Incentive Contracts and Total Factor Productivity

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Abstract

This paper proposes a transactions cost theory of total factor productivity. In a world with asymmetric information and transactions costs, effort, and thus productivity, must be induced by incentive schemes. Labor contracts trade off the marginal benefits and the marginal costs of effort. The latter include, in addition to the workers' marginal disutility of effort, also organizational costs and rents. As the economy grows, the optimal contracts change endogenously, inducing higher effort and measured productivity. Transactions costs are also affected by societal characteristics that determine the power of incentive contracts. Therefore, differences in these characteristics may explain cross-economy productivity differences. Numerical experiments demonstrate that the model is consistent both with time series and cross-country observations.

[jel. D82, O40]

keywords: Incentive contracts, Total factor productivity, Economic Growth

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1. Introduction

Understanding the large differences in total factor productivity (hereafter TFP) among countries is a challenge of great importance to the economics profession. The striking fact is that at the aggregate level, TFP is closely correlated with income (see, for example, Jones [1998]). As a matter of fact, the observation that TFP differences are "responsible" for almost the entire differences in income, has motivated Prescott to impress upon the economics profession the "need" for "a theory of total factor productivity" (Prescott [1998]). Here we explain productivity as a reflection of endogenous incentive contracts.

The differences in TFP have been associated by some economists with differences in the access to technology (Romer, [1993]). Others have pointed to differences in factor endowments (in particular of skilled workers) as a source of differences in TFP (Mankiw, Romer and Weil [1992]). Acemoglu and Zilibotti [2001] take the impact of the factor endowment a step further. According to their view, economies which are well endowed with skilled workers are also those that develop new technologies. However, these technologies are suited to skilled workers and not to the less-skilled workers found in LDCs, and therefore the free flow of ideas is insufficient to close the TFP gap.

Prescott [1998] argues that TFP differences are not necessarily due to differences in the stock of knowledge. He cites several studies that demonstrate that TFP differences are associated with differences in work practices and organization. Hall and Jones [1999] argue that social obstacles hinder some economies from adopting high-productivity production technologies. They concentrate on "social infrastructure" as an explanatory variable. According to this explanation, countries whose policies are "favorable to productive activities - rather than diversion - produce much more output per worker". Parente and Prescott [1999] argue that poor economies remain poor because monopolists that control factor supply prevent the adoption of superior technologies. Kocherlakota [2001] concentrates on the technology adoption issue formally. In his paper, it is the ability to enforce a social contract that makes the difference. Economies in which such an enforcement is not possible, do not adopt a superior production technology (which is available at some cost), while economies in which the social contract is enforceable, do.

While all above explanations have merit, we suggest an additional channel affecting productivity. We link productivity neither with the knowledge of how to produce, nor with factor endowment or the composition of the labor force, but rather with organizational aspects of the economy that affect productivity through effort. In a world with asymmetric information and transactions costs, effort, and thus productivity, must be induced by incentive schemes. Labor contracts trade off the marginal benefits and the marginal costs of effort. The latter include, in addition to the workers' marginal disutility of effort (and, possibly, marginal risk premia), also organizational costs and rents. As the economy grows, the optimal contracts change endogenously, inducing higher effort and measured productivity.[1] In addition, transactions costs are affected by societal characteristics, like institutional and legal structures, preferences and norms. Therefore, differences in these characteristics may explain cross-economy productivity differences.

[1]Leamer (1999) also links productivity with effort. However, his model has no organizational aspects. Furthermore, while Leamer does not discuss growth, in contrast with our results, his model suggests that effort should decrease as the economy grows.

In order to demonstrate the mechanisms at work, we combine two strands of economic literature, organization theory and growth. Organization theory provides the basis for our discussion of transactions costs.[2] Out of this literature, we choose a specific model where transactions cost arise because of the need to monitor workers' actions.[3] This model is then embedded within a standard growth environment. In our economy two technologies may be used to produce the same good. The first technology uses only labor as input and workers are "self employed" (i.e. there are no organizational costs). The second technology uses capital and labor and is operated by "firms". In this technology workers' productivity depends on the amount of effort they exert. Effort is not verifiable, thereby creating a standard moral hazard problem. To provide incentives, firms are engaged in monitoring. Monitoring precision is costly and also not verifiable, a fact that creates another moral hazard problem between workers and employers. The ensuing Nash game between workers and employers, where the former choose effort and the latter monitoring intensity, results in a bonus scheme. The scheme optimally trades off the workers' rent against efficiency.

The analysis is incorporated in a dynamic growth setting. The economy is populated by infinitely lived risk neutral households that maximize their discounted expected utility. Each household chooses every period whether its members will be self-employed or employees. In the latter case, workers face the bonus scheme and select their effort level. In addition to labor income, households receive interest payments. They allocate their income to consumption and saving in the

[2]The organization theory views transactions cost as arising from imperfect information, incomplete contracts, bounded rationality and the implications of these impediments.

[3]Monitoring theory derives from Alchian and Demsetz (1972), who explain the existence of firms by the need to resolve the free-ridership problem associated with team production.

standard way.

Firms hire capital and decide on the monitoring intensity every period so as to maximize profits. The optimal structure of the bonus contract that emerges turns out to depend on the amount of capital hired by the firms. This implies that the equilibrium effort level and the number of employees also depend on that amount of capital.

The growth process out of steady state is characterized by increases in capital and in labor productivity. Specifically, higher amounts of capital increase the demand for labor. Since the additional labor needs to be enticed away from self-employment, labor contracts have to become more attractive, reflecting the higher productivity of workers in their alternative occupation. The "better" labor contracts entail higher bonuses and more monitoring, thereby inducing more effort. Consequently, as the economy grows, more workers become employees, and productivity increases without any technical progress or change in human capital.[4]

It is difficult to find a systematic characterization of labor contracts prevailing in different economies at the aggregate level. Nevertheless, we provide evidence documenting the link between labor market institutions, incentives and productivity. Moreover, we show that our model may be quantitatively consistent with the relationships between productivity growth, increases in monitoring costs, and changes in the fraction of the labor force employed by the corporate sector, that exist in the data. We also show that the cross-country productivity differences may be reconciled, at least in part, within our framework.

[4] Once the economy reaches a steady state this process stops. We choose to abstract from sustained growth in order to highlight the interrelationship between the changes in capital and the incentive contracts.

The paper starts with a short presentation of some stylized facts and evidence. Next, we introduce a formal presentation of the model. In this section we discuss the static problem of the workers and of the firms and derive the optimal bonus contract. We also show that the contract is consistent with the dynamic optimization problem of the workers. Next we parameterize some key functions in our economy and derive the equilibrium conditions for that specific case. We conduct some comparative static experiments on the steady-state of the economy and asses the impact of particular parameters. Finally, we numerically evaluate a dynamic equilibrium path and discuss its properties. In the last section of the paper, we summarize our results and discuss other sources of organization costs that may lead to similar conclusions.

2. Some Evidence and Stylized Facts

2.1. Incentives and Productivity

The model presented below associates changes in monitoring and the optimal bonus schemes with intensification of effort and productivity gains. The strength of this link depends on a number of parameters that represent the societal characteristics of the economy. For example, the extent to which effort is allowed to affect boni is key to our analysis. This, however, is likely to be influenced by regulations, legal rules and their enforcement, norms and preferences. While it is hard to find direct information on the entire chain of linkage, there is evidence concerning various subsections of it. In the following we discuss some of this evidence.

