a decrease in net firm entry, particularly in sectors that are more finance dependent, while the latter point to higher intermediation margins, higher credit to the public sector but lower credit to the private sector.

4.2 Effects of financial frictions on wage inequality and firm size

Capital-skill complementarity implies a clear link between the use of capital in production and wages of skilled workers. Hence, in our model we expect financial development that alters firms' capital intensities to have different effects for wages of skilled and unskilled workers, ultimately affecting wage inequality. The left hand graph of Figure 7 displays the percentage changes in skilled and unskilled wages as financial markets develop from an initially low $\chi = 1.1$ to $\chi = \infty$, for different levels of educational attainment. Financial development increases both skilled and unskilled wages, but the effect is much larger for skilled wages, hence increasing wage inequality. In particular, the effect on skilled wages is between two to four times larger than the effect on unskilled wages. By how much wage inequality increases depends on a country's initial level of educational attainment. We observe stronger increases in wage inequality when financial development is carried out in countries where very few individuals hold a college degree.

Removing financial frictions allows entrepreneurs to hire the optimal amount of capital and to grow to their optimal size. Within the framework of our model, we hence also predict financial development to affect average firm size. The right hand graph of Figure 7 shows the change in average firm size as financial markets develop from an initially low $\chi = 1.1$

Figure 7: Effects of removing financial frictions on wage inequality and firm size



Notes: Based on model simulations. Both graphs consider a situation where financial markets develop from $\chi = 1.1$ to $\chi = \infty$ for different levels of educational attainment, θ.The left hand graph displays how skilled and unskilled wages change, whereas the right hand graph shows how average firm size is affected.

to $\chi = \infty$, for different levels of educational attainment. Financial development would, in general, increase average firm size. The only exception is a situation in which only 1 percent of the population has tertiary education. In this case, there is an extreme shortage of human capital and skilled wages are very high. Very few firms are profitable, and those that are, will prefer to hire a large number of unskilled workers whose wages are very low. Hence in this case, average firm size turns out to be slightly larger than in our US benchmark.

4.3 Cross-country and firm-level regressions

In our model, increases in educational attainment and the removal of financial frictions lead to higher aggregate output. Running cross-country regressions, we first investigate if and how this relationship holds in the data. In particular, we regress the log of GDP per capita on the fraction of the population with tertiary education and on the ratio of domestic credit to GDP. These regressions produce the conditional slopes presented in Figure 1. We then reproduce the same regressions using model-generated data. Table 4 displays the unweighted regressions, and Table A.2 in Appendix A shows the model regressions where each grid point is weighted by the number of countries whose data is closest. Unweighted and weighted results are very similar. The positive relationships from our model also hold in the data. In particular, and similar to Buera, Kaboski and Shin [2011], our model accounts for one third of the observed relationship between GDP and domestic credit. Regarding educational

Table 4: Cross-country regressions: model and data

	Data			**Model Closed Economy**	
	Domestic Credit to GDP	% of tertiary educated	Obs. (R^2)	Domestic Credit to GDP	% of tertiary educated
GDP per capita (relative to US)	0.339*** [0.18,0.49]	1.482*** [0.41,2.55]	131 (0.33)	0.106*** [0.078, 0.133]	1.346*** [1.224,1.467]
TFP (relative to US)	0.269*** [0.16,0.37]	0.690* [-0.04,1.42]	67 (0.50)	0.037*** [0.013, 0.061]	0.772*** [0.666, 0.878]
Firm size (logs)	0.0051** [0.001,0.010]	0.0155 [-0.01,0.04]	97 (0.10)	0.0010*** [0.0004, 0.0015]	-0.0014 [-0.0037, 0.0009]
Labor Share	0.102*** [0.058,0.147]	0.034 [-0.265,0.333]	128 (0.10)	0.0010*** [0.0023, 0.0177]	-0.505*** [-0.5395, -0.4720]
College premium (logs)	0.002** [0.000,0.005]	-0.02** [-0.04,-0.003]	97 (0.08)	0.001 [-0.000, 0.003]	-0.084*** [-0.091, -0.076]

*Notes: The 95% confidence intervals are shown in brackets.*** significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level. For each country, data is the average for 2004-2016. Sources: GDP per capita PPP and Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013] Data; TFP from Buera and Shin [2013]; Firm size in logs from Enterprise survey; Labor share data from ILO; College premium in logs taken from ILO (ratio of average wage in occupation of Professionals over Plant and machine operators, and assemblers).*

attainment and GDP, it accounts for two thirds of the empirical relationship.[6]

We also run similar regressions for TFP, firm size, labor share, and college premia. To calculate TFP in our model we assume a Cobb Douglas production function with capital and aggregate labor and a capital share of one third. Our measure of aggregate labor sums skilled and unskilled workers. Our model reproduces well the positive relationship between educational attainment and TFP, and it is able to capture 15 percent of the relationship between domestic credit and TFP. Furthermore our model also reproduces the positive relationship between average firm size and domestic credit, as well as the absence of a clear relationship between average firm size and educational attainment. As for the labor share, the model captures 10 percent of the positive relationship with domestic credit found in the

[6] Table A.1 in Appendix A shows regressions that include quadratic terms for both domestic credit and educational attainment, as well as an interaction term between the two. Coefficients on domestic credit and educational attainment in the data indicate a concave relationship with GDP per capita. However, in the model only the latter survives. The coefficient on the interaction term is positive and significant in both data and model regressions. However, with five estimated coefficients the comparison of the two regressions is more complicated, and hence we prefer to analyze linear specification.

