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ABSTRACT

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One of the most salient features of developing economies is the existence of a large informal sector. This paper uses quantitative theory to study the dynamic implications of informality on wage inequality, human capital accumulation, child labor and long-run growth. Our model can generate transitory informality equilibria or informality-induced poverty traps. Its calibration reveals that the case for the poverty-trap hypothesis is strong: although informality serves to protect low-skilled workers from extreme poverty in the short-run, it prevents income convergence between developed and developing nations in the long run. Sudden elimination of informality would induce severe welfare losses for several generations on the transition path. Hence, we examine the effectiveness of different development policies to exit the poverty trap. Our numerical experiments show that using means-tested education subsidies is the most cost-effective single policy option. However, for longer time horizons, or as the economy gets closer to the poverty trap threshold, combining means-tested education and wage subsidies is even more effective.

JEL Classification: O11, O15, O17

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1 Introduction

In this paper, we develop a two-sector growth model to analyze the dynamic implications of informality for long-run growth. The model features bidirectional causal links between informality and human capital accumulation, our source of economic growth. On the one hand, the existence of an informal sector influences the incentive to accumulate human capital; this is because informality lowers the skill premium and facilitates child labor. On the other hand, human capital affects the size of the informal sector; when the number of high-skilled workers is small, labor demand is low in the formal economy and informality increases. First, we theoretically show that these interdependencies between human capital accumulation and informality can be the source of transitory informality equilibria or informality-induced poverty traps. Second, we parametrize the model to match a set of stylized facts that describe the relationships between informality, human capital, child labor and growth. The calibrated model reveals that the case for the poverty trap is strong. In this context, we explore different policies that could enable a developing country to escape the poverty trap.

The informal economy is defined as the part of an economy that is not taxed, monitored by any form of government, or included in gross national product. Although it is difficult to measure precisely, informality is undoubtedly a widespread phenomenon in developing countries. For example, Schneider et al. (2010) estimate the average size of the shadow economy as a percentage of "official" GDP and obtain an average share of 38.4 percent in Sub-Saharan Africa, 34.7 percent in Latin America and the Caribbean, 25.1 percent in South Asia, and 13.5 percent in high-income OECD countries. The nature of the informal economy differs between rich and poor countries. In developed countries, the informal sector is characterized by unreported employment and sales. Informal activities are governed by the same production technology as in the formal sector and are simply hidden from the state for tax, social security or labor law purposes. Such *tax-based* informality ranges from 10 to 15 percent of official GDP in high-income countries (Schneider, 2005). The informal economy is of a different nature in developing countries (although tax evasion might also play a role). *Poverty-based* informality is characterized by low-skill intensive technology and provides a precious source of income to many low-skilled individuals who have very limited opportunities to be hired in the formal sector.[1]

The existing literature mainly focuses on tax-evasion motive and possible coordination failures in entrepreneurs' decisions. As far as *tax-based* informality is concerned, a large amount of literature has formalized firms' and workers' decisions to join the informal sector to avoid taxation or regulation from the government. Among others, Zenou (2008) exploits a search-matching model a la Mortensen-Pissarides to explain its emergence. A growing empirical literature aims at assessing the effect of

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[1] A similar division of the informal sector can be found in Fields (1990) or Maloney (2004). Fields (1990) distinguishes the *upper tier* and the *free entry* part of the informal sector. Maloney (2004) argues that it is hard to classify firms in each tier and that there is no consensus on the size of each.

taxes on informality in middle-income countries.[2] Inspired by the seminal work of Rosenstein-Rodan (1943), another strand of the literature (see Murphy et al. 1989, or Krugman 1991) demonstrates that the predominance of *poverty-based* informality can be seen as a result of a coordination failure, impeding the process of industrialization and productivity growth. These authors develop models of multiple equilibria, in which firms can choose to operate in the informal sector (characterized by low productivity and wages) or in the formal sector (characterized by high productivity and wages, and fixed equipment costs). Each firm has an incentive to move from informality to formality if the demand for the goods produced is large enough. This occurs when the economy-wide average income is high, i.e., when other firms industrialize and pay higher wages. Hence, a firm's decision whether to industrialize or not depends on its expectation of what other firms will do.

In this paper, we focus on *poverty-based* informality and disregard tax evasion.[3] We want to explore the relationships between informality, wage inequality, human capital accumulation, child labor and long-run growth in a unified model. We require the model to be compatible with five major stylized facts (presented in more detail in the next section). First, the size of the informal economy diminishes with development. Second, the informal sector employs mostly low-skilled workers and exhibits low total factor productivity (henceforth TFP). Third, child labor increases with informality. Fourth, skill premia are limited in poor countries, and no standard labor market model can account for such low skill premia. Fifth, the elasticity of recorded GDP per capita to human capital is close to unity and school enrolment rates are lower in poor countries.

We build a two-sector model, in which people choose to join or not to join the informal sector. We disregard taxation and simply assume the existence of technological differences between sectors (as in Murphy et al. 1989, or Krugman 1991). Then we investigate the implications of *poverty-based* informality on welfare, inequality, growth, and effectiveness of development policies. Our philosophy is to use an abstract economic model, which highlights the major economic mechanisms underlying the formation and persistence of the informal sector and development. Incentives to invest in children's education and opportunities to obtain income from children will play a key role. We then confront the theory to the data, calibrate the parameters of our model and study its dynamic properties. Such a quantitative theory approach is now the dominant research paradigm used by economists incorporating rational expectations and dynamic choice into short-run macroeconomic and monetary economics models (King, 1995). However, little work has been done so far with this methodology in long-term macroeconomics and development economics.

In our framework, the main link between informality and long-run growth operates

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[2]Using a survey of firms in Brazil, De Paula and Scheinkman (2010, 2011) emphasize the role of value added taxes in transmitting informality through chain effects: informality of a firm is correlated with the informality of firms from which it buys or sells.

[3]The stylized facts presented below will provide a tentative identification of the size of *poverty-based* informality in poor countries.

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through the accumulation of human capital. The incentive to accumulate human capital is lowered by the existence of the informal sector for two reasons. On the one hand, since the informal sector absorbs a large share of the unskilled labor force, the supply of unskilled workers to the formal sector is reduced, leading to a smaller skill premium. On the other hand, the occurrence of child labor is facilitated by the existence of the informal economy. Faced with lower skill premia and easier access to child labor, altruistic parents tend to choose less schooling for their children.

The model may generate multiple equilibria or a unique equilibrium, depending on the parameter values. In the absence of informality, the model predicts long-run convergence in income across nations. Informality may slow down this convergence process or be the source of a poverty trap. Using the stylized facts above and other consensual parameters from the literature, we calibrate our model and study its quantitative properties. This allows us to discriminate between the poverty-trap and slow-convergence hypotheses. The calibration exercise reveals that the case for the poverty-trap hypothesis is strong: although informality serves to protect low-skilled workers in the short run, it prevents income convergence across countries.

On this basis, we assess the effectiveness of different policy options. Sudden elimination of informality would induce large welfare losses for several generations of poor people on the transition path.[4] We thus compare different Pigouvian policies (subsidizing education to all families, or to low-income families, subsidizing high-skilled formal employment, or low-skilled formal employment) assuming that subsidies are financed by development assistance. Two criteria are used to evaluate these policies: cost-effectiveness and the length of the transition required to exit the poverty trap. Among the four subsidies considered, education subsidies paid to low-income families dominate the others in terms of cost efficiency. Moreover, only wage subsidies for low-skill jobs in the formal sector play a distinct and complementary role in the transition to the high-income equilibrium. Whereas the education and the high-skilled formal employment subsidies speed up the accumulation of human capital, the low-skill wage subsidy reduces the threshold at which the informal sector disappears. Therefore, targeted education subsidies are the cheapest single policy, but for medium time horizons, a combination of the two policies is found to be the most cost-efficient choice.

The remainder of this paper is organized as follows. Section 2 discusses the main stylized facts and Section 3 describes the model. The implications of informality are examined in Section 4. In Section 5, we calibrate the model and study its quantitative properties. Section 6 concludes.

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[4]For similar reasons, we do not consider the introduction of a child labor ban. Such a ban might even have the unintentional effect of increasing child labor (Bharadwaj et al. 2013).

2 Stylized facts

We require our model to be compatible with five major stylized facts (SF1 to SF5) on *poverty-based* informality and development, as illustrated in Figures 1(a) to 1(d).[5]

SF1. Informality decreases with development. Figure 1(a) shows the relation between the proportion of tertiary educated (completed college education) and the ratio of output between the informal and formal sectors in year 2000. In high-income countries, the average size of the informal sector is 13.5 percent (see dashed line in the figure) and it is mainly related to tax evasion.[6] Since *taxed-based* informality is not the focus of this paper, we disregard it and concentrate on the remaining part of informality (above the dashed line). Figure 1(a) shows a downward sloping relationship between informality and the proportion of high-skilled workers. Our model will endogenize the size of the informal sector and be consistent with this fact. The rationale is the following: low-skilled workers are mobile across sectors whereas high-skilled individuals only work in the formal sector. When the number of high-skilled workers is small, there is little demand for low-skilled labor in the formal sector and formal firms pay low wages to the less educated. Many low-skilled workers then move to the informal sector where wages are more attractive. Informality thus serves to protect low-skilled workers against very low levels of income offered in the formal sector and extreme poverty.

SF2. The informal sector exhibits lower TFP and employs low-skilled workers. This is a consensual hypothesis in informality models (Rosenstein-Rodan 1943, Murphy et al. 1989, Krugman 1991) which is supported by empirical studies. De Paula and Scheinkman (2011) show that informal firms are managed by less able entrepreneurs, are smaller and exhibit low capital-labor ratios. They estimate that the cost of capital faced by informal firms is at least 1.3 times the cost of capital of formal firms. Similarly, La Porta and Shleifer (2008) find evidence of a substantial difference between the registered and the unregistered firms regarding the skills of their managers, and suggested that this may drive many other differences, including the quality of inputs and access to finance. Rodrik (2013) points out that there is rapid unconditional convergence between rich and poor countries in manu-

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[5]In regression lines of Figures 1(a), 1(b), and 1(d), we exclude observations for socialist countries (in red) because informality in these countries is of a different nature.

[6]Measuring informality is a difficult task. People and firms who are engaged in illegal activities do not want to be known, or do not report their illegal activities. Measurement techniques can be grouped in direct and indirect methods; none of them are exempt from criticism. While direct methods use household micro surveys, indirect methods are more macroeconomic in essence: they look at the discrepancy between aggregate income and expenditure, electricity consumption versus economic activity, or monetary indicators (illegal activities conduct more transactions in cash). We also find authors who combine several indirect methods, as Schneider and coauthors. They use structural-equation estimation (MIMIC) that distinguishes between causes and indicators. The main causes are tax and social security contribution burdens, intensity of regulations, quality of public sector services, and state of the official economy. Among the indicators we can find monetary indicators, labor market indicators (comparison between total labor force and formal employment), or the state of the economy.

facturing industries, but this phenomenon is hidden by a persistent specialization of poor countries in low-productivity (formal and informal) activities. Based on these facts, our model defines informality as a sector with lower productivity, low-skilled employment, and constant marginal productivity of labor. By contrast, the formal sector combines high-skilled and less educated workers, exhibits decreasing marginal productivity, constant returns to scale, and higher total factor productivity.

SF3. Child labor increases with informality. One of the underlying aspects of informality is the existence of child labor. We can think of different forms of child labor, from shoeshine boys to children working in mining extraction. In general, children are not reported as part of the official labor force. Even if formal firms employ children, they are not recorded as part of their formal workers by the state agencies. Figure 1(b) plots the percentage of male children who work against the share of the informal economy, expressed as a percentage of GDP in 2000.[7] We can observe a positive correlation between informality and child labor. Note that the relation would be much steeper if high-income countries were included. Child labor is more likely to occur in poor families working in the informal economy. As these wealth-constrained families have to rely on the income from child labor, their children are unable to attend school and will therefore have little chance of escaping from poverty.

SF4. Skill premia are limited in poor countries, and no standard labor market model can account for such low skill premia. The relationship between the rate of return to one year of college (Hendricks 2004) and the proportion of college graduates in the labor force (Barro and Lee 2010) is represented in Figure 1(c).[8] Although returns to education decrease with human capital, they do not exceed 20 percent per year of schooling in low-income countries. Standard labor market models predict much larger return rates in developing countries. The CES representation is common in labor markets studies (such as Katz and Murphy, 1992, Card and Lemieux, 2001) and in cross-country analysis of relative productivity (Caselli and Coleman, 2006). Elasticities of substitution between 1.3 and 2 are obtained in most labor market studies including Angrist (1995), Borjas and Katz (2007) and Katz and Murphy (1992). Assuming that college graduates have ten years more education than the less educated and wages are equal to the marginal productivity of labor, the thin lines in Figure 1(c) represent the prediction of CES models with elasticities of substitution equal to one (Cobb-Douglas), 1.3 or 2.0. None of these models match the data. The average share of college graduates is around 3 percent in low-income countries. For such countries, the models predict a return to schooling comprised between 26 percent and 50 percent. The data provided in Hendricks (2004) show a maximal return to schooling of around 15 percent. We conclude that either the elasticities of

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[7]More precisely, Figure 1(b) depicts logarithms of percentages on both axes. In the World Bank data, child labor is defined as work by children involved in economic activity for at least one hour in the reference week of the survey.