Recent research on the determinants of growth has documented the relationship between organizational aspects of economies and their growth performance. For example, Acemoglu, Johnson and Robinson (2001) exploit differences in colonial histories to argue that "institutions" have a large effect on per-capita income. However, their study does not focus on any specific institution. Botero et. al. (2004), trace labor market regulations and their association to the legal origins of the respective countries.[5] Caballero et. al. (2004) use the Botero et. al. characterization of the labor markets and show that annual productivity growth may be reduced by up to 1% in countries with stringent job security regulation.

In addition to the aforementioned studies (and others) that associate institutions to growth in a general way, there exists microeconomic evidence linking incentives to productivity more directly. At the industry level, Schmitz's (2004) very detailed study of labor productivity of the U.S. and Canadian iron-ore industries, shows that great productivity gains can be attributed to changes in effort per hour worked due to changes in institutional and work rules. Schmitz suggests that similar non-technological productivity effects may explain productivity also in other industries.

Closer to our approach, Nakamura and Hübler (1998) study the wage structure in Germany, Japan and the U.S. According to their findings, during the 1980s the ratio of bonus to regular pay was 0.317 in Japan, 0.121 in Germany and 0.194 in the U.S.(Table 1, page 224). In the discussion of their findings, Nakamura and Hübler argue that the long-term nature of the Japanese working relationship implies that it is impractical to prespecify job contents, and therefore impossible to compare performance with job task. This, in turn, implies that monitoring is

[5] Botero et. al. essentially distinguish between "common and civil law traditions" that "utilize different strategies for dealing with market failure".

costly and therefore bonuses are required.[6]

Groves et. al. (1994) exploit the natural experiment of the reform in China that shifted responsibility from the state to the firm. Their work is inspired by the work of McAffee and McMillan (1995), whose results are very close to ours. In McAffee and McMillan the informational asymmetries are related to the hierarchical structure of an organization, and result in labor contracts that provide incomplete performance incentives. As the hierarchy becomes shorter, the decision maker need to worry less about providing incentives to information transmission, and may concentrate on performance incentives. Groves et. al. view the reform in China as shortening the hierarchy, and the results of the reform as a test of the theory. They show that managers in China gradually adopted the bonus structure. The proportion of worker income received as bonuses roughly doubled from about 10% of renumeration in 1980 to 19% in 1989 (page 193).Total factor productivity increased over this period by an annual rate of 4.5% (page 195). The econometric analysis of Groves et. al. carefully studies the link between bonuses and productivity, and shows that bonuses are significantly (positively) associated with productivity.

The management literature also contains evidence relevant to our analysis. For example, Green (2004) exploits manager and worker survey data collected in Great Britain over the last two decades of the previous century. Specifically, man-

[6]In a similar line of argument, Clark (1987) documents large productivity differences among farmers in the northern U.S. and Britain at the beginning of the 19th century as compared to Eastern European farmers at the same time, and medieval England. The productivity differences are associated with corresponding wage differences. He argues that these differences are mostly due to variations in labor intensity, rather than technology or endowments. As Clark notes, a possible organizational explanation would be that the low productivity farmers lived in "servile societies", whereas those with high productivity were working mainly on their own.

agers were asked to assess whether "there has been any change in this workplace compared with five years ago in how hard people work here". He reports that "more use of performance related pay" is highly significant in explaining work intensification, especially among small firms (Table 4, page 730). Ichniowski, Shaw and Premushi (1997) also use survey results of U.S. steel companies, and show that their measure of productivity (uptime) is significantly and positively related to "human resource management" practices, including,, among other things, incentive schemes.

Any link between incentives and productivity necessitates monitoring. Accordingly, the above evidence indirectly indicates that there have been variations in monitoring. There exists some suggestive evidence to this effect. The Proudfoot consulting firm publishes yearly productivity studies, based on executive surveys and on its own observations among its customers in eight countries. Its 2004 report claims that 72% of "productivity loss" (relative to some norm) can be attributed to "poor management", and in particular to "insufficient management planning and control" and "inadequate supervision".[7] Furthermore, the report states that 63% of managers say that they spend "most time" on "planning, measuring and monitoring". We interpret these findings as pointing out that while monitoring is a costly activity, it is instrumental to increase productivity

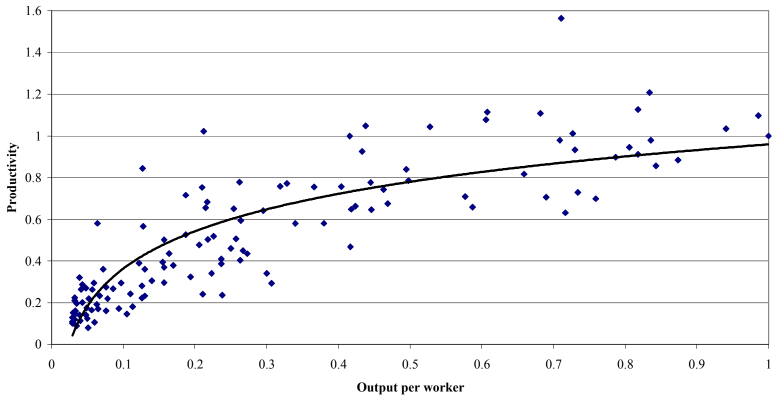
2.2. Key Stylized Facts

Hall and Jones (1999) compute productivity indices (relative to the US) and per-capita output of 127 countries. They (and many others) find large differences among countries, and a very clear (possibly non-linear) relationship between out-

[7] The Wall Street Journal carried an item about this report on September 6, 2004.

put per-worker and productivity, as depicted in Figure 1(see also Hall and Jones, Figure 1):[8]

Figure 1:
Output and Productivity



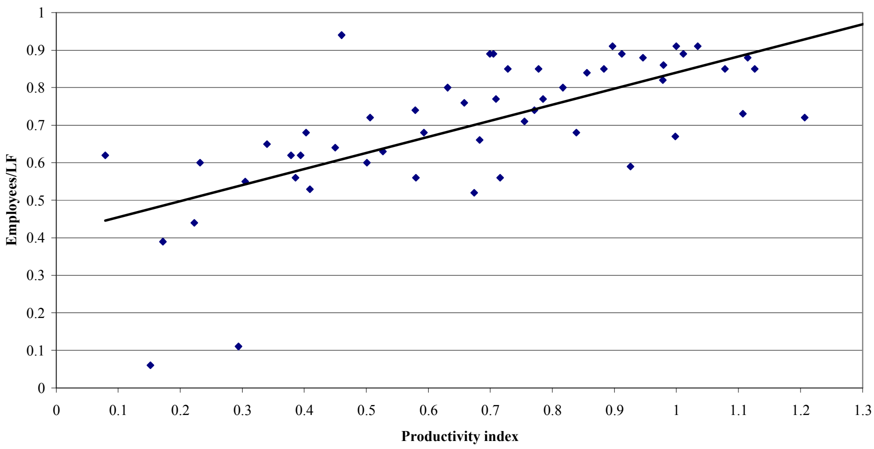
We have augmented the Hall and Jones data with two features related to the labor market in various economies, as reported in Bernanke and Gürkaynak (2001). Specifically, Table X of that paper reports the fraction of corporate employee in the labor force for many countries, and several (highly correlated) measures of the labor share in income that correct for possible under-reporting of income of workers who are outside the corporate sector (self-employed and others).[9] Figure 2 shows the relationship between the Hall and Jones productivity measure and