Table 5: Firm-level regressions: model and data

	Data			Model		
Log of firm's assets	3.395***			2.767***		
	[2.92,4.19]			[2.761,2.773]		
Log of firm's assets ×						
domestic credit/GDP	-0.021***	Min(18)	Max(123)	-0.015***	Min(7)	Max(155)
	[-0.03,-0.01]	3.17	0.93	[-0.015,-0.016]	2.66	0.37
Country dummies	X			X		
Industry dummies	X					
Observations	6135			2,010,083		
R-squared	0.429			0.909		

*Notes: T-statistics are shown in brackets.*** indicates significance at the 1% level, ** indicates significance at the 5% level, and * indicates significance at the 10% level. Dependent variable is the % of workers with >10 years education. Using simulated data, each firm is weighted by its mass.*

data. However, the model has a clear prediction that the labor share declines with education, while in the data we find no statistically significant relationship between the two variables. Furthermore, our model is unable to capture the positive relationship between college premia and domestic credit, and it predicts a negative relationship between college premia and educational attainment that is stronger than the one observed in the data. The latter suggests that other elements that are absent from our model, namely skill-biased technological change, have raised returns to education.

Our model also generates predictions for the relationship between output, human capital, and access to finance at the firm level. To compare these predictions to those observed in the data, we turn to the World Bank's Enterprise Survey, and we regress the share of educated workers (with 10-12 years of education) within a firm on the log of firms' assets. We also control for country and industry fixed effects, and we include an interaction term between the log of firms' assets and the respective country's domestic credit to GDP ratio. Table 5 shows the results from these regressions. We find a positive and significant relationship between the share of educated workers within a firm and a firm's level of assets. The positive and significant coefficient on firms' assets however is smaller in countries with higher domestic credit to GDP ratios. From the minimum to the maximum value of domestic credit to GDP, the slope coefficient varies between 3.17 and 0.93. This indicates that, particularly in countries with low financial development, firms with more assets employ a higher fraction of educated workers. We reproduce this regression in the model and estimate similar coefficients and a similar slope varying from 2.66 to 0.37.

5 Robustness

We check the robustness of our findings along three different dimensions. We first consider an open economy version of our model. Second, we replicate the model assuming a Cobb-Douglas production function, and finally we consider a version of the model where we let individuals decide if they want to acquire an education.

5.1 Open Economy

Our benchmark model considers a closed economy where financial frictions and investment decisions of entrepreneurs affect the equilibrium interest rate and thus savings decisions of individuals. This is different in an (small) open economy where the world interest rate remains constant as financial frictions are removed. To check by how much our results change in such an environment, we consider an open economy version of our model, and we repeat all exercises. Note that we do not have to adjust the calibration of the model. When changing financial frictions (χ) and educational attainment (θ), we simply keep the interest rate constant at its value from our benchmark calibration (4.5 percent). Appendix B displays all exercises for the open economy version of the model. Throughout the range of simulations, the interaction effect of financial frictions and educational attainment turns out to be as high as 57 percent.

In the open economy version of our model, output gains from financial development are much lower than in the closed economy version. However, they still depend crucially on countries' educational attainments. In particular, output gains from financial development in open economies vary from 2.4 percent in Malawi to 11 percent in Mexico to 17 percent in the Philippines. We find the effects of financial development on wage inequality to be similar to the ones in our baseline economy. Our cross-country regressions also yield similar results. However, in the firm level regression, the coefficient on firms' assets is only equal to 33% of the one estimated in the data, compared to 82% when considering the coefficient from our baseline regression.

5.2 Cobb-Douglas production function

We argued before that financial frictions and capital-skill complementarity were key elements in our model. In order to check how much capital-skill complementarity contributes to our results, we consider a version of our model with a Cobb-Douglas production function. In this case we need to re-calibrate the model (see Tables C.1 and C.2 in Appendix C for this calibration as well as targeted and non-targeted moments). Note that this version of the model does as well as the baseline model in matching both targeted and un-targeted moments.

We then reproduce all our exercises; see Appendix C. If technology were described by a Cobb-Douglas production function, many of our baseline results would be overturned. In particular, this version of our model fails to replicate the empirical firm level regression of the share of skilled workers on the log of firms' assets. Because with a Cobb-Douglas technology all firms within a country have the same skilled to unskilled labor ratio. Furthermore, financial development alone would have much larger effects on output, and these effects would be larger for countries with lower educational attainment. In our case studies, financial development would raise output by 29 percent in the Philippines, 33 percent in Mexico, and 43 percent in Malawi. Furthermore, the effects of the two reforms would seem rather independent, with an interaction effect of only 1 percent in the Philippines, 3 percent in Mexico but 38 percent in Malawi. In addition, and contrary to our baseline results, financial development would reduce wage inequality, particular when educational attainment is very low.

5.3 Endogenizing educational attainment

Throughout the paper, we took both educational attainment of the population as well as financial frictions as given. This allowed us to focus on the decomposition of the relative contribution of each factor and their interaction for differences in aggregate output. However, given that financial frictions are important drivers behind wage inequality it seem reasonable that changes in financial development could themselves affect individuals' choices to acquire an education. While the current paper does not aim to rigorously study the effects of financial frictions on human capital accumulation, we propose a simple variation of our model that endogenizes educational attainment.

