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Information, coordination, and the industrialization of countries

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INFORMATION COORDINATION, AND THE INDUSTRIALIZATION OF COUNTRIES

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INFORMATION COORDINATION, AND THE INDUSTRIALIZATION OF COUNTRIES

Abstract

The industrialization process of a country is often plagued by a failure to coordinate investment decisions. Using the Global Games approach we can solve this coordination problem and eliminate the problem of multiple equilibria. We show how appropriate information provision enhances efficiency. We discuss extensions of the model and argue that subsidies may be a property of a signalling equilibrium to overcome credibility problems in information provision. In addition we point out possible problems with overreaction to public information. Furthermore, we suggest a new focus for development policy.

JEL Code: C72, C79, D82, F21, O12, O14.

Keywords: information, coordination, industrialization, development, global games, equilibrium refinements, big push.

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1 Introduction

Economists have long struggled to explain vastly differing growth patterns of countries starting out from apparently very similar initial conditions. Models of complementarities in investment decisions have featured prominently in the literature.[1] In the presence of such complementarities, multiple equilibria can emerge and two identical economies can end up at very different levels of development.

Though models with multiple equilibria can in principle account for the various observed development outcomes they are considered somewhat unsatisfactory as they lack predictive power. Moreover, so far no satisfying theory exists to explain the transition from one equilibrium to another. Thus often 'brute force' direct state controlled coordination has been suggested to be the appropriate policy.

We use recent theoretical developments in equilibrium selection and suggest a more subtle mechanism to change the equilibrium – information policy. Introduced by Carlsson and van Damme (1993) and further extended by Morris and Shin (1998) the theory of Global Games ties equilibrium selection to initial informational conditions. Those informational conditions can in principle be influenced, e.g. by the government or international organizations, and thus the arising equilibrium can be ascertained. We show how an appropriate information policy enhances efficiency. We discuss extensions of the model and argue that subsidies may be a property of a signalling equilibrium to overcome credibility problems in information provision. In addition we point out possible problems with overreaction to public information

The industrialization of an economy is widely considered as central for its lasting development. All now developed countries went through a phase of industrialization at one point in their history. The UK did so in the early 19th century, the US, Germany and France in the second part of the 19th century. And the Asian Countries industrialized before - as in the case of Japan - or after WWII like South Korea, Singapore or Taiwan. But apparently not all countries manage to enter this process and so initially similar countries take very different courses of development. Whereas industrialized economies tend to grow faster and

[1] Cf. Basu and Nayak (1992) or Ray (1998).

more sustainable, the non-industrialized economies lag behind. Therefore it is often argued that industrializing countries is an integral part of a good development policy.

Why there are some countries that manage to industrialize while there are at the same time apparently similar countries that fail to do so has often been explained by the presence of multiple equilibria. In pioneering work Rosenstein-Rodan (1943) argued that industrializing a country only works if many sectors at once are industrialized as one industrialized sector alone would not be able to operate profitably. Hence he argued for a 'Big Push' in development policy. The essence of Rosenstein-Rodan's argument is that one firm's decision to invest in industrializing a sector has positive effects on other firms' profits from investing in industrializing other sectors. Using game theoretic language, investors' decisions are strategic complements, i.e. one investor's expected profit increases in the other's decision to invest. Consequently there are multiple equilibria: If nobody invests it is optimal not to invest either. If everybody else invests it is optimal to invest as well. So the observation that some countries did not industrialize can be explained by a failure to coordinate.

Several authors have formalized this argument, e.g. Faini (1984), Murphy, Shleifer, and Vishny (1989), Matsuyama (1991), Ciccone and Matsuyama (1996), or Trindade (2005), and set out the conditions under which multiple equilibria can arise, i.e. what the nature of these strategic complementarities driving this result has to be[2]. We use these papers as a starting point and assume that there exist strategic complementarities in firms' investment decisions. However, we go beyond the existing literature along two dimensions and use the Global Games approach to solve the aforementioned coordination problem.[3]

Our first novel assumption is that the profitability of a firm's investment does not only depend on the number of other firms investing. In general it will be the case that the profitability of an investment in a country depends on many other factors like the political

[2]Models with multiple equilibria are notoriously hard to test empirically. However, Graham and Temple (2001) lend credibility to their explanatory power. They calibrate a numerical model with multiple equilibria and argue that for a number of countries, e.g. Honduras, India, Indonesia, Turkey, Brazil, Costa Rica, Mexico, Korea, Malaysia, Taiwan, Greece, Poland, and Yugoslavia, an equilibrium change story plausibly allows to interpret their growth pattern.