[8] The simple correlation between productivity and output in this data set is 0.85. The data can be found at the site http://elsa.berkeley.edu/users/chad/datasets.html

[9] Bernanke and Gürkaynak report only their calculations for countries where the fraction of the corporate workers in the labor force exceeds 50%. For countries with low fraction of corporate employees they get very high labor shares in income, which they think are unreasonable. Our model predicts that under certain circumstances, there may indeed exist a very high correlation between the fraction of workers outside the corporate sector and labor share in income.

the corporate employee fraction in the labor force. As can be seen, these two variables are quite highly correlated (a simple correlation of 0.68).[10]

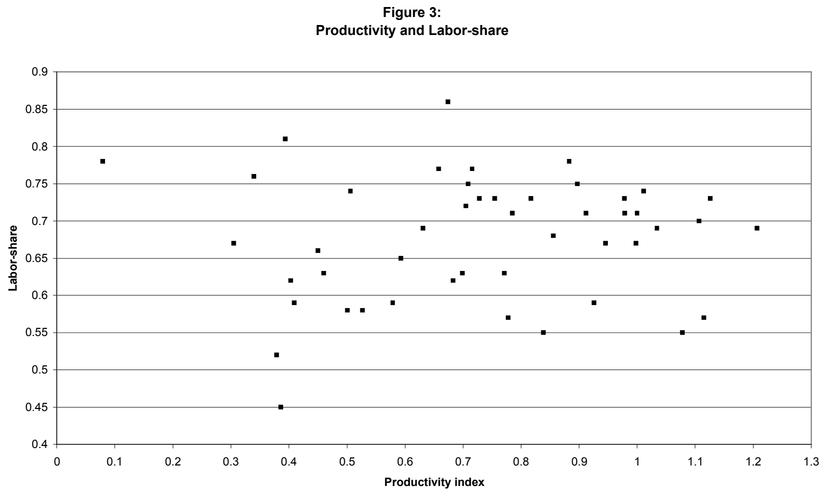
Figure 2:
Productivity and Employment



In contrast, there is basically no relationship between the labor share in income and the Hall and Jones productivity measure (simple correlation of 0.08), as Figure 3 shows:[11]

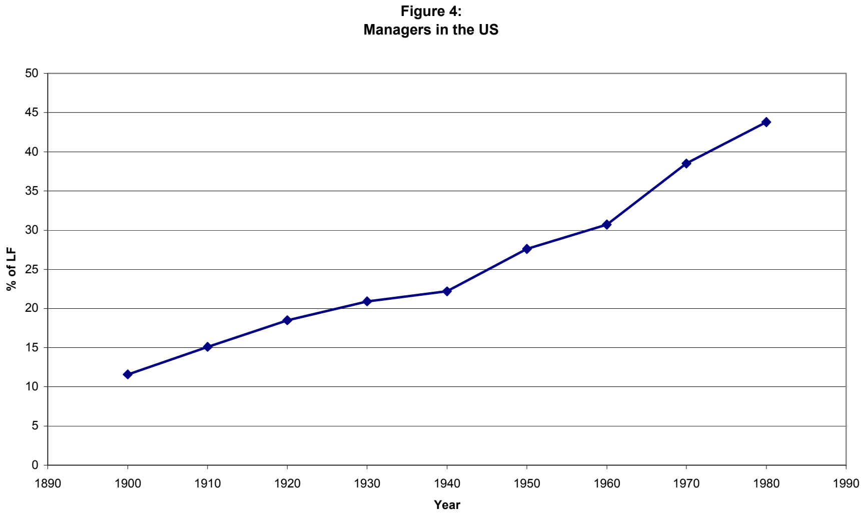
[10]Bernanke and Gürkaynak base their calculations on Gollin (2002). Clearly, Figures 1 and 2 imply a negative relationship between the fraction of self-employed in the labor force and per capita GDP, a fact that is reported by Gollin in his Figure 3 (page 466).

[11]The labor share in income used in Figure 3 uses the variable called "LF" in Table X of Bernanke and Gürkaynak. This variable essentially reports the share of labor in corporate income, which corresponds most closely to the varialbe we generate in our model.



Finally, there is some evidence on the role of management in a growing economy. Radner (1992) presents evidence concerning the increased *share* of resources used for the purpose of "managing in the economy".[12] Figure 4 replicates Radner's Table 6, that reports the fraction of managers in the (experienced) US labor force between 1900 and 1980.

[12]Radner's partial list of "what managers do" includes, of course "monitor the actions of other firm members" (p. 1388). Radner define "managers" as all employees that "are classified as exempt from the provisions of the Fair Labor Standards Act"" (page 1387). This includes, in addition to "standard" managers, also supporting staff such as clerical workers.



3. The model

We consider a single good, discrete time economy with a constant population of infinitely lived households indexed on the unit interval by h. We describe the households in some detail, before we specify the two technologies with which the good can be produced

3.1. Households

Each household h consists of a continuum of identical members over the unit interval. The household owns $k_t(h)$ units of capital at the beginning of period t that are inelastically supplied to the capital market at the rental rate r_t. In addition, each member of the household is endowed with 1 unit of labor per period that is inelastically supplied. Every member i of the household may exert effort $\epsilon_t^i(h)$. Effort has a potential effect on that member's labor productivity in a way to be specified below. However, household members are not decision-making units. They are agents of the household and carry out its decisions, in particular those concerning effort.[13]

All households in the economy have identical preferences. At every period, they are assumed to care (positively) about their aggregate consumption, x_t, and (negatively) about the amount of effort exerted by their members, ϵ_t. [14] Households are assumed to be maximizing the discounted stream of momentary utility:

$$\sum_{t=0}^{\infty} \eta^t u(x_t, \epsilon_t) \tag{3.1}$$

where η denotes the discount factor. For the momentary utility, we specify

$$u(x_t, \epsilon_t) = x_t - c(\epsilon_t) \tag{3.2}$$

where the function $c(\epsilon)$ measures the disutility of effort. The function $c(\epsilon)$ is assumed to be increasing and convex with $c(0) = 0$. In addition, we impose a minimum subsistence level per member denoted by $\underline{x}$.[15]

[13] The goal of this structure is to remove any idiosyncratic uncertainty at the household level (see Shi [1998] for a similarly motivated specification). Specifically, one may think of the household members as "machines" that are "programmed" by the household and have no will of their own. Alternatively, one may think of the household as an institution that can fully and costlessly monitor its members.

[14] Clearly, one may also think of the household preferences as the aggregate over individual member preferences, defined over their consumption and effort, i.e.

$$\int u(x_t^i, \epsilon_t^i) dh \ .$$

However (3.1) follows since $x_t^i = x_t$ and $\epsilon_t^i = \epsilon_t$ for all members $i \in [0, 1]$ of the household.

[15] The linear specification of the utility function is used for parsimony to keep the subsequent

Labor can be used in either one of two technologies. In one of them, the workers will be referred to as being "self-employed" and in the other as "employees". If self-employed, a member of household h produces output $y(h)$ at no effort cost.[16] Without loss of generality, households are ordered in such a way that $y'(\cdot) > 0$.