In particular, we assume that prior to entering the labor market, individuals decide whether to invest in higher education comparing the returns to education with the cost of acquiring an education. We assume that individuals calculate their returns to education under the "veil of ignorance," i.e. they do not anticipate how the number of college graduates or financial market development could affect returns to education in the future. Furthermore, we assume that the cost of education c is drawn from a lognormal distribution G with mean μ and variance σ. We denote by V^s and V^u the values of having or not acquired higher education respectively. In equilibrium, there will be a threshold cost, c^* above which people decide not to obtain higher education. At the threshold cost, individuals are indifferent and hence $V^s - V^u = c^*$. The fraction of individuals with higher education then becomes endogenous, and is given by

$$\theta = G(V^s - V^u). \tag{8}$$

In this version of our model, Equation 8 is hence added to the previous four equilibrium conditions. Note that this model has two additional parameters that need to be calibrated: the mean and variance of the distribution from which the cost of acquiring an education is drawn. We match the fraction of college graduates (which was previously exogenous) to calibrate the mean of this distribution ($\mu = 3.552$), and we choose the variance ($\sigma = 4.331$) to target an average spending on tertiary education in the US of 2.6 percent of GDP (taken from OECD Statistics). As we target a share of college graduates of 0.31, the value for all remaining parameters is the same as in our baseline calibration. Appendix D shows the results.

In this version of our model, we find that varying financial frictions from autarky to perfect capital markets, leads to a variation in educational attainment of just 2 percentage points. This hence only marginally amplifies the effects of financial frictions.

6 Conclusion

Capital-skill complementarity in production implies non-trivial interactions between firms' availability of human and physical capital. This has important implications for economic development, as gains from financial deepening depend on countries' educational attainment. Our analysis shows that these gains are very small when educational attainment is low. In our baseline model we take educational attainment and financial frictions as given, and we hence carry out an accounting exercise rather than a horse race. We do so because we think that there are many other channels outside the scope of our model that make both financial frictions and educational attainment endogenous. Additionally, we find that there are substantial synergies of implementing educational and financial reforms jointly. However, our analysis is positive, rather than normative, and hence our results do not suggest that one reform is preferable to the other. To be able to make such statements would require precise cost estimates including the time it would take to implement each reform. We leave this type of analysis for future work.

Our results also indicate that financial frictions are an important driver of wage inequality, raising wages of skilled workers two to four times more than wages of unskilled workers. This raises an interesting question. Literature has typicaly linked rising wage inequality to the complementarity between technology and skilled labor, see for instance Acemoglu [1998]. However, depending on the estimation procedure and controls used, it is possible that previous literature might have attributed increases in wage inequality to skill-biased technological change instead of financial market development. We leave an investigation into this hypothesis for future research.

Our paper also has implications for the literature studying the economic effects of resource misallocation. We show that one way to make interference about the misallocation of resources is by studying how the skill composition of a firm differs from that of the average firm in the sector. In particular, if a firm's ratio of skilled to unskilled labor is lower than the sector average, this might be an indicator that the firm is financially constrained and cannot operate at its desired level of capital.

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COMPANION APPENDIX

Human capital and Financial Development: Firm-Level Interactions and Macroeconomic Implications

Lian Allub, Pedro Gomes and Zoë Kuehn

A Additional results

A.1 Deriving the entrepreneur's optimal decisions

The first-order conditions of the entrepreneur's problem are:

$$z_i^{(1-\gamma)}\gamma X_i^{\frac{\gamma}{\sigma}-1}[\lambda(k_i)^\rho+(1-\lambda)(n_i^s)^\rho]^{\frac{\sigma}{\rho}-1}](1-\lambda)(1-\mu)(n_i^s)^{\rho-1}=w^s, \tag{A.1}$$

$$z_i^{(1-\gamma)}\gamma X_i^{\frac{\gamma}{\sigma}-1}\mu(n_i^u)^{\sigma-1}=w^u, \tag{A.2}$$

$$z_i^{(1-\gamma)}\gamma X_i^{\frac{\gamma}{\sigma}-1}[\lambda(k_i)^\rho+(1-\lambda)(n_i^s)^\rho]^{\frac{\sigma}{\rho}-1}]\lambda(1-\mu)k_i^{\rho-1}=r_i, \tag{A.3}$$

where $X_i=[\mu(n_i^u)^\sigma+(1-\mu)[\lambda(k_i)^\rho+(1-\lambda)(n_i^s)^\rho]^{\frac{\sigma}{\rho}}]$ and $r_i=r+\omega_i$. Combining equations A.1 and A.2 we obtain:

$$\frac{w^u}{w^s}=\frac{\mu}{1-\mu}\frac{(n_i^u)^{\sigma-1}}{[\lambda(k_i/n_i^s)^\rho+(1-\lambda)]^{\frac{\sigma}{\rho}-1}(1-\lambda)(n_i^s)^{\sigma-1}}, \tag{A.4}$$

and Equations A.1 and A.3 provide us with the optimal ratio of capital to skilled labor:

$$\frac{k_i}{n_i^s}=\left[\frac{\lambda}{1-\lambda}\frac{w^s}{r_i}\right]^{\frac{1}{1-\rho}}\equiv B_i. \tag{A.5}$$