[3]Karayalcin and Mitra (1999) analyze a dynamic learning model to select one of the two equilibria.

stability of the country, its degree of openness, the quality of contract enforcement or pre-existing infrastructure. We assume that these factors can be summarized in one variable, the country's investment environment.

These states can be ordered such that there exist three distinct categories of countries: Countries where there are so many obstacles to investment that investing never pays even if all firms would manage to coordinate on investing. For these countries there exists a unique equilibrium in which nobody invests. Think of areas with long lasting political unrest or even civil wars like many states in Sub Saharan Africa.

Countries where in contrast an investment pays off even if nobody else is going to invest. Therefore, here the unique equilibrium has everybody investing. Examples could be the former Eastern Bloc states of Eastern Europe with a well trained labor force and effective institutions as for example the Czech Republic.

Finally countries characterized by mediocre investment environments where the above discussed problem of multiple equilibria persists, as there the number of others investing determines whether or not an investment is worthwhile. Presumably a large fraction of countries lies in that intermediate region and is therefore plagued by a coordination problem.

Our second novel assumption is that we introduce private information. Although there may be a lot of publicly observable data concerning a country's investment environment, potential investors are likely to interpret these observed facts in a slightly different manner. Think of the different firms' research departments producing country reports. Another interpretation is that a potential investor requesting information from a country never can be sure whether he gets the same information as other potential investors. That is, firms receive private signals over a country's quality.

Summing up, our set-up has the following features: 1) The payoff of firms' actions depends on an underlying variable, i.e. the country's investment environment. 2) The firms hold private information about the true state of a country. 3) The players' actions are strategic complements, and for some intermediate states there exists a coordination problem. These features make our set-up suitable to apply the techniques of the Global Games Approach,

which was pioneered by Carlsson and van Damme (1993) and further extended by Morris and Shin (1998), and to eliminate multiple equilibria. It has the additional attractive feature that it opens the scope for an interesting policy tool to mitigate the coordination problem - the provision of information. Like Morris and Shin (1998) most applications of the Global Games Approach are set in financial markets or currency crises models. To the best of our knowledge our paper is the first to use this approach in a development context.

The following reasoning helps to grasp the basic intuition of the Global Games Approach. Start from the insight that the basic problem in coordination problems is the Knightian nature of the strategic uncertainty, i.e. players cannot assign probabilities to different events (here other players' actions). Conventional game theory deals with this problem by only analyzing equilibrium behavior, where there is no problem as players' actions are perfectly correlated. Introducing private information renders common knowledge infeasible and turns the Knightian uncertainty into Bayesian uncertainty and so agents can form expectations over gains and losses from their actions. So we get an additional equilibrium constraint that allows us to eliminate multiple equilibria and end up with a unique equilibrium prediction.

Morris and Shin (1998) show for coordination problems like the one at hand that it is possible to derive a unique threshold for a firm's belief about the value of the underlying variable (in our model the country's investment environment), which determines whether or not it takes a specific action. This threshold in turn depends on the firm's private information. For our model that says that if and only if a firm believes the country's investment environment to be better than this threshold it is going to invest. If it receives a signal that the environment is worse than this threshold it does not invest. Therefore there is no longer a problem of multiple equilibria.

While that might have some appeal from a theoretical point of view – as we now can uniquely pin down the equilibrium of the game – it does not help too much in terms of providing policy advice. In general the threshold for the signal will be somewhere within the region of countries with intermediate investment environments. That is there are some countries where the (now unique) equilibrium has no firm investing, although investment would be efficient as long as coordination is ensured.

Fortunately, the Global Games Approach allows us to do more than just equilibrium refinements. An 'appropriate' information policy can reduce the inefficiency arising from a too high threshold. 'Appropriate' here means simply more precise. By providing firms with a more accurate signal about the true investment environment the equilibrium threshold can be shifted and efficiency enhanced. So while e.g. Murphy, Shleifer, and Vishny (1989) suggested subsidizing investments in order to overcome the coordination problem, we now offer another way to deal with the problem. Providing information in the right way achieves a more efficient allocation.