Alternatively, a household may decide to send its members to the labor market as employees. Once employed, each member exerts the household determined effort level ϵ, and obtains a corresponding compensation in terms of output. Despite the fact that members of distinct households have different productivity if self-employed, they are assumed to be equally productive as employees.[17]

The budget constraint of the household depends on the employment status of its members. We discuss the specifics after the introduction of the optimal bonus scheme. To keep the language simple, we refer to the representative household member as "employee" or "self-employed" according to the corresponding status.

3.2. Firms

Firms are employing capital and labor. The effectiveness of labor provided by an employee depends on the effort ϵ exerted by that employee. Anticipating that it will be to the firms' advantage to provide equal effort incentive across workers, we write the production function of firms as $F(K, \epsilon L)$ where K and L denote the

employment contract simple. The subsistence level is introduced to generate more realistic dynamics in the face of that linearity.

[16] Obviously, including effort costs would not change anything as $y(h)$ could be interpreted as production net of these costs. Furthermore, the assumption that the self-employed technology does not require capital is made purely for convenience and does not affect the conclusions.

[17] Relaxing this assumption would considerably complicate contracts as they would have to be type dependent. However, this would not substantially alter our conclusions.

per-firm capital and labor employment.[18] We make standard assumptions on the production function. In particular, it is assumed that the production function is homogeneous of degree 1 in both arguments.

3.3. The double moral hazard problem

In this subsection, we solely focus on the contractual game between a representative household and a firm. We assume that the game has to be played every period independently of the past. In doing so, we rule out long term contracts and any reputation effect either on the part of firms or households.[19]

Our key assumption is that workers' effort is not directly contractible. As a result, households' behavior is affected by problems of moral hazard. On the other hand, it is assumed that firms can generate contractible information on effort. This introduces the ability to mitigate the moral hazard problem through the use of proper incentives. More concretely, we assume that every worker is emitting noisy signals related to the effort level. At some costs, these signals can be measured and made verifiable. Accordingly, these signals become contractible. However, the fact that these measurements are costly to the firm introduces a further moral hazard problem, this time on the part of employers. Our assumption here is that though information is verifiable, the precision of that information is not.[20] This

[18] Assuming effective labor is additive across workers, production can be written as $F(K, \int_L \epsilon(h)dh)$ where L is the set of employees of the firm.

[19] Obviously, this restriction is a very simple way to generate rents. In general, any modelling device that sustains the existence of rents (or risk premium) will lead to organizational transaction costs that underly our analysis.

[20] To give a concrete example, suppose that university contract promises a positive tenure decision whenever a tenure commission presents two 'good' reports from external qualified academics. The precision of such a scheme is obviously manipulable since a tenure commission could always ask for more than two reports and only present those reports that are found advantageous.

double moral-hazard problem is resolved through a game which determines the precision at which the signals will be measured and the extent to which they will be used in the labor contract.[21]

In order to derive the optimal decision of the firm in the appropriate game, we assume here that in each period households maximize their income net of effort costs. In the next subsection, we show that under the derived contract, this presumed behavior is consistent with the preference specification as given in (3.1) and (3.2). Because the same game is repeated every period, we omit the time index whenever confusion is not possible.

The firm faces the problem of how much effort to induce. This decision entails a choice of an employment contract and of the amount of resources it allocates to the process of measuring the emitted signals. The latter determines the precision at which these signals are measured, which is parameterized by θ.

At this point, we can draw from existing results in the literature. In particular, it is known that in the current setting – due to the risk-neutrality of both parties – optimal incentive contracts are of the bonus type where a worker receives a fixed payment A, and depending on the realization of the measured signal, a bonus B.[22] These results depend on the aforementioned assumption that the distribution of the signals is affected by the worker's effort. Moreover, consistent with the moral hazard problem of the firm, it is assumed that this distribution also depends on the precision of measurement.

[21] The introduction of variable precision is essential for the dynamic analysis below. Precision could also be assumed contractible, in which case there would be a one-sided moral hazard problem. However, the double moral hazard framework turns out to be easier to analyze as it introduces an additional credibility constraint.

[22] See Park [1995], Kim [1997] and Demougin and Fluet [1998].

Since the optimal contract is of the bonus type, the measured signals can be aggregated to a binary random variable, $\chi \in \{0, 1\}$, where the worker receives the bonus if $\chi = 0$. We denote

$$p(\epsilon, \theta) = \Pr[\chi = 0 \mid \epsilon, \theta] \ . \tag{3.3}$$

We assume that $p_\epsilon > 0$ and $p_{\epsilon\epsilon} < 0$. Heuristically the first requirement means that $\chi = 0$ constitutes a 'favorable' information with respect to the agent's action in the sense of Milgrom (1981). The concavity requirement guarantees that the agent's problem is well behaved. The conditions are necessary and sufficient for any action to be implementable with the binary signal χ. [23]

Finally, we let $\phi(\theta)$ denote the resource cost of precision per worker. Regarding precision, we assume $p_\theta < 0, p_{\theta\theta} > 0$ and $\phi_\theta > 0, \phi_{\theta\theta} > 0$. The conditions on the first derivative are not real restrictions. They would naturally follow if one were to fully model the information acquisition problem of firms. The convexity requirements guarantee that the first order conditions are sufficient.

The timing of the game between firms and households (within a period) is as follows. Firms offer a bonus contract $\{A, B\}$ where A denotes the fixed payment and B the bonus part of the contract. In addition, firms announce a precision level θ by which they intend to measure the signals. We assume that θ is not contractible, which creates the double moral hazard problem and requires the firm to make a credible announcement. Households either decide to have their

[23] The derivative requirements on the probability distribution of the binary variable impose conditions on the underlying information structure. Demougin and Fluet [1998] have shown that if the underlying information system satisfies the Monotone Likelihood Ratio Condition (MLRC) and the Convexity of the Density Function Condition (CDFC) then the required conditions are indeed satisfied.

members work for firms or to remain self-employed. Employee households select their level of effort, given the announced precision. The firms select the precision, which, in equilibrium, is the same they have announced. Finally, signals are observed and payments are made.

3.4. The bonus contract

For the subgame where firms select precision and households make a choice of effort, we use the Nash equilibrium concept. Starting with the problem of the household, suppose it has chosen to send its members to work for firms. That household faces a bonus contract (A, B) and expects the firm to implement a precision level θ. The household chooses effort to maximize utility derived from the employment contract. Analytically, it solves

$$\max_{\epsilon} \quad A + Bp(\epsilon, \theta) - c(\epsilon) \; . \tag{3.4}$$

From the foregoing, the first-order condition is sufficient. Rewriting that condition yields the bonus which the firm must pay to induce effort ϵ, given the precision level θ:

$$B = \frac{c'(\epsilon)}{p_{\epsilon}(\epsilon, \theta)} \; . \tag{3.5}$$

Given that each worker works for a firm according to the bonus scheme $\{A, B\}$, and given that the firm expects each worker to produce the effort ϵ, the firm will choose precision, θ, to minimize its expected costs – i.e. the sum of precision costs plus expected bonus and fixed payments to workers. Hence, a firm will solve

$$\min_{\theta} \quad A + Bp(\epsilon, \theta) + \phi(\theta) \; . \tag{3.6}$$

Again, the first-order condition is sufficient, yielding:

$$Bp_\theta(\epsilon,\theta) + \phi'(\theta) = 0. \tag{3.7}$$

Given a contract $\{A, B\}$, the solution to the Nash game is a pair (ϵ, θ) that solves (3.5) and (3.7). [24]