Combining the expressions above we arrive at the entrepreneur's optimal ratio of skilled to unskilled labor:

$$\frac{n_i^s}{n_i^u}=\left[\frac{w^u}{w^s}\frac{(1-\lambda)(1-\mu)[\lambda(\frac{\lambda w^s}{(1-\lambda)r_i})^{\frac{\rho}{1-\rho}}+(1-\lambda)]^{\frac{\sigma-\rho}{\rho}}}{\mu}\right]^{1/(1-\sigma)}\equiv A_i. \tag{A.6}$$

Finally, re-writing $X_i=\left[\frac{\mu}{A_i^\sigma B_i^\sigma}+(1-\mu)\left(\lambda+\frac{(1-\lambda}{B_i^\rho}\right)^{\frac{\sigma}{\rho}}\right]k_i^\sigma$, we obtain the entrepreneur's optimal capital-output ratio:

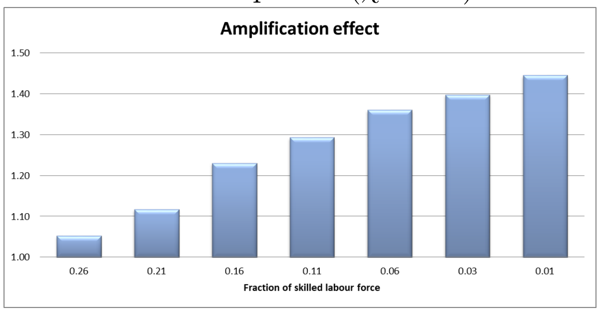
$$\frac{k_i}{y_i}=\frac{\gamma}{r_i}\frac{\lambda(1-\mu)\left(\lambda+\frac{(1-\lambda)}{B_i^\rho}\right)^{\frac{\sigma}{\rho}-1}}{\left[\frac{\mu}{A_i^\sigma B_i^\sigma}+(1-\mu)\left(\lambda+\frac{(1-\lambda}{B_i^\rho}\right)^{\frac{\sigma}{\rho}}\right]}. \tag{A.7}$$

Figure A.1: Cross-country statistics: data and model

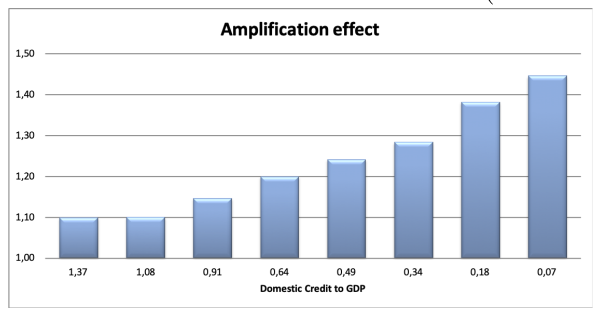
Notes: The top-left graph shows GDP per capita relative to the US in the data for countries around each grid point. For instance, the bottom left grid point indicates that countries with lowest educational attainment and domestic credit to GDP ratios have a GDP per capita that is 3 percent of that of the US. The top-right graph shows GDP per capita relative to the US measured in the model, for countries around each grid point. For instance, the bottom left grid point indicates that in the model, countries with the lowest educational attainment and domestic credit to GDP ratio, have a GDP per capita that is 41 percent of that of the US. The bottom-left graph shows the number of countries around each grid point in the data. For instance, the bottom left grid point indicates that in the data there are 5 countries with the lowest educational attainment and domestic credit to GDP ratio. The bottom-right graph shows the percentage of GDP per capita relative to the US explained by the model due to differences in educational attainment and financial frictions. For instance, the bottom left grid point indicates that the model explains 58 percent of the observed GDP difference for countries with the lowest educational attainment and domestic credit to GDP ratios.

Figure A.2: Amplification of joint reforms on output

Low financial development ($\chi = 1.1$)



Low educational attainment ($\theta = 0.01$)



Notes: Based on model simulations. The graphs plot the contribution of the interaction effect of financial development and education expansion carried out jointly to explain differences in GDP relative to the US. The left hand graph starts at $\chi = 1.1$ with different values of θ. The right hand graph starts at $\theta = 0.01$ with different values of χ.

Table A.1: Cross-country regressions of GDP per capita with quadratic terms

	Data		**Model**	
Domestic credit to GDP				
Linear	0.694***	[0.253,1.137]	0.016	[-0.0402,0.0724]
Quadratic	-0.0037**	[-0.0066,-0.0009]	0.109	[-0.0001,0.0006]
% of tertiary educated				
Linear	4.641***	[1.937,7.346]	2.7549***	[2.5151,2.9948]
Quadratic	-0.2275***	[-0.3541, -0.1008]	-0.0541***	[-0.0611,-0.0471]
Domestic credit ×				
% tertiary	0.0281**	[0.0033,0.0529]	0.003***	[0.0019,0.0045]
Observation	131		72	
R-squared	0.407		0.978	

*Notes: The 95% confidence intervals are shown in brackets.*** significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level. For each country, data is average for 1995-2005. Sources: GDP per capita PPP and Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013].*