Birdsall, Rodrik, and Subramanian (2005) report that among all the former Eastern Block states those that were about to enter the European Union were by far the most successful in attracting investments and experienced the strongest growth. One can interpret this in the light of our model. In the process of entering the European Union those countries have to implement several system changes which make the information structure a lot more transparent. This might have changed the threshold sufficiently to ensure coordination on the desired equilibrium.

A natural question to ask is who should provide this information. An obvious answer is 'the country's government'. However, one might argue that governments have misguided incentives in this context. Several reasons come to mind why they may prefer to have their country industrialized (even if this is not efficient): An optimistic view might imply benevolent motives towards its citizens. A more pessimistic view might imply that it is simply easier to collect bribes or other perks from industry firms. So a credibility problem in information provision arises.

One way to cope with that would be to transfer the provision of information to intermediaries that do not have a direct interest in the outcome. Private rating agencies or international bodies like the Worldbank or the IMF could serve this purpose. Another solution would be to find ways for the government to credibly signal the country's true quality. In this context there may again be some scope for subsidies but now with a quite different notion than in Murphy, Shleifer, and Vishny (1989). Here the government does not take away the financial risk of a coordination failure from the firm but subsidies emerge as an

equilibrium property of a signalling game. If it is easier for a country with a good investment environment to recoup subsidies, e.g. by taxing firms' profits, than for a country with a more difficult investment environment, subsidies are a less costly signal for such a high quality country. These differing signalling costs allow for a separating equilibrium. That is subsidies might be a second best policy instrument.

Though with a slightly different focus, Rodrik, Grossman, and Norman (1995) describe the development success stories of South Korea and Taiwan. They argue that in both countries the main source of growth was, as in our model, an investment boom and that the boom started after a coordination failure was overcome. They point out the crucial role of subsidies to achieve this by directing investment to the desired destinations. Another key feature for the development success pointed out by Rodrik, Grossman, and Norman (1995) is improvement of the 'investment climate'. This matches neatly to the investment environment variable we use and again points at a specific role for development policy: Improving the investment environment, i.e. creating political stability, improving the enforceability of contracts, etc., opens up the possibility for those economies to become industrialized and thus develop faster.

The remainder of the paper is structured as follows: Section 2 discusses the assumptions and sets out the basic model. In Section 3 we deal with the problem of multiple equilibria and derive the unique equilibrium threshold. Section 4 analyzes the scope for efficiency enhancing informational policy. In Section 5 we discuss extensions of the model. We conclude in Section 6. The Appendix contains the proofs.

2 The Model

There is a continuum of firms with mass 1. Each firm can decide whether to invest in one sector of a non–industrialized country or not. If one firm invests in a sector this sector is called industrialized. Following the reasoning of Murphy, Shleifer and Vishny (1989) we assume that firms then are monopolists in their respective sectors and thus can earn positive profits. We assume there are no coordination problems among firms in what sector to invest.

Relaxing this assumption would considerably complicate the analysis without contributing to a better understanding of the problem.

Each firm i's profit π depends on the share α^{-i} of other firms investing in the country. Each firm has to bear costs $C(z)$ of investing. These costs depend on the investment environment z in a country. We think of the investment environment in very broad terms and subsume basically all factors which are important for successful investment in it, e.g. institutional features like political stability, quality of contract enforcement, or security of property rights. But also the existing infrastructure and the stock of human capital could be subsumed in it.

z is uniformly distributed between $\underline{z}$ and $\overline{z}$, where $\underline{z}$ describes a very favorable investment environment with only little obstacles to overcome whereas $\overline{z}$ describes an extremely adverse investment environment. It is in principle possible to allow for more general informational structures[4]. However, to ease the exposition we stick to this simple setting.

Therefore the profit of an investing firm is given by

$$\Pi = \pi(\alpha) - C(z), \tag{1}$$

with $\frac{\partial \pi}{\partial \alpha} > 0$, $\frac{\partial C}{\partial z} > 0$ and $\frac{\partial^2 C}{\partial z^2} > 0$.