3.5. The overall problem of the firm

In this subsection, we embed the contractual game in the larger context of the firm's overall decision problem. At this stage, in addition to determining the bonus contract – thereby inducing the desired effort – the firm must also select precision, capital and employment. The firm takes as given the rental rate of capital. In addition the firm faces a reservation utility for households. Altogether, the firm's problem can be written as:

$$\max_{\epsilon,\theta,A,B,K,L} \quad F(K,\epsilon L) - [A + Bp(\epsilon,\theta) + \phi(\theta)]\, L - rK + (1-\delta)K \tag{3.8}$$

$$Bp_\epsilon(\epsilon,\theta) - c'(\epsilon) = 0 \tag{3.9a}$$

$$A + Bp(\epsilon,\theta) - c(\epsilon) \geq \overline{y} \tag{3.9b}$$

$$Bp_\theta(\epsilon,\theta) + \phi'(\theta) = 0 \tag{3.9c}$$

[24] Note that the solution may not be unique. This, however, is not a problem since by announcing the contract the firm can select the best equilibrium for itself.

where δ is the depreciation rate, and $\overline{y}$ denotes the reservation utility of worker households. The constraints (3.9a) and (3.9b) are the household's incentive and participation conditions and (3.9c) is the credibility requirement for the firm's announcement of precision.

In the remaining, it is advantageous to use the homogeneity of the production function to rewrite the objective function of the firm in per worker terms. Specifically denote

$$Lf(k,\epsilon) \equiv F(kL, \epsilon L) \ ,$$

where k measures the capital labor ratio. Substituting this definition in the firm's problem and abstracting from the employment decision, we can rewrite problem (3.8). Since the firm takes $\overline{y}$ as given, it is easily seen that (3.9b) will be just binding. Therefore A can be eliminated from the firm's problem. Similarly, B can be eliminated by using the constraints (3.9a) and (3.9c). Altogether the optimization problem of the firm can be reduced to a Lagrange problem:

$$\max_{\epsilon,\theta,k} \ \mathcal{L} = f(k,\epsilon) - [c(\epsilon) + \overline{y} + \phi(\theta)] + (1-\delta-r)k \\ + \lambda \left(\phi'(\theta) + \frac{p_\theta(\epsilon,\theta)}{p_\epsilon(\epsilon,\theta)} c'(\epsilon) \right) \tag{3.10}$$

3.6. The household's problem revisited

When deriving the optimal bonus contract above, $\mathcal{C} = \{A, B, \theta\}$ we have assumed that households care about the expected income net of effort costs of each of their members (see (3.4)). Due to the linearity of preferences with respect to consumption, this assumption is consistent with the dynamic optimization problem of households.[25]

4. A specification

4.1. Monitoring

The monitoring part is the least standard in our paper. Therefore, the specification used in the sequel needs special motivation. Consider an environment where an agent in the course of carrying out his work emits signals that are related to his effort. In particular, these signals take the value 0 or 1 where 0 is the "favorable" signal. Let Y denote the number of unfavorable signals. We assume that Y is generated by a Poisson distribution. The density parameter of that distribution (i.e. the expected value of unfavorable signals) is negatively related to the agent's effort. In particular, we specify that relationship to be $\epsilon^{-\nu}$ where ν is the elasticity of the density parameter with respect to effort. The signals may be detected by a monitoring technology.

Let

$$a(\epsilon) = \exp(-\epsilon^{-\nu}) \tag{4.1}$$

denote the probability that no adverse signal is observed when all signals are detected. Let θ be the proportion of signals sampled by the monitoring device. Accordingly, the probability that no adverse signal is observed within the sample is $a(\epsilon)^{\theta}$.

We know from the foregoing that, in this environment, bonus contracts are

[25] For a proof, see our former discussion paper.

optimal. Moreover, Demougin and Fluet (2001) have shown that the bonus should be paid only when no unfavorable signal is detected. Thus, the probability of receiving the bonus becomes

$$p(\epsilon, \theta) = a(\epsilon)^{\theta} \tag{4.2}$$

4.2. Production and costs

We assume that the cost functions are represented by

$$\phi(\theta) = \phi \cdot \theta^{\alpha}, \;\; \alpha \geqslant 1 \tag{4.3a}$$

$$c(\epsilon) = c \cdot \epsilon^{\beta}, \;\; \beta \geqslant 1 \tag{4.3b}$$

Finally, the production technologies are specified to be a standard Cobb-Douglas function for the industrial sector and an exponential function for the self-employed

$$f(k, \epsilon) = Tk^{\gamma}\epsilon^{1-\gamma} \;\; 0 < \gamma < 1, \tag{4.4a}$$

$$y(z) = y_0 z^{\mu}, \tag{4.4b}$$

where T and y_0 are positive constants.

5. Equilibrium

An equilibrium is a sequence of $\{K_{t+1}, X_t, \mathcal{C}_t, \epsilon_t, \overline{y}_t, z_t, k_t, r_t\}_{t=0}^{\infty}$ where $K_{t+1} = \int k_{t+1}(h)dh$ and $X_t = \int x_t(h)dh$ are denoting aggregate capital and consumption, and K_0 is given, such that

(i) firms solve problem (10),

(ii) households solve (11),

(iii) firms' profit are zero,

(iv) $k_t = K_t/z_t$,

(v) $\overline{y}_t = y(z_t)$.

Using the above specification a steady state of the economy is given by three sets of conditions. The first follows from the first order conditions of the optimization problem of the firm, including the credibility constraint :

$$T(1-\gamma)k^{\gamma}\epsilon^{-\gamma} - \beta c\epsilon^{\beta-1} - \lambda\beta^2 c\epsilon^{\beta-1}\nu^{-1} = 0 \tag{5.5a}$$

$$T\gamma k^{\gamma-1}\epsilon^{1-\gamma} + (1-\delta-r) = 0 \tag{5.5b}$$

$$-\phi\alpha\theta^{\alpha-1} + \lambda\phi\alpha^2\theta^{\alpha-1} = 0 \tag{5.5c}$$

$$\alpha\phi\theta^{\alpha} - \nu^{-1}\beta c\epsilon^{\beta} = 0 \tag{5.5d}$$

The second set of conditions results from the household incentive and participation constraints:

$$B\theta\nu\epsilon^{-\nu-1}\exp\left[-\theta\epsilon^{-\nu}\right]-\beta c\epsilon^{\beta-1}=0 \tag{5.6a}$$

$$A+B\exp\left[-\theta\epsilon^{-\nu}\right]-c\epsilon^{\beta}=\overline{y} \tag{5.6b}$$

The third set of conditions consists of the market clearing requirements:

$$Tk^{\gamma}\epsilon^{1-\gamma}-A-B\exp\left[-\theta\epsilon^{-\nu}\right]-\phi\theta^{\alpha}+(1-\delta-r)k=0 \tag{5.7a}$$

$$r=\frac{1}{\eta} \tag{5.7b}$$

$$y(z)=\overline{y} \tag{5.7c}$$

Equation (5.7a) is the zero profit condition. Condition (5.7b) requires that in the steady state the market clearing interest rate be given by the household discount factor. Finally, (5.7c) determines the opportunity cost of the marginal household in the firm sector.