Table A.2: Cross-country regressions, weighted

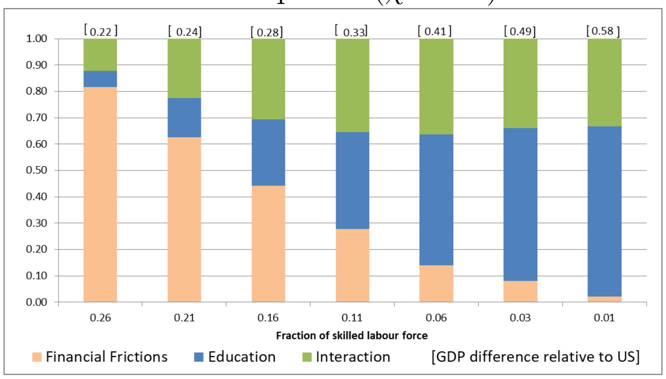
	Data			**Model**	
	Domestic Credit to GDP	% of tertiary educated	Obs. (R^2)	Domestic Credit to GDP	% of tertiary educated
GDP per capita	0.339***	1.482***	131	0.121***	1.737***
(relative to US)	[0.18,0.49]	[0.41,2.55]	(0.33)	[0.049, 0.193]	[1.442,2.032]
TFP	0.269***	0.690*	67	0.063**	1.139***
(relative to US)	[0.16,0.37]	[-0.04,1.42]	(0.50)	[0.006, 0.120]	[0.906, 1.372]
Firm size	0.0051**	0.0155	97	0.001	-0.0065***
(logs)	[0.001,0.010]	[-0.01,0.04]	(0.10)	[-0.0003, 0.0019]	[-0.0111, -0.0019]
Labor Share	0.102***	0.034	128	0.0011***	-0.6188***
	[0.058,0.147]	[-0.265,0.333]	(0.10)	[0.0042, 0.0184]	[-0.6635, -0.5741]
College premium	0.002**	-0.02**	97	-0.0006	-0.105***
(logs)	[0.000,0.005]	[-0.04,-0.003]	(0.08)	[-0.005, 0.003]	[-0.123, -0.086]

*Notes: The 95% confidence intervals are shown in brackets.*** significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level. For each country, data is the average for 2004-2016. Sources: GDP per capita PPP and Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013]; TFP from Buera and Shin [2013]; Firm size in logs from World Bank Enterprise survey; Labor share data from ILO; College premium in logs taken from ILO (ratio of average wage in occupation Professionals over Plant and machine operators, and assemblers). In the model regressions, each observation (grid point) is weighted by the number of countries in the same grid point in the data equivalent (shown in the bottom left graph of Figure A.1).*

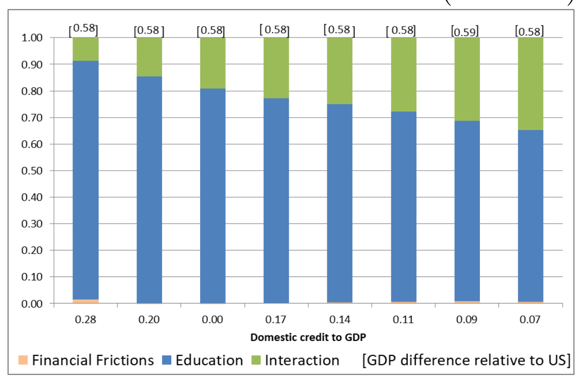
B Robustness: Open Economy

Figure B.1: Open Economy - effects of financial frictions and educational attainment on output

Low financial development ($\chi = 1.1$)

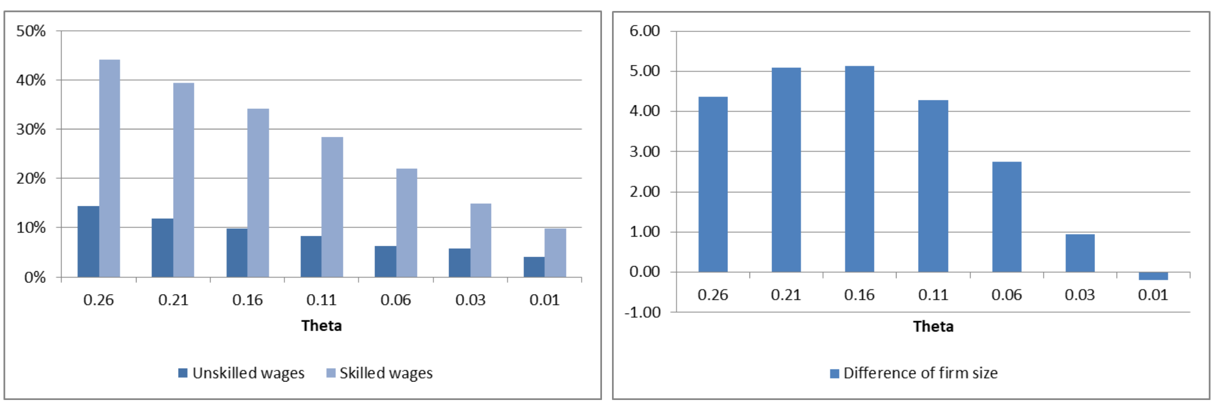


Low educational attainment ($\theta = 0.01$)



Notes: Based on simulations of the open economy version of our model. The graphs plot the contribution of each factor (financial frictions, educational attainment and their interaction) to explain differences in GDP relative to the US. The left hand graph starts at $\chi = 1.1$ with different values of θ. The right hand graph starts at $\theta = 0.01$ with different values of χ. Numbers in brackets indicate GDP difference relative to the US. The last columns of the two graphs coincide.