$\frac{\partial \pi}{\partial \alpha} > 0$ captures the fact that firms' investment decisions are strategic complements. The costs are convex in z, capturing the idea that it gets harder and harder to profitably invest in a country when the investment environment becomes more difficult. If the firm does not invest its profit is normalized to 0.

We impose two additional assumptions:

$$\exists \breve{z} < \overline{z} \qquad s.t. \qquad \pi(1) < C(z) \qquad \forall z \geq \breve{z}. \tag{2}$$

There exists a threshold such that for every value of z above $\breve{z}$ it does not pay for a firm to invest because the investment environment is so bad that it would make losses even if all other firms would invest. Therefore it is a dominant strategy not to invest in this region.

$$\exists \hat{z} > \underline{z} \qquad s.t. \qquad \pi(0) > C(z) \qquad \forall z \leq \hat{z}. \tag{3}$$

[4]See e.g. Morris and Shin (2003).

However, if the investment environment is very favorable, i.e. z is below $\hat{z}$, it pays for a firm to invest even if it is the only one to do so. It is therefore a dominant strategy to invest.

To make the problem interesting assume $\breve{z} > \hat{z}$. Now we have two regions with dominant strategies at the extremes of the support of z and only for the intermediate region $z \in [\hat{z}, \breve{z}]$ the initial coordination problem persists. Henceforth we will call the regions below $\hat{z}$ and above $\breve{z}$ the 'dominance regions'. If there is common knowledge on the true quality of the country we have two equilibria in this region where either all firms invest or no firm invests.

Figure I

Now we introduce private information. Each firm i knows the support and distribution from which the realization of z is drawn but receives only a noisy signal z^i of the true value of z. These signals are only privately observed.

The signal z^i is uniformly distributed between $[z - \epsilon, z + \epsilon]$[5]. All private signals are independent. Furthermore it is common knowledge that every firm receives such a private signal. It is possible to allow for heterogeneity among firms with respect to the quality of the private signals, i.e. have better or less well informed firms. To ease exposition we focus on the case with symmetric information.

Each firm can now decide dependent on z^i whether or not to invest or whether to play a mixed strategy over the two alternatives. The strategy of firm i is therefore a function $s^i(z^i) : [\underline{z}, \overline{z}] \rightarrow [0, 1]$.

This completes the description of the game. We turn now to the analysis of the equilibrium.

[5]This modelling is based on Morris and Shin (1998). Again richer information structures are possible. See e.g. Morris and Shin (2003).

3 Uniqueness of Equilibrium

There exists a unique Bayesian Nash Equilibrium in the game with private information. In this equilibrium firms invest if and only if their signal is below a threshold $z^\star$. To show this, we first assume that every firm follows a simple switching strategy and invests if and only if it receives a signal below a threshold k. By continuity arguments it is easy to show that indeed such a simple switching strategy is optimal, i.e. imposing it in the first place is without loss of generality. Assuming that everybody else uses such a switching strategy we calculate expected profits of investing or not investing conditional on received signals. Then iterated elimination of dominated strategies starts.

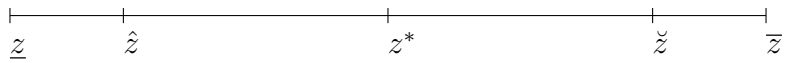

Figure II

If a firm observes a signal close to one of the dominance regions there is a substantial probability that some other firms received a signal in the dominance region and therefore have a dominant strategy. This is enough to ensure that the firm itself has a dominant strategy, too. Iterating this process starting from both dominance regions eventually results in a unique threshold at which a firm is just indifferent between investing and not investing. The following equation

$$\Pi(z^\star, I_{z^\star}) = \frac{1}{2\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}[\pi(\alpha(z)) - C(z)]dz = 0$$

captures that at the threshold $z^\star$ the expected profit from investing has to equal 0, the profit from not investing. Thereby the threshold is implicitly defined. This finding is captured in the following proposition.

Proposition 1 *There exists a unique threshold $z^\star$ where a firm with $z^i < z^\star$ invests and a firm with $z^i \geq z^\star$ does not invest.*

Proof The proof can be found in the appendix.