[8]We use the most recent year of information of Mincerian returns in each country from Hendricks (2004).

substitution estimated for developed countries do not fit the production function of developing countries (an elasticity of 4.25 would be needed to match observations!), or the structure of the labor market differs across countries.[9] We plead for the second hypothesis and see informality as a key factor limiting the skill premium and wage inequality in poor countries. Informality maintains a large skill ratio (i.e., ratio of college graduates to less educated workers) in the formal sector, thus keeping the return to schooling at a low level (Rodrik, 2013).

SF5. The elasticity of recorded GDP per capita to human capital is close to unity and school enrolment is lower in poor countries. Although many studies point out that education has not generated as much growth as expected in developing countries, it is also reported that education is one of the necessary components for growth. As shown in Figure 1(d), the correlation between the proportion of college graduates in the labor force and GDP per capita is large, and the elasticity is close to unity. Despite scarcity in human capital, contemporaneous school enrolment rates are lower in poor countries.

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[9]Another possibility would be to assume that technologies differ between rich and poor countries, as in Caselli and Coleman (2006).

(a) Tertiary educated and informal sector size in 2000
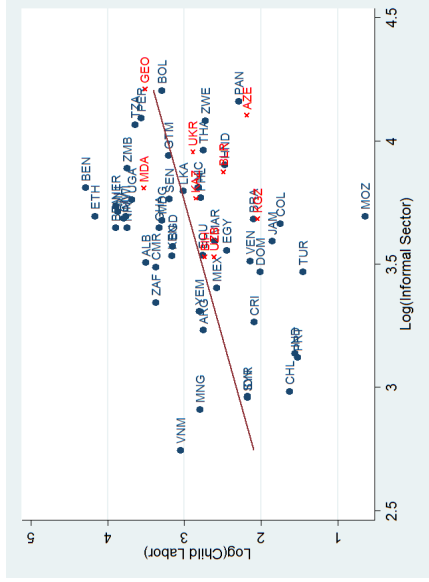
(b) Child labor and informal sector size in 2000
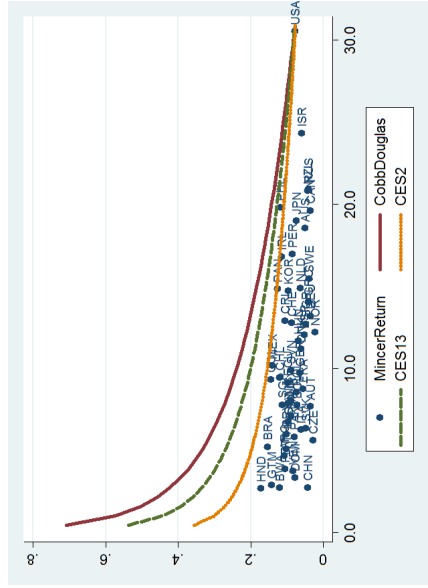
(c) Tertiary educated and return to one year of schooling
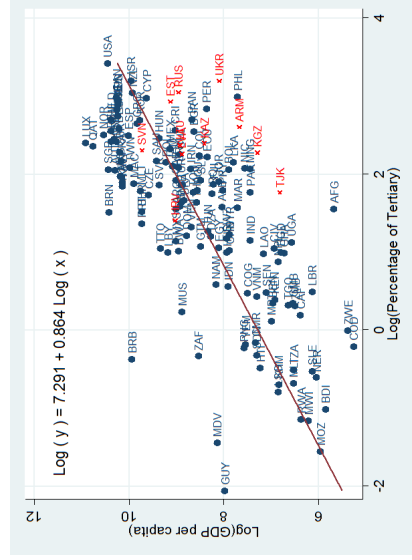
(d) GDP per capita and tertiary educated in 2000

Figure 1: Stylized facts on informality, education and development. Data sources. Education: Barro and Lee (2010); Informality: Schneider (2005); GDP: PWT 7.0; Child labor: World Development Indicators (2012); Returns to schooling: Hendricks (2004).

3 Model

We develop a two-period overlapping generations model in infinite discrete time with children and working-age adults. In every period, a single homogeneous good can be produced in two different sectors, the formal and informal sectors (labeled f and i). Formal firms employ high- and low-skilled workers whereas the informal sector only employs low-skilled workers. In each period there is an endogenous number of adults of each type who choose how much to consume and how much to invest in the education of their children. All decisions are made in the adult period of life, i.e., children do not get to decide anything. Below, we describe the technology, preferences, the dynamics, and define the competitive equilibrium path of our economy.

3.1 Production

A single good can be produced in two sectors. The formal sector employs high- and low-skilled labor and the informal sector only uses low-skilled labor. Let h_t be the proportion of high-skilled adults at time t, and N_t the total labor force of adults. We denote by $\overline{H}_t = h_t N_t$ and $\overline{L}_t = (1 - h_t)N_t$ the size of high- and low-skilled labor forces, respectively. Low-skilled workers are assumed to be perfectly mobile across sectors, whereas high-skilled workers have no incentive to join the informal sector.[10] Output Y_t is the sum of output $Y_{f,t}$ produced in the formal sector and output $Y_{i,t}$ produced in the informal one. Output produced in each sector is given by:

$$Y_{f,t} = A_t H_t^\alpha L_{f,t}^{1-\alpha}, \tag{1}$$

$$Y_{i,t} = B L_{i,t}, \tag{2}$$

where α is the elasticity of output with respect to high-skilled labor in the formal sector, A_t is a time-varying scale factor representing the state of technology, H_t is the quantity of high-skilled workers employed in the formal sector, $L_{f,t}$ and $L_{i,t}$ are the quantities of low-skilled workers employed in formal and informal sectors, respectively, and B is a scale factor associated with the technology in the informal sector, which is assumed to be constant.

We assume that total factor productivity (TFP) A_t in the formal sector is endogenous. It is a concave function of the skill ratio in the formal sector.[11] For simplicity and in reference to the AK model, the elasticity of TFP with respect to the skill ratio equals $1 - \alpha$, i.e.,

$$A_t = A_0 \left(\frac{H_t}{L_{f,t}} \right)^{1-\alpha}. \tag{3}$$

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[10]Our model does not account for brain waste, which may be responsible for employment of educated workers in informality.

[11]This assumption implies that the proportion of high-skilled individuals generates a positive externality on aggregate productivity. It is a particular case of Lucas' (1988) model and is also related to other AK models as the ones presented by Romer (1986) and Rebelo (1991).

For simplicity purposes, we write $B = \widetilde{\gamma} A_0$, where $\widetilde{\gamma}$ is a parameter that allows us to write B in terms of the scale factor A_0.[12] Moreover, B also defines the minimum wage that can be earned in the informal sector.

Firms choose inputs by maximizing profits

$$Y_{f,t} - w_{h,t} H_t - w_{l,t} L_{f,t} \tag{4}$$

and

$$Y_{i,t} - w_{l,t} L_{i,t}, \tag{5}$$

subject to $Y_{i,t} \geq 0$.[13] Under perfect competition, firms in formal and informal sectors choose employment levels by equalizing the marginal productivity of high- and low-skilled workers with their wage rates $w_{h,t}$ and $w_{l,t}$. In the formal sector, these conditions are

$$w_{h,t} = A_t \alpha \left(\frac{L_{f,t}}{H_t} \right)^{1-\alpha}, \tag{6}$$

$$w_{l,t} = A_t (1 - \alpha) \left(\frac{L_{f,t}}{H_t} \right)^{-\alpha}. \tag{7}$$

The output and employment decisions in the informal sector can be described by the complementary slackness conditions

$$\frac{w_{l,t}}{\widetilde{\gamma} A_0} \geq 1, \quad Y_{i,t} \geq 0, \quad \text{and} \quad \left(\frac{w_{l,t}}{\widetilde{\gamma} A_0} - 1 \right) Y_{i,t} = 0, \tag{8}$$

which depict two possible equilibrium regimes:

1. output in the informal sector is positive and the wage $w_{l,t}$ of low-skilled workers in both sectors is equal to the constant marginal productivity $\widetilde{\gamma} A_0$ of labor in the informal sector;

2. firms in the informal sector produce no output and the wage $w_{l,t}$ of low-skilled workers in the formal economy exceeds the marginal productivity of labor in the informal sector.

3.2 Preferences

Each adult of type $k \in \{h, l\}$ at period t chooses consumption $c_{k,t}$ and the proportion $q_{k,t} \in [0,1]$ of children sent to college to maximize utility. The utility function is

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[12] We require $\widetilde{\gamma} \in [0, \alpha]$ to be consistent with *SF2*. Productivity in the informal sector must be low enough (relative to the formal sector) to ensure that wages of low-skilled workers are not higher than wages of high-skilled workers. This condition is satisfied if $\widetilde{\gamma} \leq \alpha$ (which follows directly from equation (24) below).

[13] For simplicity, we omit the constraint $Y_{f,t} \geq 0$ because it is never binding in equilibrium.

logarithmic and depends on consumption $c_{k,t}$ and the average future wage $\overline{w}_{k,t+1}$ of children,

$$U_{k,t} = \ln(c_{k,t}) + \beta \ln(\overline{w}_{k,t+1}) \tag{9}$$

where β is the rate of preference for the income of children, and the average future wage of children is

$$\overline{w}_{k,t+1} = (1 - q_{k,t})w_{l,t+1} + q_{k,t}w_{h,t+1} = w_{l,t+1}(1 + q_{k,t}\sigma_{t+1}), \tag{10}$$

which depends on the value of the skill premium $\sigma_{t+1} = (w_{h,t+1} - w_{l,t+1})/w_{l,t+1}$ in the next period.

Educating a child incurs a monetary cost $\tilde{e}$.[14] Non-educated children can work in the informal sector as long as the informal sector exists, whereas educated children go to school and have no time left to work. In the informal sector, children receive a fraction $\eta \in [0,1]$ of the low-skilled wage rate because they lack experience and physical strength compared to adults. The budget constraint is

$$c_{k,t} = w_{k,t} - n_k q_{k,t}\tilde{e} + n_k(1 - q_{k,t})\eta w_{l,t}d_t, \tag{11}$$

where n_k is the (exogenous) number of children of a k-type adult, and d_t is a dummy variable equal to 1 if some output is produced in the informal sector, and 0 otherwise.

Plugging (10) and (11) into (9) and maximizing utility with respect to $q_{k,t}$, we obtain

$$\hat{q}_{k,t} = \frac{\beta\sigma_{t+1}(w_{k,t} + n_k\eta w_{l,t}d_t) - n_k(\tilde{e} + \eta w_{l,t}d_t)}{(1 + \beta)n_k(\tilde{e} + \eta w_{l,t}d_t)\sigma_{t+1}}. \tag{12}$$

Therefore, the optimal level of education is

$$q^*_{k,t} = \begin{cases} 0 & \text{if } \hat{q}_{k,t} < 0 \\ \hat{q}_{k,t} & \text{if } 0 \le \hat{q}_{k,t} \le 1 \\ 1 & \text{if } \hat{q}_{k,t} > 1. \end{cases} \tag{13}$$

3.3 Dynamics and competitive equilibrium

In the previous section we obtained adults' optimal decision on the proportion of children to be educated. Hence, given the proportion h_t of high-skilled workers in period t, fertility rates n_h and n_l, and the equilibrium condition (13), we can compute the proportion h_{t+1} of high-skilled workers in the next period. For simplicity, we assume that high-skilled parents educate all their children, i.e., we assume that parameters are such that $\hat{q}_{h,t} \ge 1$, which implies that $q^*_{h,t} = 1$.[15] By contrast, low-skilled parents

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[14]As we will observe later, equilibrium high-skilled wages will be constant. Hence, a constant education cost is equivalent to education costs being proportional to high-skilled wages, which implies that education is more difficult to obtain for low-skilled than for high-skilled workers.