Figure B.2: Open Economy - effects of removing financial frictions on wage inequality and firm size



Notes: Based on model simulations of the open economy version of our model. Both graphs consider a situation where financial markets develop from $\chi = 1.1$ to $\chi = \infty$ for different levels of educational attainment, θ. The left hand graph displays how skilled and unskilled wages change, whereas the right hand graph shows how average firm size is affected.

Table B.1: Open Economy: Three case studies

	Mexico	**Philippines**	**Malawi**
Share of college educated	$\theta = 0.11$	$\theta = 0.21$	$\theta^s = 0.01$
Financial frictions	$\xi = 1.38$	$\xi = 1.38$	$\xi = 2.001.1$
Output model	0.498	0.564	0.303
Output with $\theta = 0.31$	0.595	0.595	0.626
Output with $\chi = \infty$	0.553	0.657	0.310
Gains from education expansion	**19.6 %**	**5.5 %**	**107.0 %**
Gains from financial development	**11.1 %**	**16.5 %**	**2.4 %**
Sum of both reforms	**30.7 %**	**21.9 %**	**109.3 %**
Output US in the model	0.723	0.723	0.723
Both reforms jointly	**45.3 %**	**28.1 %**	**138.8 %**
Output relative to US data	**0.32**	**0.11**	**0.02**
Output relative to US model	**0.69**	**0.78**	**0.42**

Table B.2: Open Economy: Cross-country regressions

	Data			**Model: Open Economy**	
	Domestic Credit to GDP	% of tertiary educated	Obs. (R^2)	Domestic Credit to GDP	% of tertiary educated
GDP per capita	0.339***	1.482***	131	0.146***	1.134***
(relative to US)	[0.18,0.49]	[0.41,2.55]	(0.33)	[0.112, 0.180]	[1.011,1.257]
TFP	0.269***	0.690*	67	0.012*	0.349***
(relative to US)	[0.16,0.37]	[-0.04,1.42]	(0.50)	[-0.001, 0.024]	[0.304, 0.394]
Firm size	0.0051**	0.0155	97	0.0013***	-0.008
(logs)	[0.001,0.010]	[-0.01,0.04]	(0.10)	[0.0008, 0.0018]	[-0.0096, -0.0057]
Labor Share	0.102***	0.034	128	0.0071	-0.502***
	[0.058,0.147]	[-0.265,0.333]	(0.10)	[-0.0045, 0.0187]	[-0.5447, -0.4607]
College premium	0.002**	-0.02**	97	0.001	-0.082***
(logs)	[0.000,0.005]	[-0.04,-0.003]	(0.08)	[-0.002, 0.003]	[-0.091, -0.072]

*Notes: The 95% confidence intervals are shown in brackets.*** significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level. For each country, data is the average for 1995-2005. Sources: GDP per capita PPP and Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013]; TFP from Buera and Shin [2013]; Firm size in logs from World Bank Enterprise survey; Labor share data from ILO; College premium in logs taken from ILO (ratio of average wage in occupation Professionals over Plant and machine operators, and assemblers).*

Table B.3: Open Economy: Firm-level regressions

	Data			**Model: Open Economy**		
Log of firm's assets	3.395***			1.090***		
	[2.92,4.19]			[1.083, 1.096]		
Log of firm's assets ×						
domestic credit/GDP	-0.021***	Min(18)	Max(123)	-0.0046***	Min(7)	Max(155)
	[-0.03,-0.01]	3.17	0.93	[0.0016,0.0022]	1.08	0.37
Country dummies	X			X		
Industry dummies	X					
Observations	6135			614,953		
R-squared	0.429			0.948		

*Notes: T-statistics are shown in brackets.*** indicates significance at the 1% level, ** indicates significance at the 5% level, and * indicates significance at the 10% level. Dependent variable is the % of workers with >10 years education. Using simulated data, each firm is weighted by its mass.*

C Robustness: Cobb-Douglas production function

Table C.1: Calibration of model with a Cobb-Douglas production function

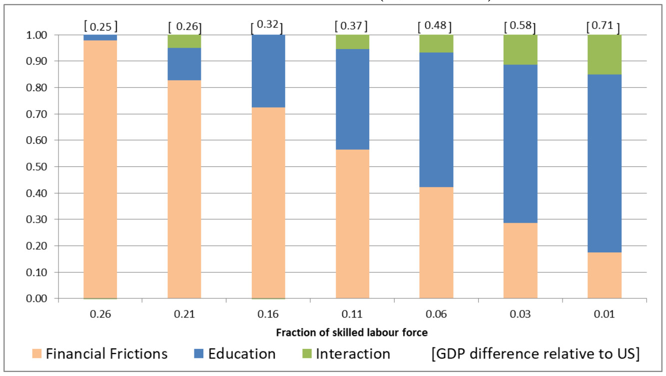
Parameters set exogenously	Baseline	Cobb-Douglas	Source
Depreciation rate (δ)	0.060	0.060	Buera and Shin [2013]
Risk aversion (ψ)	1.5	1.5	Buera and Shin [2013]
Prob. of drawing a new ability	0.106	0.106	Buera and Shin [2013]
Fraction of skilled	0.31	0.31	Barro and Lee [2013]
Tightness of financial friction (χ)	∞	∞	normalization
Substitutability			
Capital and skilled labor (σ)	0.401	0.0001	Krusell et al. [2000]
Capital and unskilled labor (ρ)	-0.495	-0.0001	Krusell et al. [2000]
Calibrated parameters	**Baseline**	**Cobb-Douglas**	**Target**
Span-of-Control (γ)	0.87	0.87	Profits to GDP ratio
Discount factor (β)	0.929	0.928	Real interest rate
Production function			
Weights			
Unskilled labor in production (μ)	0.4385	0.433	College premium
Capital in Production (λ)	0.619	0.426	Capital-output ratio
Distribution of ability			
Shape parameter (α)	1.047	1.021	Mean establishment size
Scale parameter (ξ)	0.426	0.0715	Relative size establishment unskilled-skilled manager