Note that the expected profit from investing - and therefore the equilibrium threshold $z^\star$ - depends on the precision ϵ of the private signal.

By applying the Global Games Approach we get rid of the multiplicity of equilibria and can make unambiguous predictions for the outcome of the game, i.e. the industrialization process. This outcome depends on the underlying quality of the country **and** on the precision of the private signal. Although that might be interesting from a theoretical point of view so far we have not gained much from a policy point of view. But fortunately we can do a bit more.

4 Scope for Informational Policy

As pointed out earlier, the location of the threshold depends on the precision of the private signal. In the following lemma we show that this dependence is locally monotonic.[6]

Lemma 2 *In equilibrium it holds that* $\frac{\partial z^\star}{\partial \epsilon} < 0$.

Proof The proof can be found in the appendix.

This lemma says that the location of the threshold depends on the precision of private information. The precision of the private signals can be expressed by ϵ. A higher ϵ means a bigger support of the distribution of signals and therefore a higher variance. If ϵ decreases the private signals get more precise and the threshold shifts to the right, i.e. for more values of z it is now a dominant strategy to invest. From an ex ante perspective the probability of industrialization increases[7].

[6] Heinemann and Illing (2002) make a similar argument within the Morris and Shin (1998) framework. In their model a central bank tries to minimize the risk of a speculative attack on a currency.

[7] This feature does not always carry over to general informational structures. Morris and Shin (2003) discuss problems with normally distributed states and errors.

This opens up scope for informational policy. We argue that an increase in the precision of the signal can be interpreted as a more transparent regime. If more and better data are made available, if the sources of this information are easily comprehensible, or if the information is validated by an independent third party, the precision of the private signals, generated on basis of these data, increases.

But this implies that a country can make up for inferior innate quality by a superior information policy, i.e. by providing more precise information. To illustrate this consider two countries A and B where A's investment environment is slightly worse. If A now provides sufficiently better information – in terms of precision – it is more likely for A to be industrialized than for B. This is captured in the following proposition.

Proposition 3 *Sufficiently more precise information policy can compensate for innate disadvantages in a country's investment environment.*

Proof. Follows immediately from Lemma 2. ■

This now gives scope for an additional policy instrument. To reach a more efficient situation a country no longer has to rely only on undifferentiated subsidies or direct coordinating intervention, but informational policy can be used to increase efficiency.

5 Extensions and Discussion

5.1 Credibility of Information

We have shown that informational policy can be used to enhance efficiency. But the question arises how that policy should be performed and who should provide this information. The straightforward answer seems to be national governments. But one can easily argue that these governments have misguided incentives. They may strictly prefer their country to be industrialized, either for benevolent reasons as raising standards of living or for the fact that

they can collect bribes or taxes from industries. Therefore they may provide biased, i.e. too positive, information in order to attract investors.

There are two possible ways of doing this. On the one hand a country can simply withhold disadvantageous information and it may well be impossible to observe whether or not information has been withheld. On the other hand it may be possible to simply make up good news without the possibility of this window dressing being exposed. Therefore credibility of information is a serious problem here[8].

One approach could be to rely on external bodies to provide this information. External bodies are institutions that have no such credibility problems as national governments. One could think of the World Bank, the UN or the IMF as such institutions. Another approach could be to resort to market institutions like rating agencies in financial markets. These companies make their money from their reputation of providing reliable information. Indeed such institutions exist and offer very detailed information on numerous variables such as political stability or the quality of the judicial system. The "Economist Intelligence Unit"[9] or the "International Country Risk Guide"[10] are only two examples.

An economic theorist however might resort to another solution to this credibility problem. If countries can at some cost signal their true investment environment (and if these countries differ systematically with respect to their costs of signalling) it would be possible to separate countries according to quality.

Subsidies are such an instrument. The 'better' a country the more likely it is that this country is able to recoup the subsidies over time through taxing the firms' profits or higher tax revenues in the whole economy. Reversely, the worse the environment in a country, the less likely it is to recoup these subsidies, i.e. the more costly it is for a 'bad' country to mimic a 'good' country by offering generous subsidy schemes to investing firms. Along this line of reasoning it is possible to explain observed subsidies not as ad hoc policy instruments

[8]Milgrom (1981) has shown that this is not the case if the only way of lying is to omit negative information and agents can observe omittance. By holding very pessimistic beliefs upon observing omittance in equilibrium all relevant information is revealed. However, generally the environment here is more hostile.