The overall system is block recursive and can be easily simplified. First, we eliminate r and $\overline{y}$ from (5.7b) and (5.7c). Second, equation (5.5c) implies that $\lambda = 1/\alpha$. Using the above results in (5.5a) and in (5.5b), the system of nine equations reduces to:

$$T(1-\gamma)k^{\gamma}\epsilon^{-\gamma}-\frac{\beta c\epsilon^{\beta-1}}{\alpha}\left[\frac{\beta}{\nu}+\alpha\right]=0 \tag{5.8a}$$

$$T\gamma k^{\gamma-1}\epsilon^{1-\gamma}-(\frac{1}{\eta}-(1-\delta))=0. \tag{5.8b}$$

6. Comparing steady-states

In this section, we perform some steady state comparisons with respect to changes in the equilibrium interest rate and the effectiveness of the monitoring technology. The first exercise will allow us to examine the relationship between changes in the interest rate and some key features of the economy, in particular effort and productivity.[26] The second exercise focusses on variations in the monitoring environment and will be used to show that these changes can account for large differences in the induced productivity.

6.1. Changes in the interest rate

When the interest falls, the effort/capital ratio must fall, from (5.8b). From (5.8a) it is clear that effort must increase. Therefore, capital must increase even further. Altogether we obtain:

Result 1: *Lower steady-state interest rates are associated with higher effort.*

We now characterize the different components of the labor contract required to implement the steady-state effort. From (5.5d), we observe that ϵ and θ move in the same direction, thus, $\theta_r < 0$. However, from the point of view of the household, what really matters is the impact of these changes on its expected bonus. We refer to the expected bonus as the power of the contract, and denote it with P. From (5.6a) after some manipulation, it is easy to show that $P_r < 0$. We summarize these observations as:

Result 2: *Lower steady-state interest rates are associated with higher precision*

[26] The interest rate is, of course, endogenous. Changes in the interest rate may be due to changes in the subjective discount factor or the depreciation rate. In addition, one may introduce risk to induce such changes.

and higher contract power.

Finally, in order to obtain the effect of a change in the interest rate on the fraction of workers employed, notice that firms' profits are falling in r. Thus to keep the zero profit condition, $\overline{y}$ must also be falling with r. To bring this about, z must be changing in the same direction. Therefore we obtain:

Result 3: *Lower steady-state interest rates are associated with a larger fraction of the labor force that chooses to work for the "corporate sector".*

In sum, differences in the interest rate induce co-movements in the capital-labor ratio, in employment and effort.

6.2. Changes in the monitoring environment

We represent changes in the monitoring environment as variations in ν. To obtain intuition, note that $\nu\theta$ is the elasticity of the log of the worker's probability of obtaining a bonus with respect to effort. This implies that increasing ν makes that probability more responsive to the worker's effort. Heuristically, one may think of such a change as a reduction in transaction costs resulting from the informational asymmetries.

When ν increases, the capital/labor/effort ratio (i.e. k/ϵ) remains unaffected (see (5.8b)). This implies (from (5.8a)) that effort increases, so that k increases as well. After substituting (5.6b) into the zero profit constraint (5.7a) and using (5.5d), it is straightforward to verify that $\overline{y}$ increases, and therefore labor participation in the "corporate sector" increases. The effect on monitoring is ambiguous. The increased ν increases the impact of monitoring for a given θ. Taken by itself, this would suggest a reduction in θ. The countervailing effect is due to the increased marginal benefit of raising θ. [27]

Result 4: *More informative measures of steady state effort are associated with higher capital-labor ratios, more effort, and a higher fraction of the labor force choosing to work for the "corporate sector".*

7. The Model's Performance

In this section we turn to numerical experiments that test the behavior of the model, both qualitatively and quantitatively, in reference to the facts cited in section 2. Specifically, we vary the sensitivity of the signal detection device to effort (i.e., the parameter ν) in order to assess the potential cross-sectional impact of that factor. We then conduct a growth experiment to study the effect of capital accumulation on labor contracts and productivity.

7.1. The Baseline

The baseline economy's parameters are chosen in an attempt to emulate some common characteristic of a "typical" economy (on a yearly basis). In particular, we aim at achieving a labor share of roughly 70% of output, and a share of "employees" of roughly 70% as well.[28] We also aim at a "reasonable" saving rate of roughly 20% of output. Some of the parameters are set at their by now standard values: the depreciation rate, δ, is set at 0.08, the discount factor, η, is 0.95.

The remaining parameters were chosen by trial and error, as follows. For the monitoring cost, we have $\phi = 2$, and $\alpha = 1.45$. For the effort disutility, we

[27] In our particular case, the incentive effect is dominating as long as ν is not too large.

[28] The corresponding averages in the Bernanke and Gürkaynak sample are 70% for the share of corporate employees and 67.5% for the share of labor in income.

set: $c = 0.1$ and $\beta = 1.45$. The effort detection probability is assumed to be generated by ϵ with $\nu = 1$. The production function in the "industrial sector" is characterized by $T = 0.7$ and a standard value of 0.3 for γ. Finally, the production function for the self-employed is specified with $y_0 = 2$ and $\mu = 2$.[29] Finally, we set $\underline{x}$ (the subsistence level) to 1.1.[30]

Table 1: The Baseline Steady-State

Variable	
Per-capita Total Output ($\overline{y}$)	2.64
Saving Rate	0.20
Effort (ϵ)	4.97
θ	0.63
z	0.68
$p(\epsilon, \theta)$	0.88
$k/\overline{y}$	2.46
$w/\overline{y}^1$	0.67
$m/\overline{y}^2$	0.26
$y/\overline{y}^3$	0.83
TFP_y^4	3.07
TFP_z^5	1.42

Notes:

[29] While this value of μ may seem to be "large" in terms of its implication for the average productivity of self-employed workers, it is generating reasonable implications for the evolution of their productivity in comparison with the rest of the economy.

[30] This parameter has no implications for the steady-state. The choice is motivated by the desire to generate relatively long time series for the growth path.

[1] Share of employee and self-employed compensation in total output

[2] Share of monitoring costs in total output[31]

[3]Share of "industrial" sector in total output

[4]Total factor productivity in "industrial" sector

[5] Output per worker in "self-employed" sector.

7.2. Signal Detection

To study the importance of the incentive mechanism, we vary the sensitivity of the signal detection device to effort. Specifically, we change the likelihood of receiving a favorable signal that results from a given level of effort, by changing the value of the parameter ν. We examine in particular the resulting effect on output, productivity, share of employees in the labor force and the labor share in income. The results can then be compared to the actual performance of these variables in the data.

We allow ν to range between 0.8 and 2.4 (at steps of 0.1) and report the results in Figures 5-7.[32] Figure 5, that shows the impact on output and productivity, resembles the actual data (see Figure 1). Both measures of productivity increase as output (per-worker) increases. Moreover, the relationship is non-linear, and quantitatively similar to the analogous segment of Figure 1.[33]

[31]Notice that the monitoring costs are *not* counted as part of the economy's total output.

[32]This is the range for which the model yields interior solutions.

[33]While this example cannot match the 7.7 factor Hall and Jones [1999] find for the difference between the *U.S.* productivity and that of Niger, our model gets the slope of Figure I in their paper (on page 90) about right. There, a factor of 4 in output per worker is associated with a factor of about 2 in total factor productivity.