Table C.2: Calibration targets with a Cobb-Douglas production function

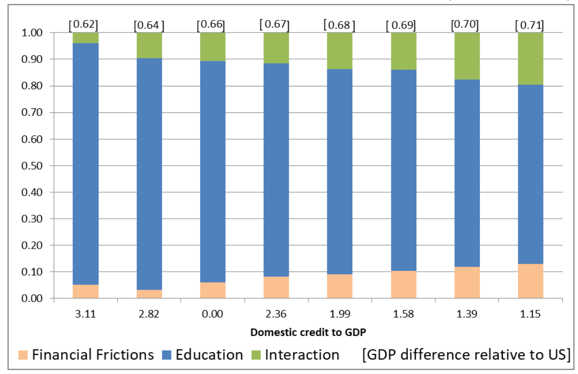
Targeted moments	Source	Data	Baseline	Cobb-Douglas
Profits to GDP ratio	BEA	0.13	0.13	0.13
Real interest rate	Buera and Shin [2013]	0.045	0.045	0.045
Mean establishment	US Census	17.46	17.49	17.49
Relative size establishment skilled manager	SBO(2007)	0.70	0.70	0.69
Capital-output-ratio	Kamps [2006]	2.00	2.00	2.00
College Premium 2000	Goldin and Katz [2009]	0.63	0.63	0.63
Non-targeted moments	**Source**	**Data**	**Baseline**	**Cobb-Douglas**
Establishment share, < 10 employees	US Census	0.70	0.538	0.538
Establishment share, $10 - 19$ employees	US Census	0.14	0.226	0.226
Establishment share, $20 - 99$ employees	US Census	0.13	0.226	0.226
Establishment share, > 100 employees	US Census	0.03	0.009	0.009
Employment share, < 10 employees	US Census	0.15	0.204	0.196
Employment share, $10 - 19$ employees	US Census	0.10	0.164	0.160
Employment share, $20 - 99$ employees	US Census	0.30	0.388	0.386
Employment share, > 100 employees	US Census	0.45	0.244	0.259
Domestic Credit/GDP	WDI (2000)	1.62	1.56	1.56
Labor share	BEA	0.63	0.66	0.66
Self-employment rate	OECD	0.07	0.05	0.05

Figure C.1: Cobb-Douglas- effects of financial frictions and educational attainment on output

Low financial development ($\chi = 1.1$)

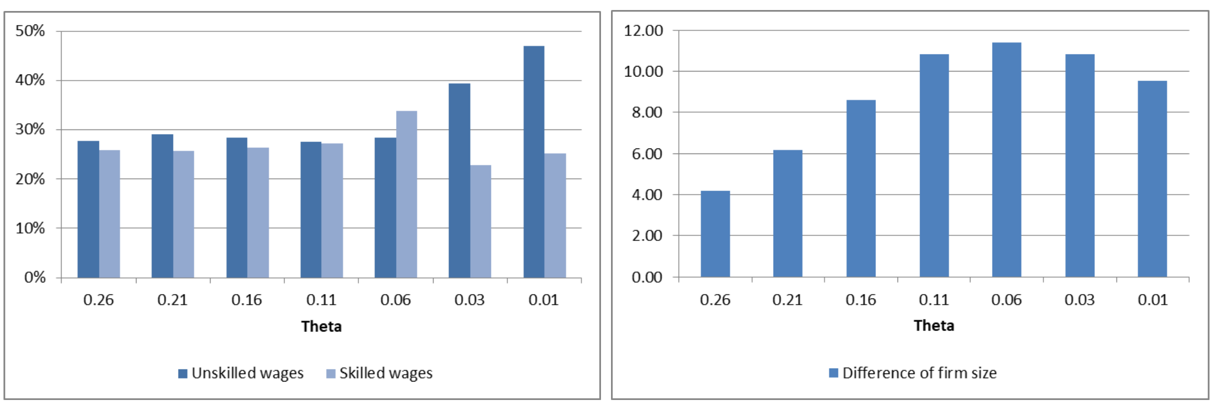


Low educational attainment ($\theta = 0.01$)



Notes: Based on simulations of the model version with a Cobb-Douglas production function. The graphs plot the contribution of each factor (financial frictions, educational attainment and their interaction) to explain differences in GDP relative to the US. The left hand graph starts at $\chi = 1.1$ with different values of θ. The right hand graph starts at $\theta = 0.01$ with different values of χ. Numbers in brackets indicate GDP difference relative to the US. The last columns of the two graphs coincide.

Figure C.2: Cobb-Douglas - effects of removing financial frictions on wage inequality and firm size



Notes: Based on simulations of the model version with a Cobb-Douglas production function. Both graphs consider a situation where financial markets develop from $\chi = 1.1$ to $\chi = \infty$ for different levels of educational attainment, θ. The left hand graph displays how skilled and unskilled wages change, whereas the right hand graph shows how average firm size is affected.