[9]http://www.eiu.com/

[10]http://www.icrgonline.com/

but as an equilibrium property of a signalling equilibrium[11].

Some people might argue that it is not at all clear that bodies like the World Bank have the right incentives to provide unbiased information. In this context one could interpret World Bank loans as a costly signal of a country's quality, too. If one talks to practitioners in the field and follows the political discussion this signal character of World Bank loans or IMF programs seems to be one important feature of these credits or programs respectively.

In a similar manner to subsidies we can also think of other forms of public spending, e.g. infrastructure projects, serving as costly signals. Keefer and Knack (2002) empirically support this thesis and argue that public spending is increased to attract investors to unattractive countries. Similar to us they deem countries with insecure property rights to be unattractive.

5.2 Dynamic Structure and Heterogeneity

Suppose there are many small investors and one big investor. A big investor could be interpreted as a firm industrializing a key sector of the economy and having a relatively large impact on marginal profits of other, smaller, firms[12]. One interpretation would be to view the big investor as a private firm providing infrastructure like railways or electricity, via this channel having a big impact on other firms' profits. Reading the model that way would deliver infrastructure as an equilibrium property. One can show that the very presence of such a big investor makes the small investors more inclined to invest[13].

In our terminology one could phrase it such that the small investors now invest given worse investment environments than they did without the big investor. If one also takes into account that big and small investors might be differently informed one gains further insights. If the large investor is better informed – and if that is common knowledge – the above mentioned effect is strengthened. If we moreover allow for a dynamic structure

[11] See for example Angeletos, Hellwig, and Pavan (2003) for an analysis of costly signalling in a model of financial crisis.

[12] Corsetti, Dasgupta, Morris, and Shin (2004) have analyzed a similar model in a currency crises setup.

[13] Cf. Corsetti, Dasgupta, Morris, and Shin (2004).

where the big player's decision to invest or not is publicly observable the effects are further strengthened as the small investors now can be sure that a substantial investment already has been made.

Again, this bears policy implications. Key investors should be the first to be given access to information and this should be made public. Also one should aim to get key investors to decide first and make these decisions as public as possible. Again subsidies for such key sectors could be a viable instrument and such things are indeed quite commonly observed.

5.3 Additional Signals

We could also allow for a richer information structure. Each firm observes not only a private signal but also a public signal[14]. It can be shown that firms react stronger to the public signal than its precision would suggest. But this type of 'over reaction' can be easily rationalized.

A public signal triggers two effects. On the one hand it conveys information as a private signal does, on the other hand it has a 'coordination effect' as everybody now knows something about other players' information and can infer about other players' dominant strategies. It is the latter coordination effect that triggers the 'over reaction' to public signals.

This, too, could be used as a policy instrument. Revealing information publicly can enhance efficiency. And the 'over reaction' gives a high leverage to this instrument. However, this effect can be dangerous as well. Even if the provided public signals are not very informative they can have large effects. So just by creating 'noise' one might trigger large reactions. Therefore it is important to be careful when releasing public information.

This reasoning in principle delivers testable predictions. For example, the 1994 Mexican Tequila crisis or the 1997 Asian crisis could be interpreted as signals that 'investments in emerging/developing markets are not without risk'. Although these signals have not much informational value we would, due to a 'coordination effect', expect a drop in investments in other emerging or developing countries in the aftermath of these crises, even if they were

[14]This situation was first studied by Morris and Shin [2002].

not affected by the original crises.

6 Conclusion

In this paper we analyze how to deal with multiple equilibria inherent in the industrialization process of countries. We augment the existing literature on investment complementarities with an additional variable, the investment environment in a country. To this somewhat richer model we apply the Global Games Approach. Thereby we are able to eliminate the multiplicity of equilibria and end up with a unique equilibrium prediction dependent on the investment environment of the country. We show how the right information provision, namely more precise private signals, can enhance efficiency and we argue that subsidies may be a property of a signalling equilibrium to overcome credibility problems in the provision of information. Finally, we point at possible problems with overreaction to public information and suggest a sequence for the industrialization process.