[15]An alternative assumption to ensure that $\hat{q}_h \ge 1$ is to assume that h can not be higher than $\bar{h} < \alpha$ and parameters are such that $(A_0\alpha/(\tilde{e}n_h) - 1)\beta \ge 1 + (1 - \alpha)\bar{h}/(\alpha - \bar{h})$. de la Croix and Docquier (2012) use the same simplifying assumption.

only educate an endogenous fraction $q_{l,t} \in [0,1)$ of their children. Therefore, the dynamics of the skill ratio across generations is governed by

$$\frac{h_{t+1}}{1 - h_{t+1}} = \frac{n_h h_t + n_l q_{l,t}(1 - h_t)}{n_l(1 - q_{l,t})(1 - h_t)} = \frac{n}{1 - q_{l,t}} \frac{h_t}{1 - h_t} + \frac{q_{l,t}}{1 - q_{l,t}}, \tag{14}$$

where $n \equiv n_h/n_l$, $n \in (0,1)$ is the fertility ratio of high- to low-skilled workers. And the number N_t of adults evolves according to

$$\frac{N_{t+1}}{N_t} = n_h h_t + n_l(1 - h_t). \tag{15}$$

In addition, the labor-market-clearing conditions are

$$H_t = \overline{H}_t, \tag{16}$$

the supply and demand of high-skilled workers should be equal in equilibrium. In the next sections, we use H to denote the equilibrium number of high-skilled workers. And

$$L_{f,t} + L_{i,t} = \overline{L}_t + \eta n_l(1 - q_{l,t})\overline{L}_t d_t, \tag{17}$$

demand for low-skilled workers in formal and informal sectors should be equal to supply of low-skilled adults and the efficiency units of children who work. Moreover, we impose the following extra condition:

$$L_{i,t} > \eta n_l(1 - q_{l,t})\overline{L}_t \text{ whenever } L_{i,t} > 0. \tag{18}$$

Some adult workers are required for the functioning of the informal sector. Indeed, it seems reasonable to assume that children cannot work in the informal sector without a minimum amount of infrastructure provided by adults. We now define the intertemporal equilibrium of our economy:

Definition 1 *Given an initial population size N_0 and an initial number H_0 of high-skilled workers, an intertemporal equilibrium consists of sequences of prices $\{w_{h,t}, w_{l,t}\}$, aggregate quantities $\{N_t, \overline{H}_t, \overline{L}_t, H_t, L_{f,t}, L_{i,t}\}$, and households' decisions $\{c_{j,t}, q_{j,t}\}$ for $j = h, l$ and for all t such that:*

1. *the households' decisions $c_{j,t}$ and $q_{j,t}$ maximize utility (9) subject to the constraints (10) and (11);*

2. *the firms' choices H_t, $L_{f,t}$, and $L_{i,t}$ maximize profits (4) and (5) subject to the constraint $Y_{i,t} \geq 0$;*

3. *the prices $w_{h,t}, w_{l,t}$, and aggregate quantities $\overline{H}_t, \overline{L}_t$ are such that markets clear, i.e., (16) and (17) hold;*

4. *aggregate variables N_t, H_t evolve according to (14) and (15);*

5. *$\overline{L}_t$, $L_{i,t}$, and q_t^l satisfy (18).*

4 Implications of informality

In this section we characterize the existence of two possible transitory regimes, and then study the implications of informality for human capital accumulation and long-run growth.

4.1 The *formality* and *informality* regimes

Two regimes arise as a consequence of informality. On the one hand, the *formality* regime arises if all low-skilled adults opt for the formal sector and the informal sector disappears. On the other hand, the *informality* regime arises if the formal and informal sector co-exist.

The *formality* regime is characterized by the absence of an informal sector. Then, plugging (3) into (6) - (8), wages and the skill premium in the *formality* regime are

$$w_{h,t} = A_0\alpha, \tag{19}$$

$$w_{l,t} = A_0(1-\alpha)\frac{h_t}{1-h_t}, \tag{20}$$

$$\sigma_t = \frac{\alpha(1-h_t)}{(1-\alpha)h_t} - 1. \tag{21}$$

Hence, in the *formality* regime, the skill premium σ_t decreases with the proportion of high-skilled workers in the economy, and the limit of the skill premium equals infinity when h_t tends to zero. A model with a single formal sector predicts huge wage disparities when human capital is low.

Production in the informal sector becomes profitable for low-skilled workers if the wage rate paid in the formal sector is lower than the wage in the informal sector. Combined with the assumption of perfect mobility of low-skilled workers across sectors, this implies that the number of low-skilled workers in the formal sector is proportional to the number of high-skilled workers in the economy, i.e., $L_{f,t} = \gamma H_t$ where $\gamma \equiv (1-\alpha)/\widetilde{\gamma}$. Again, plugging (3) into (6) - (8) and taking into account that $Y_{i,t} > 0$, wages and the skill premium in the *informality* regime are

$$w_{h,t} = A_0\alpha, \tag{22}$$

$$w_{l,t} = \frac{A_0(1-\alpha)}{\gamma}, \tag{23}$$

$$\sigma_t = \frac{\alpha\gamma}{1-\alpha} - 1 = \overline{\sigma}. \tag{24}$$

When the informal sector is operating, the skill premium σ_t is constant and does not depend on the proportion h_t of high-skilled workers. Informality explains why skill premia are limited in developing countries where the proportion of college graduates is low, as illustrated by stylized fact *SF4*.

The following lemma characterizes the emergence of the *informality* regime and shows that informality only arises in economies with low levels of human capital:

Lemma 1 *The informality regime (resp. formality regime) arises when the proportion of high-skilled workers is not too large (resp. large enough), i.e., when $h_t < 1/(1+\gamma)$ (resp. $h_t \geq 1/(1+\gamma)$).*

Proof. Low-skilled adults work in the informal sector if and only if the wage paid in the informal sector is higher than the wage paid in the formal sector. From (20) and (23) we can conclude that the *informality* regime arises if and only if $h_t < 1/(1+\gamma)$ ∎

Let us denote GDP per capita and recorded GDP per capita by $y_t = Y_t/N_t$ and $y_{f,t} = Y_{f,t}/N_t$. Consistently with stylized fact *SF5*, our model predicts that the elasticity of formal output to human capital is equal to unity, as stated in the following proposition:

Proposition 1 *In the formality regime, GDP per capita is proportional to the share of high-skilled workers in the labor force, i.e., $y_t = A_0 h_t$, and recorded GDP is equal to GDP per capita, i.e., $y_{f,t} = y_t$. Meanwhile, in the informality regime, GDP per capita exceeds recorded GDP per capita, $y_t > y_{f,t}$, and recorded GDP per capita is proportional to the share of high-skilled workers, $y_{f,t} = A_0 h_t$.*

Proof. It follows from equations (1) and (3) ∎

In the *informality* regime, wages are constant. Hence, $q_{l,t}$ is equal to

$$q_{l,t}^* = \frac{\beta(1-\alpha)(1+\eta n_l)}{(1+\beta)[e\gamma + \eta(1-\alpha)]n_l} - \frac{1}{(1+\beta)\sigma_{t+1}}. \tag{25}$$

Note that in case that next period proportion h_{t+1} of high-skilled workers is not high enough so as to achieve the threshold proportion $1/(1+\gamma)$ that defines informality, then $q_{l,t}$ is constant and equal to

$$q_{l,t}^* = \frac{\beta[\alpha(1+\gamma)-1](1-\alpha)(1+\eta n_l) - n_l(1-\alpha)[e\gamma + \eta(1-\alpha)]}{(1+\beta)[e\gamma + \eta(1-\alpha)][\alpha(1+\gamma)-1]n_l} \equiv \bar{q}_l,$$

where $e = \tilde{e}/A_0$. Moreover, $q_{l,t}^* \leq \bar{q}_l$ when $\sigma_{t+1} \leq \bar{\sigma}$.

In line with some empirical papers such as Schneider (2005) or Schneider et al. (2010), we define the informality level as the ratio of value added in the informal sector to value added in the formal sector (official GDP), i.e., $I_t = Y_{i,t}/Y_{f,t}$. Note that $I_t \equiv 0$ in the *formality* regime. Consistently with stylized fact *SF1*, we have:

Proposition 2 (Short-run effects of informality) *The informal sector increases the wage of low-skilled workers, whereas the wage of high-skilled workers is not modified. Moreover, the informality level I_t shows a decreasing relationship with respect to the proportion of high-skilled workers in the labor force in the informality regime.*

Proof. From (19) and (22) we can see that high-skilled wages are equivalent in both regimes. From (20) and (23), low-skilled wages within the *informality* regime are at least as high as in the *formality* regime if and only if $h_t/(1 - h_t) < 1/\gamma$, and, by Lemma 1, the *informality* regime exists if and only if $h_t < 1/(1 + \gamma)$, which is equivalent to $h_t/(1 - h_t) < 1/\gamma$. Moreover, in the *informality* regime

$$I_t = \frac{Y_{i,t}}{Y_{f,t}} = \frac{1 - \alpha}{\gamma} \left(\frac{(1 - h_t)(1 + \eta n_l(1 - q_{l,t}))}{h_t} - \gamma \right).$$

Note that $q_{l,t}$ is characterized by equation (25). Since (24) and (21) characterize a continuous function $\sigma(h_t) = \sigma_t$ for $h_t \in [0, 1]$, thus $q_{l,t}$ defined in equation (25) is continuous. Two cases arise, if $h_{t+1} < 1/(1+\gamma)$, then $q_{l,t} = \overline{q_l}$, and if $h_{t+1} \geq 1/(1+\gamma)$, then $q_{l,t}$ is defined by equation (25). In the former case $dq_{l,t}/dh_t = 0$, whereas in the latter case $dq_{l,t}/dh_t$ can be $\neq 0$. To compute this derivative let z_t be $h_t/(1 - h_t)$. This monotonic variable transformation enables us to write equations (14) and (25) as

$$z_{t+1} = \frac{nz_t + q_{l,t}}{1 - q_{l,t}}$$

and

$$q_{l,t}^* = \Omega - \frac{(1 - \alpha)z_{t+1}}{(1 + \beta)(\alpha - (1 - \alpha)z_{t+1})},$$

where $\Omega = (\beta (1 - \alpha)(1 + \eta n_l)) / ((1 + \beta)(e\gamma + \eta(1 - \alpha)) n_l)$. In order to compute the derivative $dq_{l,t}/dh_t$, we can plug the latter expression into the former expression and let H be a mapping from $\mathbb{R}^2$ to $\mathbb{R}$ such that

$$H(q_{l,t}, z_t) = \frac{nz_t + q_{l,t}}{1 - q_{l,t}} - \frac{\alpha}{(1 - \alpha)} \frac{(1 + \beta)(\Omega - q_{l,t})}{1 + (1 + \beta)(\Omega - q_{l,t})}.$$

The vectors $(q_{l,t}, z_t)$ such that $H(q_{l,t}, z_t) = 0$ characterize the problem. Taking partial derivatives we obtain the Jacobian

$$DH(q_{l,t}, z_t) = \left[\frac{\partial H(q_{l,t}, z_t)}{\partial q_{l,t}}, \frac{\partial H(q_{l,t}, z_t)}{\partial z_t} \right] = [DH_1, DH_2]$$

$$= \left[\frac{1 + nz_t}{(1 - q_{l,t})^2} + \frac{\alpha}{(1 - \alpha)} \frac{(1 + \beta)}{(1 + (1 + \beta)(\Omega - q_{l,t}))^2}, \frac{n}{(1 - q_{l,t})} \right].$$

Since $DH_1 > 0$, by the Implicit Function Theorem there exists a function $q_{l,t}(z_t)$ in a neighborhood of z_t and

$$\frac{dq_{l,t}}{dz_t} = -\frac{n(1 - q_{l,t})}{1 + nz_t + \frac{\alpha(1+\beta)(1-q_{l,t})^2}{(1-\alpha)\left(1+(1+\beta)(\Omega-q_{l,t})\right)^2}},$$

which implies that

$$\frac{dq_{l,t}}{dh_t} = -\frac{n(1 - q_{l,t})}{(1 - h_t)^2 + nh_t(1 - h_t) + \frac{\alpha(1+\beta)(1-q_{l,t})^2(1-h_t)^2}{(1-\alpha)\left(1+(1+\beta)(\Omega-q_{l,t})\right)^2}}.$$

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Furthermore,

$$\frac{dI_t}{dh_t} = -\frac{1-\alpha}{\gamma}\left(\frac{1+\eta n_l(1-q_{l,t})}{h_t^2} + \eta n_l \frac{dq_{l,t}}{dh_t}\frac{1-h_t}{h_t}\right)$$

for all $h_{t+1} \neq 1/(1+\gamma)$. If $h_{t+1} < 1/(1+\gamma)$ then $dq_{l,t}/dh_t = 0$ and $dI_t/dh_t < 0$. If $h_{t+1} > 1/(1+\gamma)$ then

$$\frac{dI_t}{dh_t} = -\frac{1-\alpha}{\gamma h_t}\left[\frac{1}{h_t} + \frac{\eta n_l(1-q_{l,t})}{h_t} - \frac{\eta n_l(1-q_{l,t})}{h_t + \frac{(1-h_t)}{n} + \frac{\alpha(1+\beta)(1-q_{l,t})^2(1-h_t)n}{(1-\alpha)\left(1+(1+\beta)(\Omega-q_{l,t})\right)^2}}\right] < 0,$$

which implies that the informality level I_t always shows a decreasing relationship with respect to h_t ■