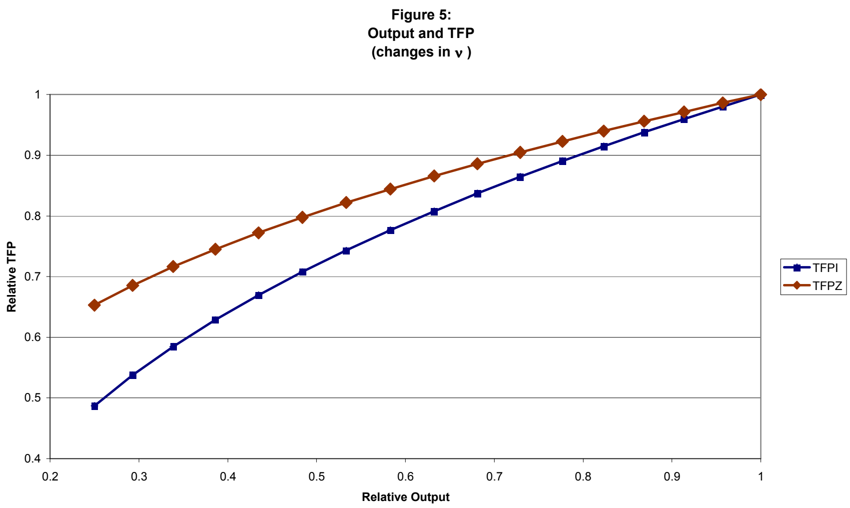
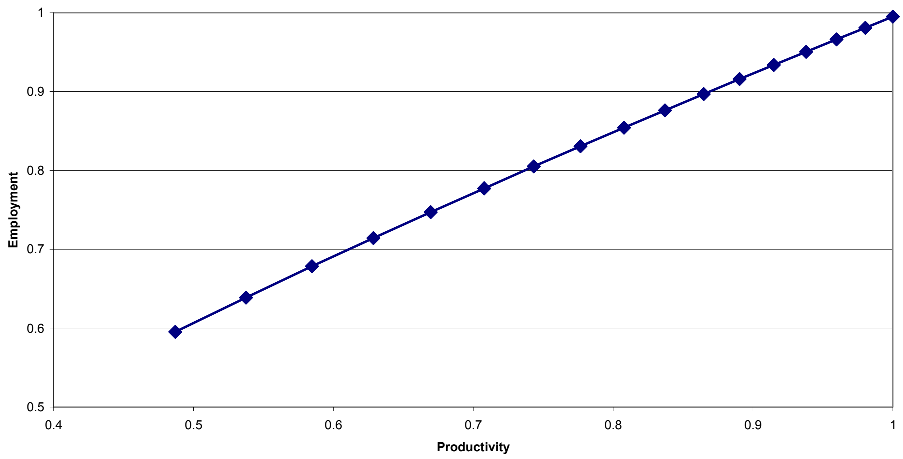


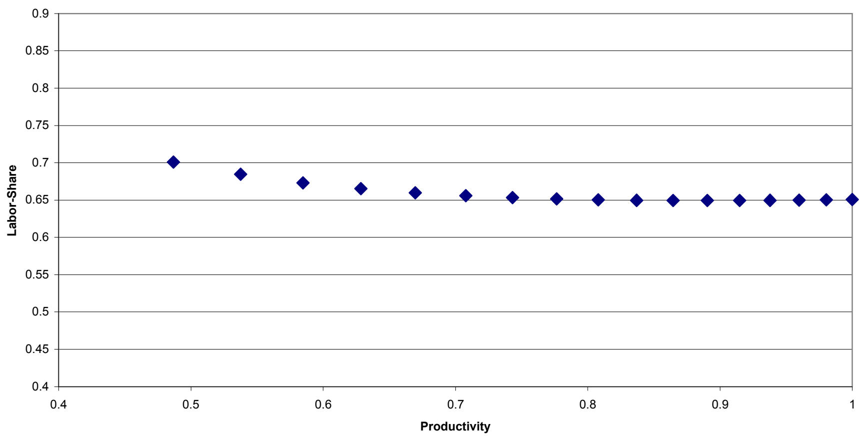
Figure 6 displays a strong association between the productivity index and the fraction of employees in the labor force. This is clearly in line with the data, as shown in Figure 2. From the quantitative point of view, not surprisingly the model generates "too much" employment in the "industrial sector", and in fact, at the highest value of ν, the entire labor force becomes "employed".

Figure 6:
Productivity and Employment
(changes in ν)



Finally, Figure 7 depicts the relationship between the labor share in income and productivity:

Figure 7:
Productivity and Labor-Share
(changes in ν)



This figure shows that the labor share has a slight inclination to decline as productivity increases, but the relationship overall is weak, as is the case in Figure 3.

The results reported above indicate that the extent to which incentives are allowed to affect behavior may have important effects on output and productivity. We capture here this relationship by a single parameter, ν, in the monitoring technology. However, as indicated in section 2, the link between effort and productivity may be due to societal characteristics (such as attitude to inequality), legal structures and, in particular, regulations of the labor market.

7.3. Dynamics

We turn to the growth path of the economy with the base-economy monitoring cost technology ($\nu = 1$). The economy is started with a third of its capital. We set $\underline{x}$ (the subsistence level) to 1.1.[34] The economy reaches the steady-state after 55 periods. We describe first the economy's growth performance, through Figure 8.

[34]This parameter has no implications for the steady-state. The choice is motivated by the desire to generate relatively long time series for the growth path.

Figure 8
Growth Rates

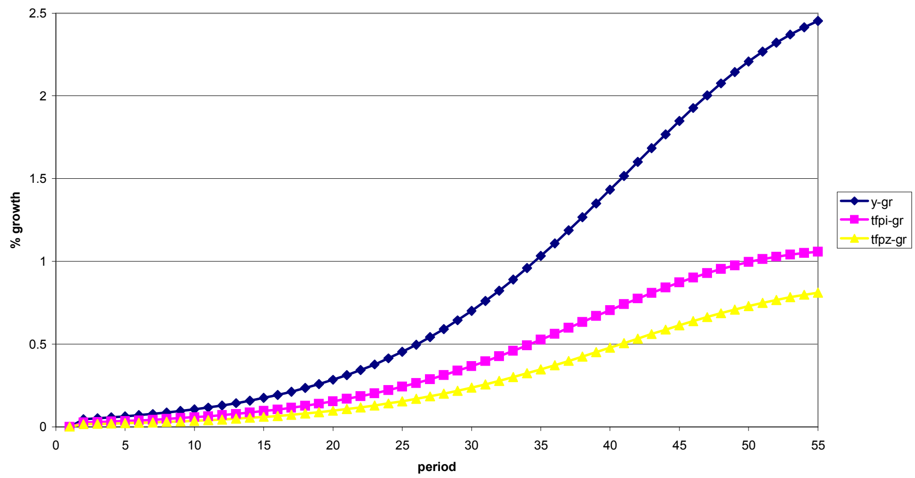
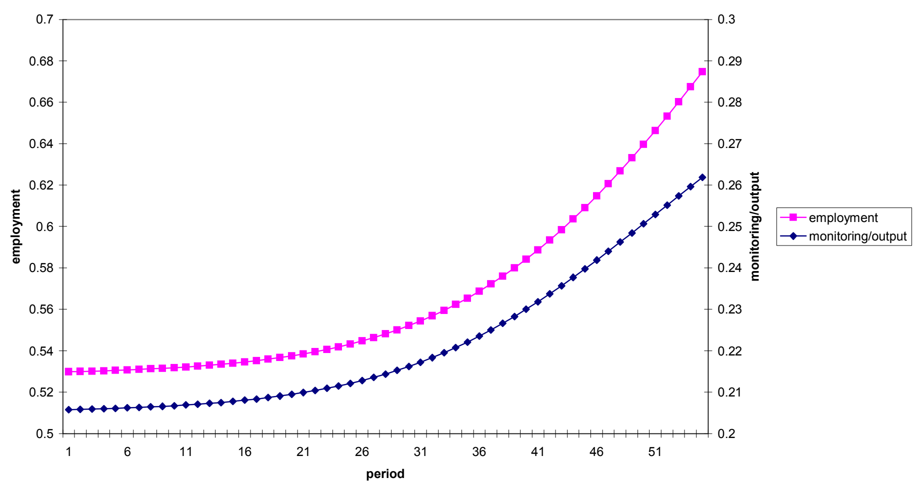