Table C.3: Cobb-Douglas production function: Three case studies

	Mexico	**Philippines**	**Malawi**
Share of college educated	$\theta = 0.11$	$\theta = 0.21$	$\theta^s = 0.01$
Financial frictions	$\xi = 1.13$	$\xi = 1.18$	$\xi = 1.101.1$
Output model	0.316	0.372	0.144
Output with $\theta = 0.31$	0.387	0.391	0.385
Output with $\chi = \infty$	0.419	0.478	0.207
Gains from education expansion	**22.7 %**	**5.1 %**	**166.6 %**
Gains from financial development	**32.9 %**	**28.5 %**	**43.3 %**
Sum of both reforms	**55.6 %**	**33.6 %**	**209.9 %**
Output US in the model	0.501	0.501	0.501
Both reforms jointly	**58.7 %**	**34.7 %**	**247.3 %**
Output relative to US data	**0.32**	**0.11**	**0.02**
Output relative to US model	**0.63**	**0.74**	**0.29**

Table C.4: Cobb-Douglas production function: Cross-country regressions

	Data			**Model: Cobb-Douglas**	
	Domestic Credit to GDP	% of tertiary educated	Obs. (R^2)	Domestic Credit to GDP	% of tertiary educated
GDP per capita (relative to US)	0.339*** [0.18,0.49]	1.482*** [0.41,2.55]	131 (0.33)	0.072*** [0.041, 0.103]	1.786*** [1.579,1.998]
TFP (relative to US)	0.269*** [0.16,0.37]	0.690* [-0.04,1.42]	67 (0.50)	0.036* [0.010, 0.062]	1.663*** [1.486, 1.841]
Firm size (logs)	0.0051** [0.001,0.010]	0.0155 [-0.01,0.04]	97 (0.10)	0.0028*** [0.0025, 0.0032]	0.0289 [0.0263, 0.0314]
Labor Share	0.102*** [0.058,0.147]	0.034 [-0.265,0.333]	128 (0.10)	0.0001*** [-0.0000, 0.0001]	-0.0017*** [-0.0019, -0.0014]
College premium (logs)	0.002** [0.000,0.005]	-0.02** [-0.04,-0.003]	97 (0.08)	0.001 [-0.001, 0.002]	-0.106*** [-0.117, -0.095]

*Notes: The 95% confidence intervals are shown in brackets.*** significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level. For each country, data is the average for 1995-2005. Sources: GDP per capita PPP and Domestic Credit to GDP from World Bank Development Indicators; Educational attainment from Barro and Lee [2013]; TFP from Buera and Shin [2013]; Firm size in logs from World Bank Enterprise survey; Labor share data from ILO; College premium in logs taken from ILO (ratio of average wage in occupation Professionals over Plant and machine operators, and assemblers).*

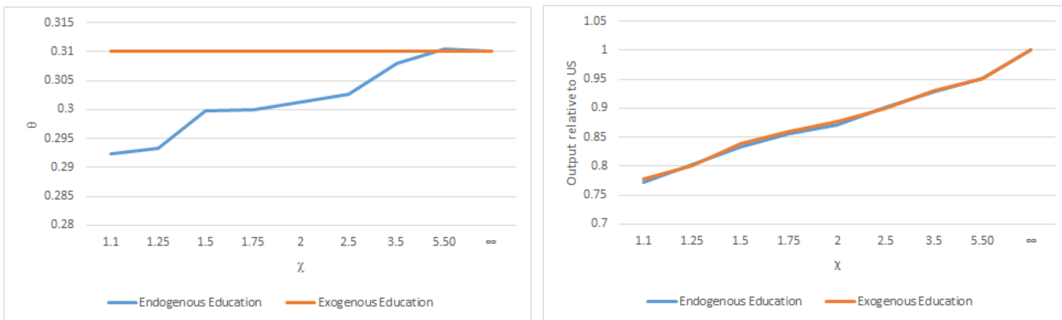
Table C.5: Cobb-Douglas production function: Firm-level regressions

	Data			**Model: Cobb-Douglas**		
Log of firm's assets	3.395***			0.0056***		
	[2.92,4.19]			[1.083, 1.096]		
Log of firm's assets × domestic credit/GDP	-0.021***	Min(18)	Max(123)	-0.00002***	Min(7)	Max(155)
	[-0.03,-0.01]	3.17	0.93	[0.00002,0.00002]	0.01	0.00
Country dummies	X			X		
Industry dummies	X					
Observations	6135			2,273,473		
R-squared	0.429			1.00		

*Notes: T-statistics are shown in brackets.*** indicates significance at the 1% level, ** indicates significance at the 5% level, and * indicates significance at the 10% level. Dependent variable is the % of workers with >10 years education. Using simulated data, each firm is weighted by its mass.*

D Robustness: Endogenizing educational attainment

Figure D.1: Endogenous Education - effects of removing financial frictions on educational attainment and output



Notes: Based on simulations of the model version with endogenous education. Both graphs consider a situation where financial markets develop from $\chi = 1.1$ to $\chi = \infty$. The left hand graph displays how the proportion of skilled individuals evolves with a financial development for our benchmark economy (exogenous and constant) and the endogenous education economy, whereas the right hand graph shows how GDP is affected in each case.