The existence of the informal sector reduces wage inequality, which can be good for growth because of the negative association between high inequality and long-run growth pointed out by some authors.[16] However, informality allows firms to recruit children from poor households for work. The following result establishes the link between child labor and informality, consistent with stylized fact *SF3*:

Corollary 1 (Child labor) *The proportion of children who work decreases as the proportion of high-skilled workers in the labor force increases in the informality regime. Hence, the proportion of children who work increases as the informality level increases.*

Proof. The proportion of children who work is

$$CL(h_t) = \frac{(1-q_{l,t})(1-h_t)n_l}{h_t n_h + (1-h_t)n_l} = \frac{(1-q_{l,t})(1-h_t)}{1-h_t(1-n)}.$$

Hence, taking the derivative with respect to h_t we obtain

$$CL'(h_t) = -\frac{dq_{l,t}}{dh_t}\frac{1-h_t}{1-h_t(1-n)} - \frac{(1-q_{l,t})n}{(1-h_t(1-n))^2}.$$

As in the previous Proposition, if $h_{t+1} < 1/(1+\gamma)$ then $dq_{l,t}/dh_t = 0$ and $CL'(h_t) < 0$. Whereas if $h_{t+1} > 1/(1+\gamma)$ then

$$CL'(h_t) = (1-q_{l,t})n\left(\frac{1}{(1-h_t(1-n))^2 + \Upsilon} - \frac{1}{(1-h_t(1-n))^2}\right) < 0,$$

where

$$\Upsilon = (1-h_t(1-n))\left(\frac{\alpha(1+\beta)(1-q_{l,t})^2(1-h_t)}{(1-\alpha)\left(1+(1+\beta)(\Omega-q_{l,t})\right)^2}\right) > 0$$

and $\Omega = (\beta(1-\alpha)(1+\eta n_l))/((1+\beta)(e\gamma + \eta(1-\alpha))n_l)$. Moreover, from the previous Proposition we know that I increases as h decreases, which implies that the proportion of children who work increases with informality ■

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[16]See Galor and Zeira (1993) or Alesina and Rodrik (1994) among others.

4.2 Effect on long-run growth

We now turn to the analysis of the long-run effects of informality, in particular, we study its effects on human capital accumulation. We distinguish three important channels. First, as informality limits the returns to schooling, it is likely to reduce the incentive to acquire human capital. Second, the existence of an informal economy allows firms to hire children for work. Third, there is an income effect due to informality that may increase the wage of low skilled workers.

In the *formality* regime, i.e., $h_t \geq 1/(1+\gamma)$, substituting wage rates (19)-(21) into (13) yields:

$$q_{l,t}^* = \frac{\beta(1-\alpha)h_t}{(1+\beta)en_l(1-h_t)} - \frac{\alpha - h_{t+1}}{(1+\beta)(1-\alpha)h_{t+1}} \equiv q_l(h_t, h_{t+1}). \qquad (26)$$

Moreover, human capital dynamics for an economy without informality are governed by

$$\frac{h_{t+1}}{1-h_{t+1}} = \frac{n}{1-q_l(h_t, h_{t+1})} \frac{h_t}{1-h_t} + \frac{q_l(h_t, h_{t+1})}{1-q_l(h_t, h_{t+1})} \equiv \varphi(h_t, h_{t+1}). \qquad (27)$$

Therefore, plugging (26) into (27) characterizes human capital dynamics. To simplify these two expressions let z_t be $h_t/(1-h_t)$. This variable transformation allows us to write equations (26) and (27) as follows:

$$q_{l,t}^* = \frac{\beta(1-\alpha)}{(1+\beta)en_l} z_t - \frac{(1-\alpha)z_{t+1}}{(1+\beta)\alpha(1+z_{t+1}) - z_{t+1}} \equiv q_l(z_t, z_{t+1})$$

and

$$z_{t+1} = \frac{n}{1-q_l(z_t, z_{t+1})} z_t + \frac{q_l(z_t, z_{t+1})}{1-q_l(z_t, z_{t+1})} \equiv \varphi(z_t, z_{t+1}).$$

Moreover, the properties of the dynamical system are not modified by this transformation. The following proposition describes the long-run convergence of human capital in the *formality* regime:

Proposition 3 (Long-run convergence in the *formality* regime) *The dynamical system characterized by (26) and (27) displays a stable steady state $h_s^{stst} > 0$ and an unstable steady state $h_u^{stst} = 0$ in $h \in [0,1]$ if and only if parameters satisfy the following condition $(1 + \alpha\beta)en_l < \alpha((1-\alpha)\beta + (1+\beta)nen_l)$.*

Proof. The proof is divided into three steps.

Step 1: there exists a function ψ that determines z_{t+1} given z_t and its slope is positive for all $z_t \geq 0$, i.e., $z_{t+1} = \psi(z_t)$ and $\psi'(z_t) > 0$.
Let F be a function $F : \mathbb{R}^2 \to \mathbb{R}$ such that $F(z_t, z_{t+1}) = \varphi(z_t, z_{t+1}) - z_{t+1}$. The

vectors (z_t, z_{t+1}) such that $F(z_t, z_{t+1}) = 0$ characterize human capital dynamics. Taking partial derivatives we obtain the Jacobian

$$DF(z_t, z_{t+1}) = \left[\frac{\partial \varphi(z_t, z_{t+1})}{\partial z_t}, \frac{\partial \varphi(z_t, z_{t+1})}{\partial z_{t+1}} - 1 \right] = [DF_1, DF_2]$$

$$= \frac{1}{(1 - q_l)^2} \left[n(1 - q_l) + q_1(1 + nz_t), q_2(1 + nz_t) - (1 - q_l)^2 \right],$$

where $q_l = q_l(z_t, z_{t+1})$, $q_1 = \partial q_l(z_t, z_{t+1})/\partial z_t = \beta(1 - \alpha)/(en_l(1 + \beta)) > 0$, and $q_2 = \partial q_l(z_t, z_{t+1})/\partial z_{t+1} = -\alpha(1 - \alpha)/\left((1 + \beta)(\alpha(1 + z_{t+1}) - z_{t+1})^2\right) < 0$ for all z_t. Since $DF_2 < 0$, by the Implicit Function Theorem there exists a function $z_{t+1}(z_t) = \psi(z_t)$ in a neighborhood of z_t (for all z_t) and

$$z'_{t+1}(z_t) = \psi'(z_t) = -\frac{n(1 - q_l) + q_1(1 + nz_t)}{q_2(1 + nz_t) - (1 - q_l)^2}.$$

Moreover, ψ is increasing for all $z_t \geq 0$, i.e., $\psi'(z_t) > 0$, because the numerator is strictly positive if $z_t \geq 0$, while the denominator is negative.

Step 2: the dynamical system displays two steady state values in $z \geq 0$: 0 and $z_+ > 0$, and they are the only ones.
The steady state values are the vectors (z_t, z_{t+1}) such that $z_t = z_{t+1}$, or the values of z such that $F(z, z) = 0$. Note that (26) and (27) become

$$q_l(z, z) = z \frac{1 - \alpha}{1 + \beta} \left(\frac{\beta}{en_l} - \frac{1}{\alpha(1 + z) - z} \right) \tag{28}$$

and

$$z = \frac{nz + q_l(z, z)}{1 - q_l(z, z)} \tag{29}$$

respectively. Plugging (28) into (29) and rearranging terms we obtain

$$F(z, z) = q_l(z, z)z + q_l(z, z) - (1 - n)z.$$

Clearly, $z = 0$ satisfies $F(0, 0) = 0$ because $q_l(0, 0) = 0$. Since we are interested in the remaining solutions to the problem $F(z, z) = 0$, we substitute q_l, divide by z, and equalize to 0. The solutions to the resulting equation can be rewritten as the roots of the following grade 2 polynomial of z:

$$a_2 z^2 + a_1 z + a_0 = 0,$$

where

$$a_0 = -\left(1 + \alpha\beta + \frac{(1 + \beta)(1 - n)en_l\alpha}{1 - \alpha} \right),$$
$$a_1 = (1 + \beta)(1 - n) - (1 - \beta + 2\alpha\beta),$$
$$a_2 = (1 - \alpha)\beta.$$

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Since $a_0 < 0$ and $a_2 > 0$, the roots of the polynomial are $z_- < 0$ and $z_+ > 0$. Hence, the steady state values of the dynamical system are z_-, 0, and z_+.

Step 3: $\lim_{z \to +\infty} \psi'(z) = 0$.
Rewrite $\psi'(z_t)$ as

$$\psi'(z_t) = \frac{\frac{n(1-q_l)}{1+nz_t} + q_1}{-q_2 + \frac{(1-q_l)^2}{1+nz_t}}$$

and note that the denominator goes to infinity when z_t goes to infinity whereas the numerator goes to 0 or to a constant because q_1 is a constant,

$$-\infty < \lim_{z_t \to +\infty} \frac{n(1 - q_l(z_t, \psi(z_t)))}{1 + nz_t} = -n\frac{\beta}{1+\beta}\frac{1-\alpha}{en_l} < +\infty,$$

$$0 \leq \lim_{z_t \to +\infty} -q_2 =< +\infty,$$

and

$$\lim_{z_t \to +\infty} \frac{(1-q_l)^2}{1+nz_t} = +\infty.$$

From *Steps 1* and *2* we know that the system is well defined and displays two different steady state values in $z \geq 0$: 0 and $z_+ > 0$. A necessary and sufficient condition for the instability of the 0 steady state is $\psi'(0) > 1$, which is equivalent to $(1 + \alpha\beta)en_l < \alpha((1-\alpha)\beta + (1+\beta)nen_l)$. Moreover, *Step 3* ensures that $z_{t+1} = \psi(z_t) < z_t$ for all $z_t > z_+$, and we can conclude that z_+ is stable because necessarily $0 < \psi'(z_+) < 1$ ∎

In the *informality* regime, i.e., $h_t < 1/(1+\gamma)$ or $z_t < 1/\gamma$, we have $q^*_{l,t} = \bar{q}_l$ if $h_{t+1} < 1/(1+\gamma)$, which is satisfied if $1 - n \geq \bar{q}_l(1+\gamma)$.[17] This condition is satisfied if the fertility ratio n is low enough, and both the relative productivity $\tilde{\gamma}$ of the informal sector and the education cost $\tilde{e}$ are sufficiently high. In this case the dynamics of the skill ratio z_t are governed by

$$z_{t+1} = \frac{n}{1 - \bar{q}_l}z_t + \frac{\bar{q}_l}{1 - \bar{q}_l} \equiv \phi(z_t), \tag{30}$$

where $\phi(z_t)$ is a linear function of z_t with $\phi(0) > 0$ and a slope smaller than one if $n < 1 - \bar{q}_l$.

Proposition 4 (Long-run effects of informality) *There are poverty traps in the informality regime if and only if $1 - n \geq \bar{q}_l(1+\gamma)$.*

Proof. Human capital dynamics are determined by (30). Thus, a stable poverty trap with informality emerges if and only if $\phi(1/\gamma) \leq 1/\gamma$, and $n/(1 - \bar{q}_l) < 1$. The

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[17] Follows from equation (14).

former condition is equivalent to $1 - n \geq \bar{q}_l(1 + \gamma)$. In addition, this condition ensures that $1 > \bar{q}_l + n$. Hence, the former condition is sufficient for the latter condition to be satisfied. Therefore, there exists a steady state level of human capital such that $h^{ss} < 1/(1 + \gamma)$ if and only if $1 - n \geq \bar{q}_l(1 + \gamma)$ ■

Hence, the key condition on parameters governing the dynamic properties of the model is:

Condition 1 $1 - n \geq \bar{q}_l(1 + \gamma)$.

If this condition holds, informality is the source of a poverty trap. Otherwise, informality is a transitory phenomenon. This condition is satisfied if the fertility ratio n is low enough, and both the relative productivity $\widetilde{\gamma}$ of the informal sector and the education cost $\tilde{e}$ are sufficiently high. Moreover, it ensures that $h_{t+1} < 1/(1+\gamma)$ in the *informality* regime.[18] We will check in the numerical part whether this condition is satisfied or not.

The previous two propositions characterize the equilibrium path of the skill ratio. Figure 2(a) shows the dynamics with and without informality. The solid line corresponds to an economy with informality if the skill ratio is lower than $z_0 = 1/\gamma$, while the dashed line corresponds to one without informality. For high enough levels of human capital there is no informal sector and both lines coincide. As predicted by Proposition 3, without the informal sector the skill ratio converges to the point A_1 as long as the initial skill ratio is larger than 0. However, if the informal sector is at work, Proposition 4 states that there can be poverty traps as the one presented in Figure 2(a). The linear part of the solid line crosses the 45° line and the skill ratio converges to the point A_2 if the initial skill ratio is lower than z_0.