Figure 8 depicts the growth rates of output as well as of the total factor productivity in the “industrial” sector and of the output per worker in the “self-employed” sector. As can be seen from the figure, the growth rates are all accelerating towards the steady-state. Total factor productivity growth amounts to a bit below one half of the output growth. This growth is due to the fact that as the economy is accumulating capital, more workers are needed for the “industrial sector”. These workers have to be enticed away from self-employment. As the productivity of the marginal self-employed worker increases, a better contract has to be offered to the industrial workers. This, in turn, entails more monitoring and higher productivity.

Finally, in Figure 9 we show the evolution of the fraction of workers employed in the “industrial sector” and the monitoring costs relative to output. The figure clearly shows that the need to entice more workers into the “industrial sector” is indeed associated with higher monitoring costs. This result corresponds closely with Radner's (1992) findings summarized above. The growth process requires an increasing allocation of resources to monitoring and "management".

Figure 9
Employment and Monitoring



8. Conclusion

This paper generates total factor productivity gains that are unrelated to any technological progress. In fact, production technologies are kept constant throughout the analysis. However, out of steady-state the economy is accumulating capital. The workers who use this capital need to be enticed away by the "corporate sector" from an alternative occupation. The productivity of the marginal worker in that alternative occupation is assumed to increase as more workers are employed. This requires a higher wage. To justify that higher wage, workers need to exert more effort. To induce that higher effort, employers must increase their investment in monitoring, and the result is higher productivity.

Thus, the model shows how increased pressure from an alternative sector (in our case - the "self employed" sector) induces intensification of effort and increased productivity in the "corporate sector". Clearly, one may think of other sources of pressure that may trigger the same effect. Increased internal competition due to deregulation, or competition from other countries generated by trade-liberalization, can all serve the same purpose (see e.g. Schmitz 2004).

While our choice to exploit monitoring as a device to create transaction costs proved to generate useful results, it is certainly not the only way to create an "organizational" link between growth and TFP. For example, coordination problems, control problems and knowledge utilization problems also create organizational costs. These costs are likely to vary along a growth path. Whether this would lead to co-movements between growth and productivity is an open question. Clearly, there is a wide scope of potential interaction between an economy's organization, its growth and its productivity, that needs to be further explored.

References

Alchian, A. A. and H. Demsetz, 1972: "Production, Information Costs, and Economic Organization", *American Economic Review*, 62, pp. 777-795.

Acemoglu, D., S. Johnson and J. A. Robinson, 2001: "The Colonial Origins of Comparative Development: An Empirical Investigation", *American Economic Review*, 91, pp. 1369-1401.

Acemoglu, D. and F. Zilibotti, 2001: "Productivity Differences", *Quarterly Journal of Economics*, 115(3), pp.563-606.

Bernanke B. S. and R. S. Gürkaynak, 2001 : "Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously", *NBER Macroeconomics Annual 2001.*

Botero, J. C., S. Djankov, R. La Porta, F. Lopez-de-Silanes, A. Shleifer, 2004, "The Regulation of Labor", *The Quarterly Journal of Economics*, forthcoming.

Caballero, R. J., K. Covan Sr., E. M. Engel and A. Micco, 2004: "Effective Labor Regulation and Microeconomic Flexibility", MIT discussion paper No. 04-30.

Clark, G., 1987: "Productivity Growth Without Technical Change in European Agriculture Before 1850", *Journal of Economic History*, 47(2), pp. 419-432.

Demougin, D. and C. Fluet, 1998: "Mechanism Sufficient Statistic in the Risk-Neutral Agency Problem", *Journal of Institutional and Theoretical Economics*, 154(4), pp. 622-639.

Demougin, D. and C. Fluet, 2001: "Monitoring versus Incentives", *European Economic Review*, 45, pp. 1741-1764.

Gollin, D., 2002: "Getting Income Shares Right", *The Journal of Political Economy*, 110(2), pp. 458-474.

Green, F., 2004: "Why Has Effort Become More Intense?", *Industrial Relations*, 43(4), pp.709-741.

Groves, T. Y. Hong, J. McMillan and B. Naughton, 1994: "Autonomy and Incentives in Chinese State Enterprise", *The Quarterly Journal of Economics*, 109(1), pp.183-209.

Hall, Robert E. and Charles I. Jones, 1999: "Why Do Some Countries Produce So Much More Output per Worker Than Others?", *The Quarterly Journal of Economics*, pp.83-116.

Ichniowski C,. K. Shaw and G. Premushi, 1997: "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines", *American Economic Review*, 87(3), pp. 291-313.

Jones, C. I., 1998: *Introduction to Economic Growth*, W. W. Norton and Company.

Kim, S. K., 1995: "Efficiency of an Information System in an Agency Problem", *Econometrica*, 63, pp. 89-102.

Kocherlakota, N. R., 2001: "Building Blocks for Barriers to Riches", Federal Reserve Bank of Minneapolis, Research Department Staff Report 288.

Leamer, E. E., 1999: "Effort, Wages, and the International Division of Labor", *The Journal of Political Economy*, 107(6), pp. 1127-1162.

McCaffee R.P. and J. McMillan, 1995: "Organizational Diseconomies of Scale", *Journal of Economics & Management Strategy*, 4(3), pp.399-426.

Milgrom, P. 1981: "Good News and Bad News: Representation Theorems and Applications", *Bell Journal of Economics*, 12, pp. 380-391.

Nakamura, M. and O. Hübler, 1998: "The Bonus Share of Flexible Pay in Germany, Japan and the US: Some Empirical Regularities", *Japan and the Word Economy*, 10, pp221-232.

Parente, S. L. and E. C. Prescott, 1999: "Monopoly Rights: A Barrier to Riches", *The American Economic Review*, 89(3), pp. 1216-1233.

Park, E. S., 1995: "Incentive Constraints Under Limited Liability", *Journal of Economics and Management Strategy*, 4, pp. 477-490.

Prescott, E. C., 1998: "Needed: A Theory of Total Factor Productivity", *International Economic Review*, 39(3), pp. 525-551.

Radner, R., 1992: "Hierarchy: The Economics of Managing", *Journal of Economic Literature*, pp 1382-1415.

Schmitz, J. A., Jr., 2004: "What Determines Labor Productivity? Lessons from the Dramatic Recovery of the U.S. and Canadian Iron-ore Industries Since their Early 1980s Crisis", Federal Reserve Bank of Minneapolis, Research Department Staff Report 286, revised.

Shi, S. , 1998: "Search for a Monetary Propagation Mechanism", *Journal of Economic Theory*, 81, pp. 314-352.