Figure 2(b) presents three different possibilities of skill ratio dynamics with informality. In all cases there is a jump from the *formality* to the *informality* regime due to child labor in the informal sector. Dynamic B is a possible situation without poverty traps. It might arise if condition 1 does not hold. This occurs, for example, if the education cost $\tilde{e}$ is low enough. Dynamic A is a case with a poverty trap in the *informality* regime, and convergence to a high proportion of high-skilled workers in the *formality* regime. Whereas Dynamic C corresponds to a case where parameters are such that there is no stable steady state without informality. Because of the existence of the informal sector the poverty trap makes the economy converge to point C, which is characterized by a low proportion of high-skilled workers in the economy.

5   Quantitative assessment

We have shown that informality may slow down income convergence across countries or be the source of a poverty trap depending on the fact that the model exhibit multiple equilibria or uniqueness. In this section, we confront the theory with the data, calibrate the model, and discriminate between these two hypotheses.

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[18]From equation (14).
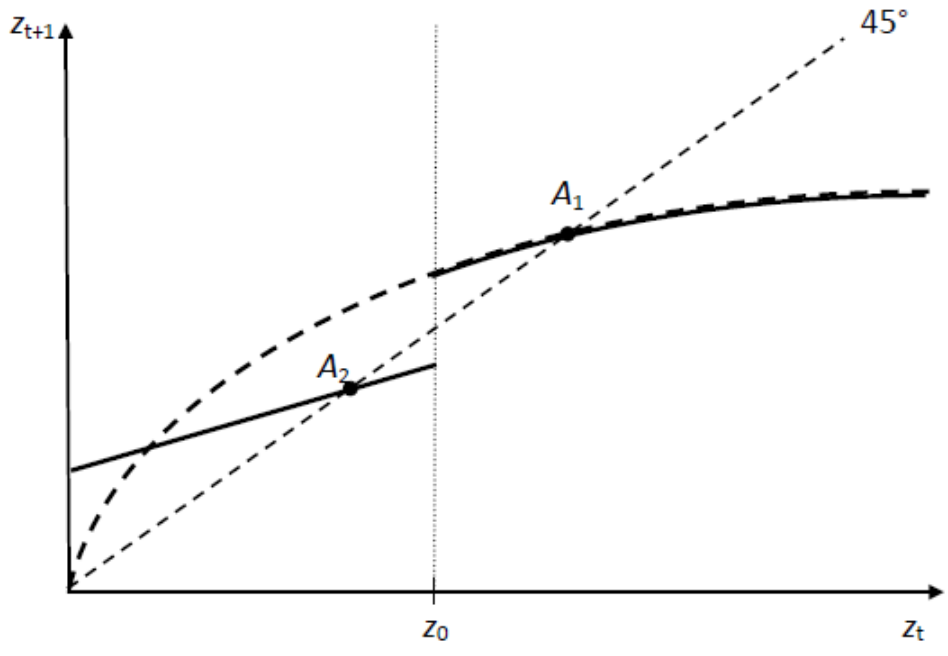
(a) Dynamics with and without informality
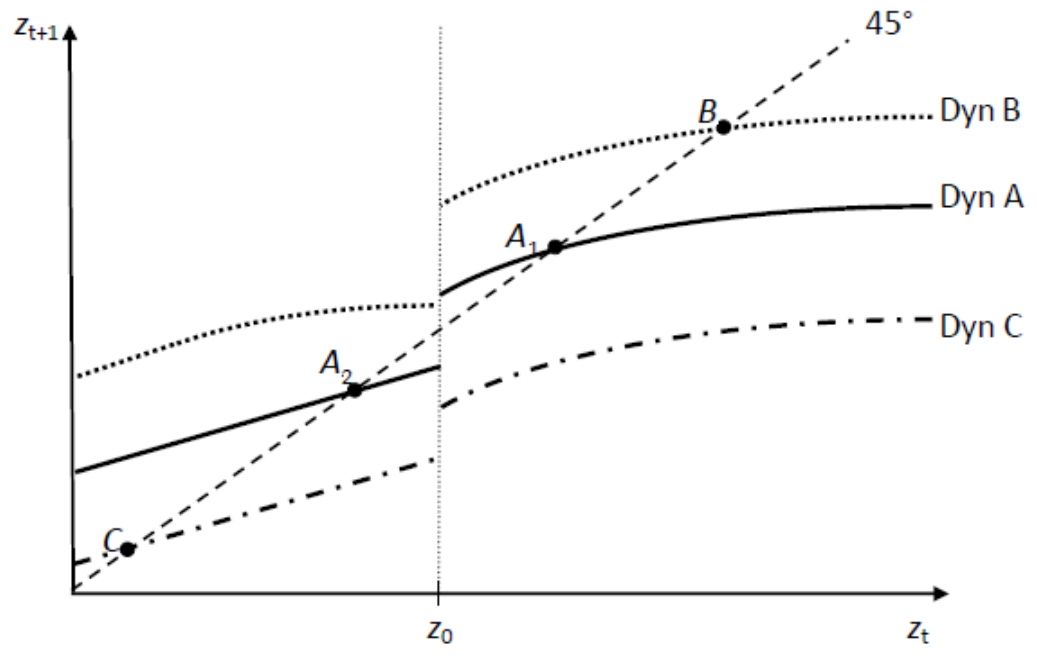
(b) Different configurations with informality

Figure 2: Dynamics of human capital accumulation with informality

5.1 Parametrization

The model is calibrated under the assumption that one period (or generation) represents 30 years, and that individuals are considered high-skilled if they have at least 10 years of education. Our parametrization strategy is based on the following principles:

- Parameters are calibrated so as to be compatible with observations for industrialized countries (i.e. the United States or an average of G7 countries) and a representative least developed economy.

- In the benchmark, the situation of the United States is considered as a possible steady state without *poverty-induced* informality. We also simulate variants in which the average situation of G7 countries (Australia, Canada, France, Germany, Japan, United Kingdom, United States) is a steady state. Least developed countries might be out of steady state and are characterized by the *informality* regime.

- We require our calibrated model to be compatible with the stylized facts described in the introduction. The underlying assumptions of our model are such that these stylized facts are matched.

- Developing countries and the United States share the same exogenous characteristics: A_0, e, η, α, γ, β, n_h and n_l.

- Several scenarios are used to check whether our conclusions are robust to the identifying assumptions.

As for the skill premium in industrialized countries (σ^{Rich}), we use recent data from Hendricks (2004). The return to schooling observed in the United States is equal to 7.83 percent per year of schooling, implying a skill premium of 112 percent for ten years of education ($\sigma_t^{US} = 1.12$). This value will be used in the benchmark scenario. Other values will be used in robustness scenarios 1 to 5. The average return to schooling in the G7 countries amounts to 6.00 percent per year of schooling, implying $\sigma_t^{G7} = 0.80$. In addition, Hendricks (2004) reports a return to schooling between 12 and 15 percent in the least developed countries, or equivalently a level of σ_t^{Poor} between 2.5 and 3.0.

As for human capital in industrialized countries (h^{rich}), we use Barro and Lee data (Barro and Lee, 2010) on the proportion of individuals aged 25 and over with tertiary education in the year 2000. The United States proportion of workers with at least one year of college completed is equal to 31 percent in 2000 ($h^{US} = 0.31$). This value will be used in the benchmark. Other values will be used in the robustness scenarios. In the G7 countries, this proportion is equal to 20 percent ($h^{G7} = 0.20$). Note that Barro and Lee also provide data on the proportion of individuals with tertiary education started but not completed: it amounts to 50 percent ($h^{USn} = 0.50$). In the least developed countries, the proportion of college graduates is around 3 percent ($h^{Poor} = 0.03$).

As for parameters affecting households' decisions, the fertility ratio n of high- to low-skilled workers is set to 0.57 from Kremer and Chen (1995). They show that n does not vary that much with the level of development, it is stable across countries and over time. In the benchmark, as we can observe in the United States and other developed economies, we assume no population growth, which implies $n_h = 0.65$ and $n_l = 1.15$. We assume these parameters are constant across countries. This generates a negative relationship between the average fertility rate and development because the proportion of low-fertility, high-skilled households increases with development. Although this underestimates the average fertility rate in the least developed countries, endogenizing fertility would make the occurrence of a poverty trap more likely.

Other parameters are identified to match the above identifying assumptions. Plugging h_{ss}^{rich} and σ^{Rich} into (21), we obtain $\alpha = 0.49$ in the benchmark. From (24), this requires γ to be equal to 4.24, which implies that $\widetilde{\gamma}$ is 0.12 and the threshold proportion of college graduates below which the *informality* regime is observed is 19 percent (h_{thres}). Assuming that the United States economy is in the steady state, we obtain $\beta = 0.19$ from (13) and (14). Haveman and Wolfe (1995) and Knowles (1999) suggest that the education cost is around 15 percent of time endowment of parents while children live with their parents. This implies that, if children live with their parents for 15 years, $e = 0.04$ in the benchmark.[19] The relative productivity η of children compared to low-skilled adults matches the empirical evidence presented by Horrell and Humphries (1995). In the benchmark scenario, we use $\eta = 0.34$ to have 25 percent of low-skilled families' income coming from child labor in the least developed countries.[20]

Table 1 shows the identifying assumptions and provides the fitted values for identified parameters in the benchmark scenario and in 5 variants. Column 1 gives the benchmark values. In Scenario 1, h^{rich} is given by the proportion of individuals with some tertiary education (not necessarily completed). In Scenario 2, the proportion of tertiary and the skill premium in rich countries are calibrated using data for G7 countries. In Scenario 3, we use a lower level for the skill premium in the least developed countries. Scenario 4 combines scenarios 2 and 3. Results for alternative scenarios 1 to 4 are provided in the Appendix.

5.2 The case for multiplicity

Figure 3(a) depicts the human capital dynamics with parameter values obtained in the benchmark scenario. As predicted by Proposition 4, a poverty trap emerges in the presence of informality because (i) the informal sector does not allow high-skilled

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[19]For example, de la Croix and Doepke (2003) assume that children live 15 out of 30 years with parents.

[20]We obtain a relative productivity of children compared to parents higher than Doepke and Zilibotti (2005) who obtain 0.1 to match the same empirical fact. However, Goldin and Sokoloff (1984) claim that that the relative productivity of children and females compared to males rose from around 0.3 in the North (.58 in the South) to .5 from 1820 to 1850, which is in line with our value.

Table 1: Identifying assumptions and fitted parameter values

|	Benchmark	Scen 1	Scen 2	Scen 3	Scen 4
σ^{Rich}	1.12	1.12	0.80	1.12	0.80
σ^{Poor}	3.0	3.0	3.0	2.5	2.5
h^{rich}	0.31	0.50	0.20	0.31	0.20
$n_l^{(a)}$	1.15	1.27	1.09	1.15	1.09
$n = n_h/n_l$	0.57	0.57	0.57	0.57	0.57
$e^{(a)}$	0.04	0.05	0.02	0.04	0.02
$\alpha^{(a)}$	0.49	0.68	0.31	0.49	0.31
$\beta^{(a)}$	0.19	0.23	0.20	0.19	0.20
$\eta^{(a)}$	0.34	0.36	0.35	0.33	0.34
$\gamma^{(a)}$	4.24	1.91	8.98	3.67	7.78
$h_{thres}^{(a)}$	0.19	0.34	0.10	0.21	0.11

[a] Fitted value for identified parameters

wages to increase enough so as to encourage education, and (ii) the existence of informality opens the door to child labor. Hence, countries starting with less than 19 percent of college graduates (i.e. 60 percent of the US level) are stuck in a poverty trap, and their proportion of educated converges to a long-run proportion of about 7 percent. By contrast, countries with an initial proportion of educated above 19 percent converge to the high steady state. Note that this threshold is consistent with the data used in Figure 1(a).

As can be seen in Figure 3(b), human capital dynamics are driven by the proportion q_l of children of low-skilled parents. In the *informality* regime a constant share of children is educated. The discontinuity in q_l is due to the fact that child labor is only possible in the *informality* regime. In the *formality* regime, education investment q_l increases up to a point where parents do not find it profitable to educate so many children (because the skill premium decreases). Hence, above a certain level of human capital, the average proportion of educated children decreases.

These two figures explain why the poverty trap emerges. The existence of the informal sector reduces the return to education and increases the opportunity cost of sending children to school (since they can only work in the informal sector). Therefore the proportion q_l is lower in the *informality* regime than in the *formality* regime for proportions h_t of high-skilled workers between 4% and 19%. Because agents do not internalize the externality of education on TFP and the low number of highly educated children, the proportion of high-skilled workers remains low and stable over time. For lower levels of human capital ($h_t < 0.04$), the income effect leads to higher education investments in the informality regime.

In the Appendix, we simulate the human capital dynamics under the four alternative sets of identifying assumptions (see figures 8 to 11). In all cases, a poverty
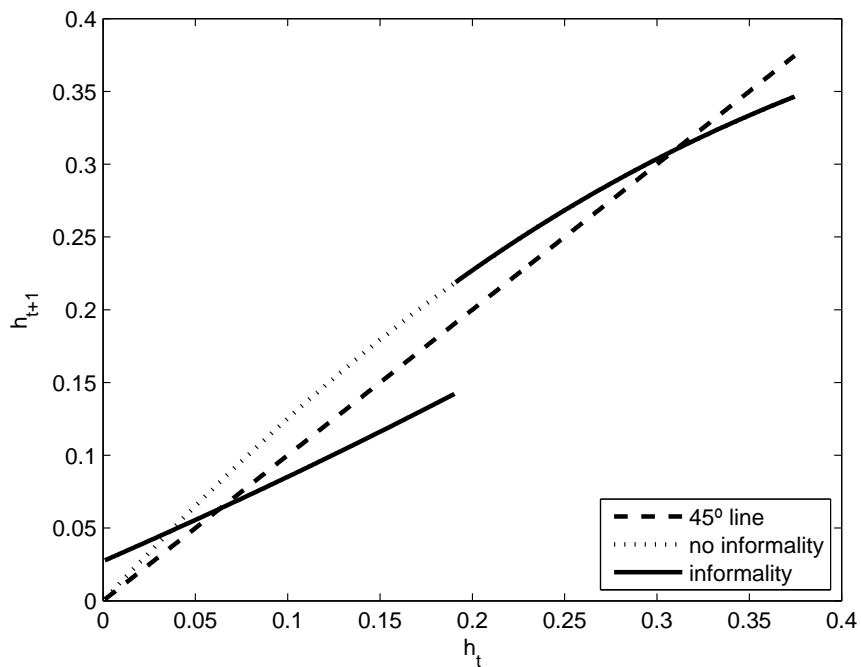
(a) $h_{t+1}(h_t)$
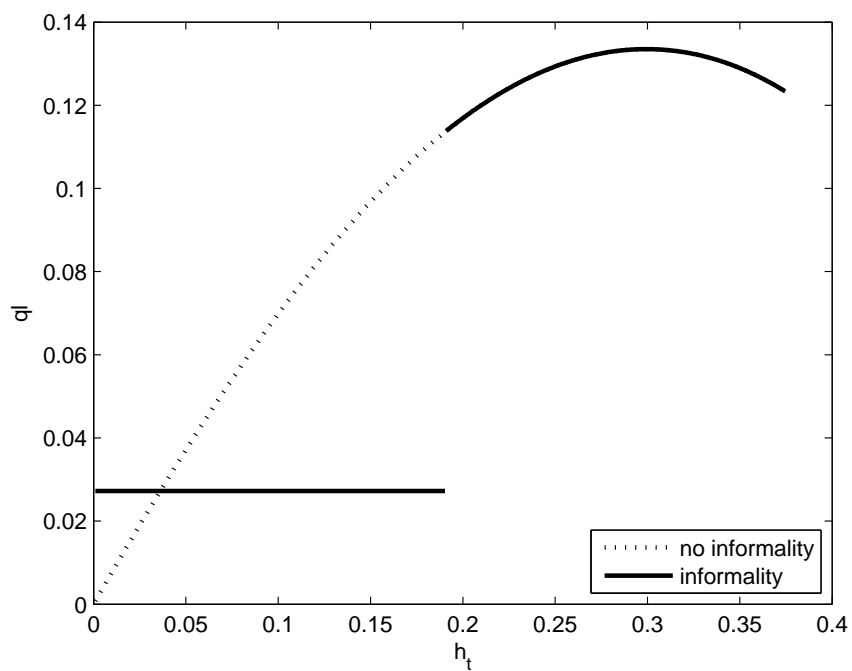
(b) $q_l(h_t)$

Figure 3: Human capital dynamics $h_{t+1}(h_t)$ and proportion $q_l(h_t)$ of educated children with and without informal sector.

trap emerges, except in scenario 2 which shows a "bifurcation" or borderline configuration. In all cases, the threshold level of human capital defining the poverty trap always corresponds to about 60 percent of the steady state proportion of educated in rich countries (the US or the G7 countries). The long-run level of human capital in the poverty trap is particulary low in scenarios 3 and 4. This situation is due to the fact that q_l becomes very low in these two scenarios.

5.3 Removing informality

In this section we look at the transition from the low steady state to the high steady state under the assumption that informality is removed. Figure 4(a) shows the transition from the low steady state to the high steady state using the benchmark parameters after removing informality. The transition would last around 300 years (or 10 periods) to reach the new steady state. At the same time, we can also observe that after 4 periods the proportion of high-skilled individuals is higher than the threshold value that defines the *informality* regime.

The question that follows is how removing informality would affect welfare in the economy. In Figure 4(b), we compute the welfare loss as percentage of the initial steady state level with informality. We first compute the new utility level after removing informality, and then derive the hypothetical amount of consumption compatible with that level of utility if the expected wage of children was constant at $\overline{w}_{k,ss}^{\mathrm{inf}}$ (this level is denoted by $\widetilde{c}_{k,t} = \exp\left[U_{k,t} - \beta \ln \overline{w}_{k,ss}^{\mathrm{inf}}\right]$ for a type-k worker). Finally, we compute the percentage deviation of consumption with respect to the initial steady state with informality, $(\widetilde{c}_{k,t} - c_{k,ss}^{inf})/c_{k,ss}^{inf}$, and use this as a consumption-equivalent variation in utility.

The utility level of high-skilled workers is not modified as their wage is constant along the transition path. For the low-skilled workers, however, utility falls by about 80% in the first period that informality vanishes. As time passes, the wage and the utility level of low-skilled workers increase to overcome the consumption level observed in the steady state with informality. Another pattern that we can depict from Figure 4(b) is with regard to the average consumption deviation. In the initial periods, it is relatively closer to the consumption deviation of low-skilled workers than the consumption deviation of high-skilled workers, but it approaches the consumption deviation of the highly skilled over time. Hence, as the economy evolves, the proportion of high-skilled workers increases, and the weight of the low-skilled workers on the average deviation diminishes.

Clearly, the first period welfare loss is due to the flow of low-skilled workers from the informal to the formal sector. As the economy evolves, the higher proportion of high-skilled adults in the formal sector increases wages of low-skilled workers. Two different effects produce the growth of wages and consumption over time, the complementarity between high- and low-skilled workers, on the one hand, and the increase in TFP, on the other hand. In sum, informality protects poor and less educated adults from a sharp wage cut in the short run but prevents the accumulation
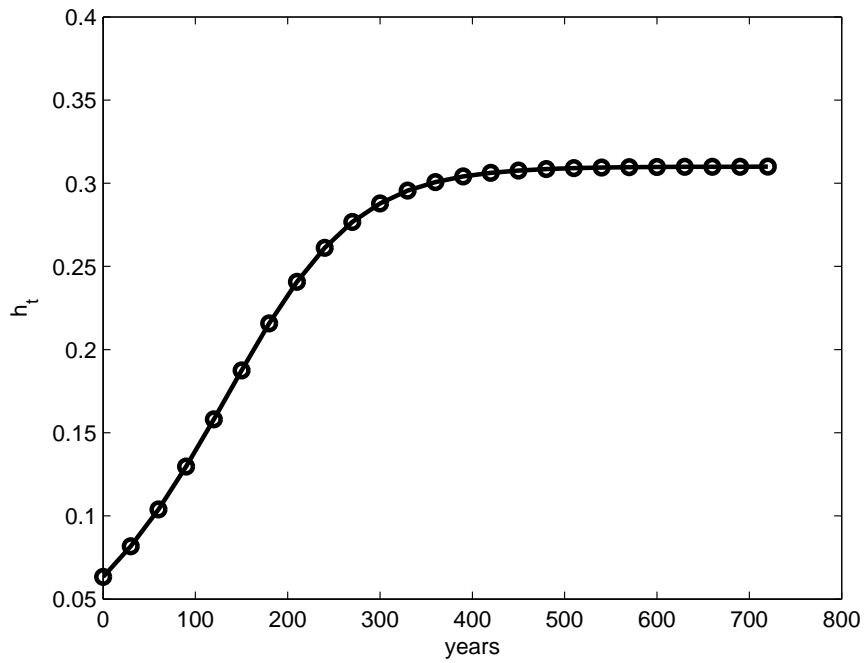
(a) Transition from low to high steady states
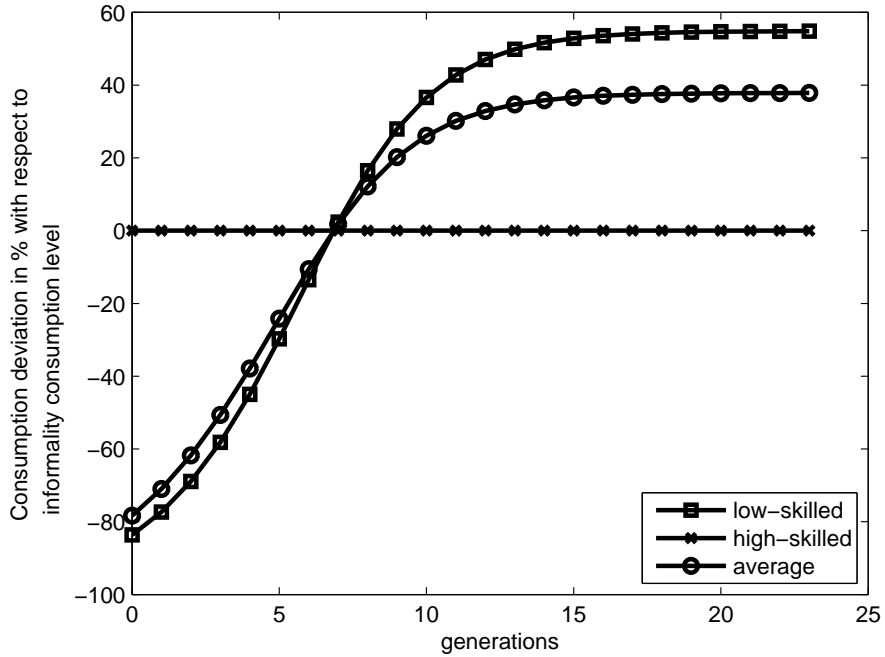
(b) Welfare loss due to transition

Figure 4: Transition from informality to formality.

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of human capital necessary to observe economic growth in the long run.

5.4   Implications for development policy

In the previous sections we established the result that the existence of an informal sector combined with human capital externalities can generate a poverty trap. We also showed that if informal activities were rendered illegal, low-skilled workers would suffer initially a quite dramatic drop in wages. In this section, we analyze policies that could help the economy to escape the poverty trap and converge towards the high-income steady state. We examine the cost efficiency of such policies under the constraint that wage losses during the transition should be avoided.

We consider the situation of a developing country trapped in the low-income steady state and assume that it will obtain a windfall gain (which might come from different sources, e.g. foreign aid or the discovery of natural resources).[21] How can the country use such a windfall gain in the most efficient way in order to escape the poverty trap? To answer this question, we analyze different policy instruments that address the human capital externality and the child labor trap, and compare their discounted costs. We first consider each instrument in isolation and then examine whether a combination of two instruments may be a cheaper alternative.

Alternative policies.   On one hand, we consider the introduction of *education subsidies* that are either paid unconditionally to all families or targeted to low-skill parents. The latter policy can be interpreted as the education component of existing conditional cash transfers.[22] On the other hand, we analyze *wage subsidies* for jobs in the formal sector, allowing for different subsidy rates for low-skill and high-skill jobs.[23] To sum up, we introduce the following policy variables in the model:

- an education subsidy at rate s_t^e (paid to all families or targeted to low-skilled parents);

- a wage subsidy for low-skilled workers in the formal sector at rate s_t^l ;

- a wage subsidy for high-skilled workers in the formal sector at rate s_t^h.

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[21]In the case of a resource-rich country, it would have to be assumed that the natural resource sector operates independently from the rest of the economy, excluding thereby Dutch disease effects.

[22]E.g., the *Oportunidades/Progresa* program in Mexico or the *Bolsa Familia* scheme in Brazil. These programs are targeted towards low-income families and provide grants for children conditional on school attendance.

[23]Equivalently the government could implement a combination of an output subsidy in the formal sector and a (progressive) tax on income from the formal sector. An output subsidy has the same effect as subsidizing high-skilled and low-skilled workers in the formal sector at the same rate. Adding a progressive income tax would be equivalent to differentiating the effective subsidy rates received by high and low-skilled workers.

From the assumptions of the model it is immediately clear that it would be inefficient to pay education subsidies to high-skilled parents since they educate all their children even without receiving any subsidies. Hence, the general education subsidy is less cost-efficient than the targeted education subsidy. As we will show below, the wage subsidy for high-skilled workers has similar effects as an education subsidy to all parents. This type of wage subsidy is therefore also dominated by the targeted education subsidy.

Policy effects in the *informality* regime.   In the *informality* regime, the introduction of subsidies does not change the income of low-skilled workers. Subsidizing low-skilled workers draws them into the formal sector but as long as the informal sector exists, the low-skill wage is determined by the (exogenous) productivity in the informal sector. By contrast, the income of high-skilled workers is increased one-by-one by the subsidy. Hence, wages (including subsidies) and the skill premium in the *informality* regime are

$$\widetilde{w}_{h,t} = A_0 \alpha (1 + s_t^h)$$
$$\widetilde{w}_{f,t} = \widetilde{w}_{i,t} = \frac{A_0 (1 - \alpha)}{\gamma}$$
$$\widetilde{\sigma}_t = \frac{\alpha \gamma}{1 - \alpha}(1 + s_t^h) - 1$$

The number of low-skilled workers in the formal sector is given by $L_{f,t} = (1 + s_t^l) \gamma H_t$. The informal sector disappears if marginal productivity of low-skilled workers in the formal sector exceeds the minimum wage in the informal economy, i.e., if $L_{f,t}/H_t \leq (1 + s_t^l)\gamma$. This condition is equivalent to

$$h_t \geq \frac{1}{1 + \gamma(1 + s_t^l)}. \tag{31}$$

The role of the two types of wage subsidies in the formal sector can now be made clear. Subsidizing high-wage jobs increases the skill premium but has no effect on the allocation of workers between sectors. By contrast, a subsidy for low-wage jobs in the formal sector does not affect the skill premium but lowers the critical human capital level at which the economy leaves the *informality* regime.

In turn, the budget constraint of adults is modified by the introduction of an education subsidy as follows:

$$c_{k,t} = \widetilde{w}_{k,t} - n_k q_{k,t} \widetilde{e}(1 - s_t^e) + \eta n_k (1 - q_{k,t}) d_t \widetilde{w}_{i,t}.$$

The proportion of children who go to school is therefore equal to

$$q_{l,t}^* = \frac{\beta(1 - \alpha)(1 + n_l \eta)}{(1 + \beta)\left[e\gamma(1 - s_t^e) + \eta(1 - \alpha)\right] n_l} - \frac{1 - \alpha}{(1 + \beta)\left[\alpha(1 + \gamma(1 + s_{t+1}^h)) - 1\right]}.$$

Subsidizing high-skilled workers in the next generation $(t + 1)$ has similar qualitative effects as subsidizing education for the current generation t. Obviously, an expected rise in the future skill premium increases the incentive to send children to school. There is, however, a decisive difference between the two types of subsidies: an education subsidy can be targeted towards low-skilled parents and is therefore more cost-effective (since high-skilled parents educate all their children even without subsidies). Moreover, subsidizing the wages of relatively rich workers rather than the education of poor children seems politically less feasible.

The preceding results enable us to highlight the different (and possibly complementary) roles of the two most promising policies: targeted education subsidies and wage subsidies for low-skilled workers in the formal sector (see Figure 5). If the economy is initially stuck in the inferior steady-state (B_2), the introduction of targeted education subsidies increases the incentive of low-skilled parents to invest in their children's education and the informal sector schedule shifts upwards in Figure 5. If the subsidy rate is sufficiently high, the country can escape the poverty trap with the help of this single policy instrument; the new situation of the economy could then be described by Dynamic A in Figure 2(b).
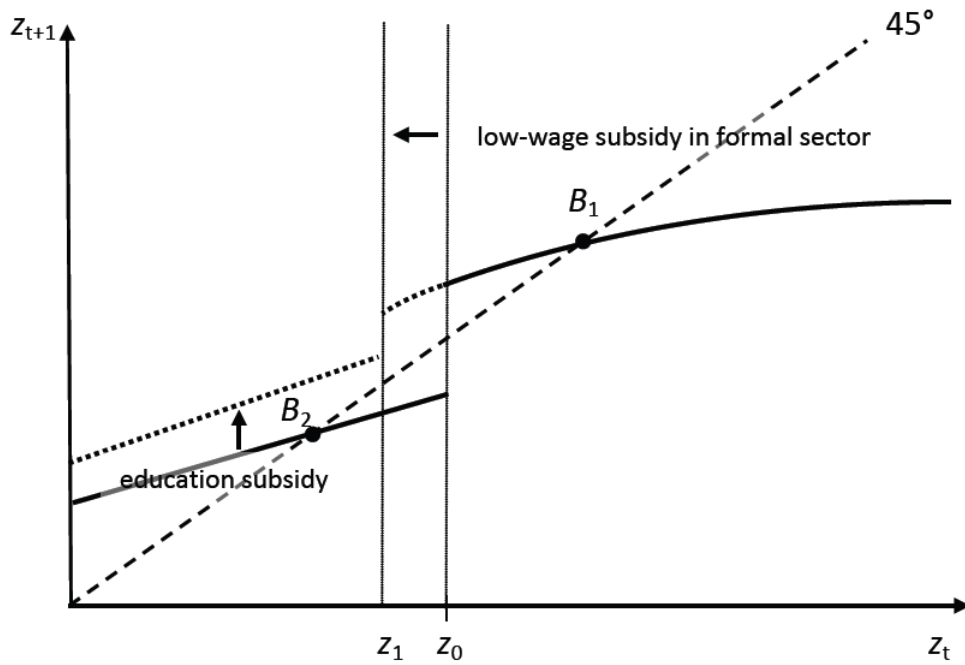

Figure 5: Dynamics of human capital accumulation: the role of policies.

By contrast, the subsidy for low-skilled workers in the formal sector pulls workers out of the informal sector and decreases the critical skill ratio from z_0 to z_1 in Figure 5 without changing the *informality* schedule. It is clear that such a low-wage subsidy has no effect on human capital accumulation if it is too small or if the economy is too

far below the critical skill ratio; the subsidy rate must be sufficiently high to eliminate informal sector employment entirely. Wage subsidies should therefore only be used as a temporary policy allowing the transition to the *formality* regime to accelerate.

As the two types of subsidies address different aspects of the transition to the high income equilibrium, they can be implemented jointly and their combined use might possibly reduce the overall cost of escaping the poverty trap. This issue will be taken up below in the simulations. In any case, we assume that subsidies are abolished as soon as the economy reaches the *formality* regime.[24]

Cost-efficient policies. The calibrated model can now be used to calculate, for each policy, the minimum windfall gain necessary to enable the country to escape the poverty trap. This windfall gain (or discounted cost of policy) depends on the time horizon within which the economy leaves the *informality* regime. Consider a constant subsidy of each type, $s_t^k \equiv s^k$ for $k \in \{e, l, h\}$. The horizontal axis of Figure 6 indicates the time needed to achieve a level of human capital that ensures convergence to the high steady state, or equivalently, the number of periods T needed to achieve a proportion of high-skilled workers higher than the threshold value $h_T > 1/(1+\gamma)$ delimiting the two regimes. For each value of T, we compute the subsidy rate required to exit the poverty trap and the discounted cost of the policy using a discount factor equal to $.99^{120} \cong 0.2994$. The vertical axis of Figure 6 shows the total discounted cost of policies for a country with an initial population of 20 million inhabitants and a scale factor A_0 of 112900.[25]

As expected, targeted education subsidies are more cost-efficient than unconditional education subsidies or high-skill wage subsidies at any time horizon. A windfall of 1.5 to 2 billion 2005 US\$ (PPP adjusted) per year is needed to help a country of around 20 million inhabitants escape from the poverty trap within one or two generations (30 or 60 years). As the initial skill ratio of this economy is far below the critical level, low-skill wage subsidies are not efficient if they are used as a single policy instrument.

Moreover, as Figure 6 makes clear, policies that take more time to leave the *informality* regime have lower discounted costs. Consider for example education subsidies targeted to low-skilled parents. The total discounted cost of attaining the critical

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[24]To avoid clutter, Figure 5 does not depict the policy-induced change in the dynamics of the *formality* regime. The two policies have different effects on the *formality* schedule. Whereas education subsidies shift the *formality* schedule unambiguously upwards, the introduction of low-skill wage subsidies has ambiguous effects: a positive income effect (low-skill parents receive a higher income which is partly spent on education of their children) and a negative substitution effect (low-wage subsidies decrease the future wage differential, diminishing the incentive for education). These changes do not seem to have a decisive influence on the transition from the *informality* to the *formality* regime.

[25]Parameter A_0 is set to 112900 to obtain that GDP per capita in the United States is 35000 in 2005 US\$ PPP adjusted, which is close to the value in PWT 7.0. The discount factor is obtained from the literature taking into account that a period lasts 30 years and the discount factor of a quarter of year is .99.
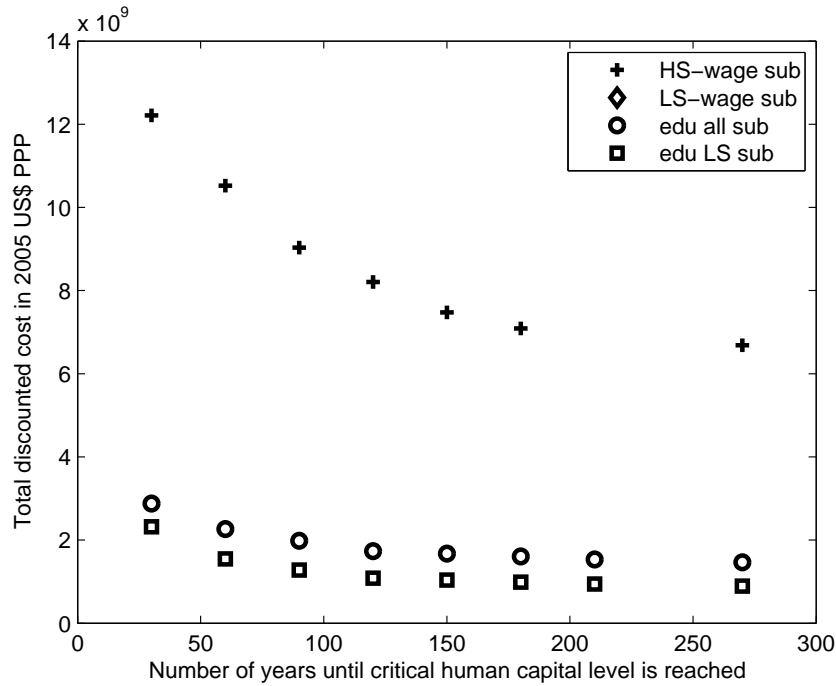
Figure 6: Total discounted cost of policies and time necessary to achieve $h_t > 1/(1 + \gamma)$.

human capital ratio is lower if the policy is implemented over several generations using a low subsidy rate (by opposition to a high-subsidy policy which operates within one generation). The reason for this result is twofold. First, within a generation the marginal cost of subsidizing education increases with the proportion of children that are educated. Second, targeted education subsidies have a cumulative impact over time: in each generation, they provide an incentive for low-skilled adults to educate a larger proportion of their children. In the following generation, these high-skilled children will provide education to all their offspring although they do not receive the (targeted) education subsidy.

Combination of policies. The preceding results leave scope for a cost-reducing combination of policies. As the marginal cost of a single policy increases with its rate, it might be more cost-efficient to combine two instruments using lower rates. We explore this possibility by combining targeted education subsidies and low-skill wage subsidies. As we have argued above, the latter should only be used as a transitory measure. Hence, in the simulations reported in Figure 7, while education subsidies are used in all periods, low-skill wage subsidies are only used in one period, i.e., when they enable the economy to reach the *formality* regime within the next generation.[26]

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[26]Alternatively, one could assume that the subsidy is phased out gradually if it takes several generations to attain the critical human capital level. This possibility is disregarded in our search
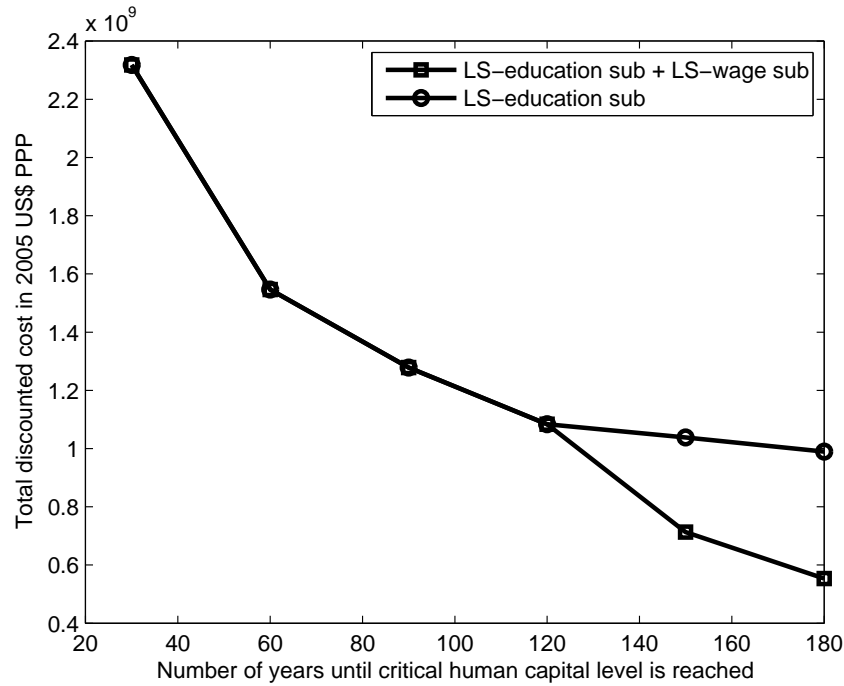
Figure 7: Cheapest combination of policies and time necessary to achieve $h_t > 1/(1 + \gamma)$.

Therefore, education subsidies are implemented in all generations, whereas low-skill wage subsidies are only implemented during one generation. Moreover, the subsidy rate of low-skill wages is set such as to make the informal sector disappear within this generation. Figure 7 shows that using both instruments is cheaper than using a single instrument for time horizons that exceed four generations (150 years). Note that for slightly richer countries (that are closer to the critical skill ratio), a combination of the two policy instruments is likely to be more cost-efficient even for shorter time horizons.

Our policy findings can be summarized as follows. First, among four possible education and wage subsidy schemes, two policies dominate the others in terms of cost efficiency: education subsidies to low-income families and wage subsidies for low-skill jobs in the formal sector. Second, these two policies play distinct and possibly complementary roles in the transition to the high-income equilibrium. Whereas the education subsidy speeds up the accumulation of human capital, the low-skill wage subsidy reduces the threshold at which the informal sector disappears. Third, targeted education subsidies are the cheapest single policy but for longer time horizons a combination of the two policies turns out to be the most cost-efficient choice.

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of the cheapest policy combination.

6 Conclusion

This paper establishes a theoretical relation between education, child labor and the informal sector. In the data we observe a direct relation between informality and education, countries with high proportions of tertiary educated workers tend to show lower levels of informality than countries with low proportions. Moreover, child labor is part of the informal sector, and the data shows that countries with more informality have more children involved in production activities. With these facts in mind we construct an overlapping generations model that is able to reproduce these relations in line with previous findings of other authors.

The model is able to explain, or to give a complementary view of, the documented fact that less-developed countries present higher levels of inequality than developed countries but much lower levels than standard models predict. The introduction of the informal sector in a model with complementarity between high- and low-skilled workers lowers the skill premium (and makes it constant). In other words, we view informality as a possible channel to reduce the skill premium in developing countries.

The reduction in inequality due to informality generates several effects in the short and the long run. On one hand, low-skilled workers may obtain a higher salary with the existence of an informal sector than in its absence, because there is an alternative sector where they can supply their working hours. However, this sector is not controlled by state agencies and enables children to use their time to work and generate an extra source of income for the household. Hence, the model is able to replicate the relations between informality and education, and between child labor and education in line with the data: the share of high-skilled workers is negatively correlated with informality, and informality is positively correlated with child labor. On the other hand, the model has several predictions for the long run. The trade-off between child income and future education of children is taken into account and is key to generate poverty traps due to informality and child labor. The "low" inequality observed in developing countries and the opportunity cost of sending children to school can have a pernicious effect on parents. They may not provide enough education for their children so as to increase the aggregate proportion of educated workers in the labor force. Parents do not internalize the positive externality of aggregate education on firms' productivity. Therefore, the informal sector can prevent the economy from developing as it would in the absence of informality.

The model is calibrated to reproduce several facts observed in the data. The model is also calibrated to evaluate different policies considered to reduce the size and effects of informality. The calibration exercise reveals that the case for the poverty-trap hypothesis is strong: although informality serves to protect low-skilled workers from extreme poverty in the short-run, it prevents income convergence between developed and developing nations. Sudden elimination of informality would induce severe welfare losses for poor people on the transition path.

Hence, we analyze policies that could help the economy to escape the poverty trap and converge towards the high-income steady state. We analyze the cost efficiency

of such policies under the constraint that wage losses during the transition should be avoided. Assuming that an inflow of resources is provided to a developing country, for example in the form of foreign aid, we analyze the effects of different subsidies. Informality can be reduced by diminishing education costs or by making the formal sector more attractive. Hence we consider four possible subsidies on education and formal firms wages. Subsidizing education is the most cost-efficient policy, and it can be targeted towards low-skilled parents to reduce costs. Subsidizing high-wage jobs increases the skill premium but has no effect on the allocation of workers between sectors. Moreover, the increase in the skill premium gives similar incentives to parents on children's education than reducing education costs. By contrast, a subsidy for low-wage jobs in the formal sector does not affect the skill premium but lowers the critical human capital level necessary to skip the poverty trap. Because of the possible complementary effect of different subsidies, we turn to analyze the cost-efficiency of a combination of subsidies on education to low-income parents and low-skilled formal firms wages. Although targeted education subsidies are the cheapest single policy, for longer time horizons, or as the economy gets closer to the poverty trap threshold, a combination of the two policies is found to be the most cost-efficient choice.

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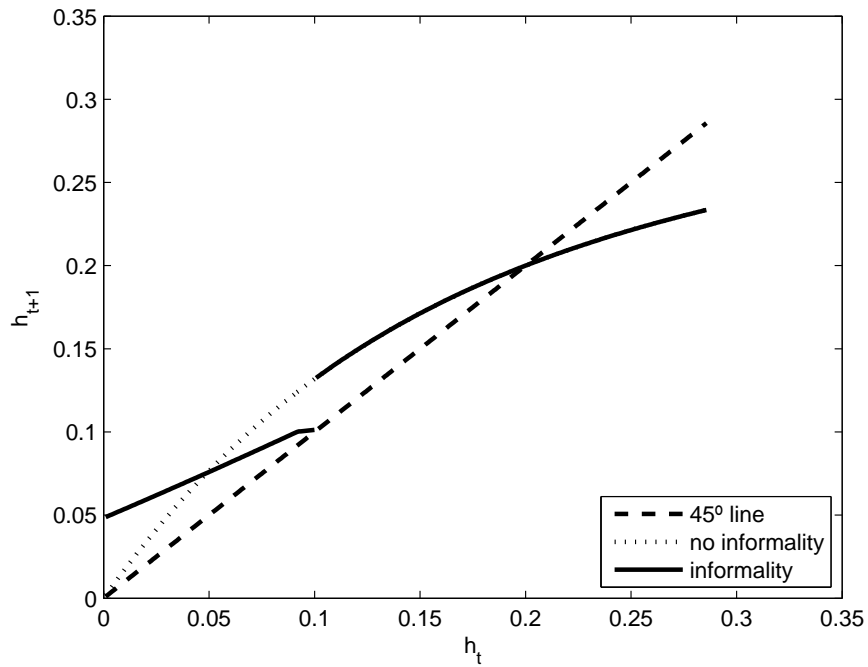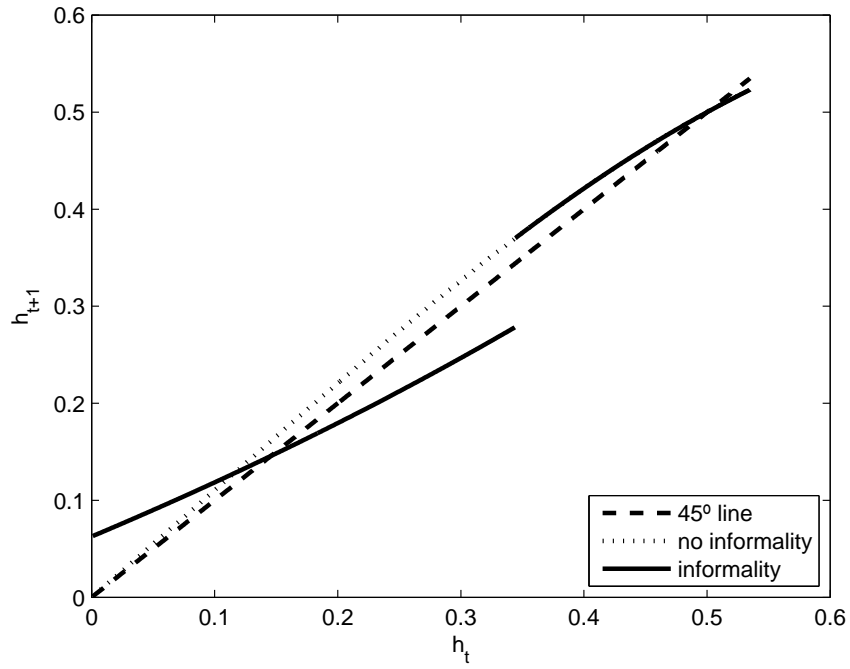
Figure 8: Scenario 1.

Figure 9: Scenario 2.
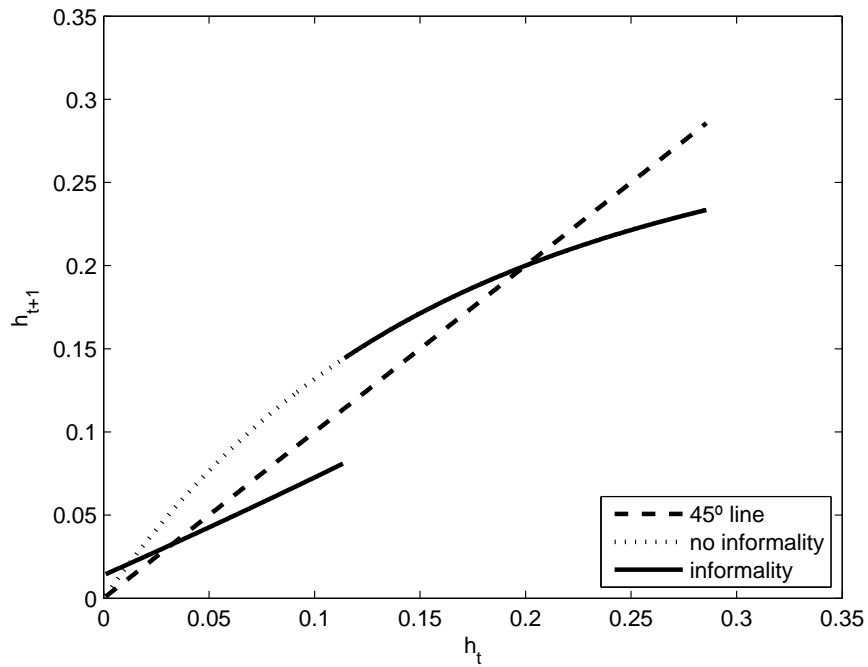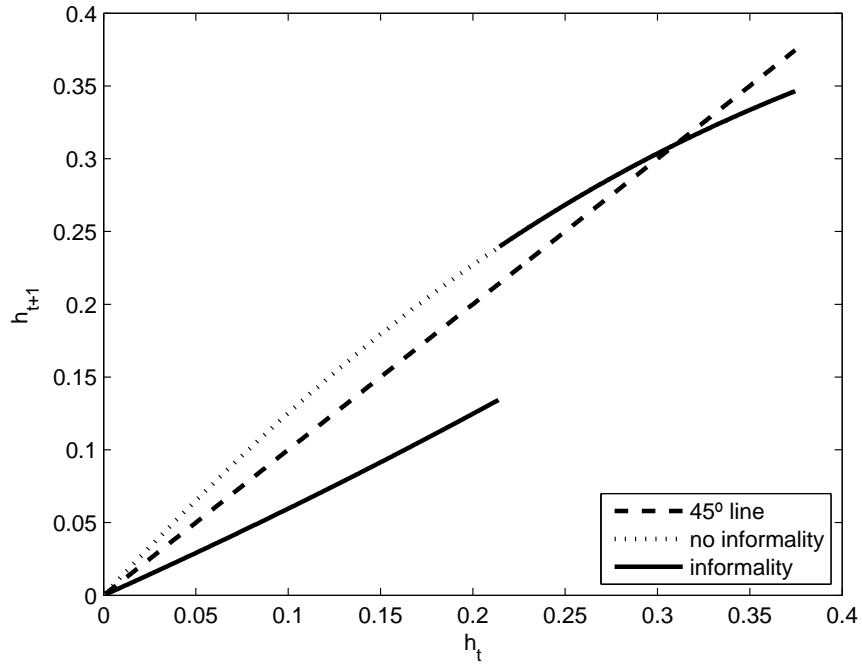
Figure 10: Scenario 3.

Figure 11: Scenario 4.