The recent finding by Jones and Olken (2005) that there are leader fixed effects in countries' growth patterns can be also interpreted in the light of our approach. A change in leadership can change the equilibrium as the new leader may have some - in their study - unobserved characteristics, e.g. being credible, that change the information structure. Rodrik, Grossman, and Norman (1995) argue that credibility and determination of the leadership in South Korea and Taiwan were important ingredients for these countries' success.

Although we think one has to be careful to use the model directly as sole basis for policy advice, we firmly belief that information plays a non trivial role in the industrialization process. We believe that a lot can be gained if development policy would pay attention to this.

Our paper can be seen as an additional argument that providing an appropriate investment environment should be the focus of development policy. And if we need subsidizing, it has to be the right kind of subsidies – informative ones.

7 Appendix

7.1 Proof of Proposition 1

Proof. The proof follows the logic in Morris and Shin (1998). The profit of firm i depends on the fraction of other firms investing α^{-i}. This fraction can be written as

$$\alpha^{-i} = \int_0^1 s^j(z^j)dj \qquad i \neq j.$$

The expected profit of firm i if it gets signal z^i and invests is therefore

$$\Pi(z^i) = E[\pi(\alpha^{-i}(z^j)) - C(z^i) \mid z^i]. \tag{4}$$

Call I_k a threshold strategy where each firm invests only if its private signal is below k,

$$I_k(z^i) = \begin{cases} 1 & \text{if } z^i \leq k \\ 0 & \text{if } z^i > k \end{cases}.$$

If each player plays such a switching strategy I_k then the expected profit of an investing firm i can be written as

$$\Pi^i(z^i, I_k) = \pi(1)\text{prob}(z^j \leq k \mid z^i) + \pi(0)\text{prob}(z^j > k \mid z^i) - E[C(z) \mid z^i]. \tag{5}$$

For the next step of the proof it is necessary to show that $\Pi(z^i, I_k)$ is strictly increasing in z^i. This can be done in the following way:
First we can write (5) as

$$\Pi^i(z^i, I_k) = (\pi(1) - \pi(0))\text{prob}(z^j \leq k \mid z^i) + \pi(0) - E[C(z) \mid z^i]. \tag{6}$$

Since $E[z^j \mid z^i] = z^i$ and z^j is triangular distributed on $[z^i - 2\epsilon, z^i + 2\epsilon]$ we have

$$\frac{\partial \text{prob}(z^j \leq k \mid z^i)}{\partial z^i} \begin{cases} = 0 & \text{if } k < z^i - 2\epsilon \text{ and } k > z^i + 2\epsilon \\ < 0 & \text{if } z^i - 2\epsilon \leq k \leq z^i + 2\epsilon. \end{cases}$$

Since $\frac{\partial(\pi(1)-\pi(0))}{\partial z^i} = 0$ the first term of (6) is weakly decreasing in z^i. It also holds that

$$\frac{\partial E[C(z) \mid z^i]}{\partial z^i} > 0 \qquad \forall z^i.$$

Thus the third term of (6) is strictly decreasing in z^i and therefore $\Pi(z^i, I_k)$ is strictly decreasing in z^i.

We can now start with the iterative elimination of strictly dominated strategies. We know from our assumptions that there must be signals $\underline{z}_0$ and $\bar{z}_0$ with

$$E[\pi(0) - C(z) \mid \underline{z}_0] = 0 \qquad E[\pi(1) - C(z) \mid \bar{z}_0] = 0.$$

Because of $\Pi(z^i, I_k)$ strictly decreasing in z^i there exists signals $\underline{z}_1 \geq \underline{z}_0$ and $\bar{z}_1 \leq \bar{z}_0$, such that

$$\Pi(z, I_{\underline{z}_0}) > 0 \qquad \forall z < \underline{z}_1 \qquad \text{and} \qquad \Pi(z, I_{\bar{z}_0}) < 0 \qquad \forall z > \bar{z}_1.$$

Moreover,

$$\Pi(\underline{z}_1, I_{\underline{z}_0}) = 0 \qquad \text{and} \qquad \Pi(\bar{z}_1, I_{\bar{z}_0}) = 0.$$

We can apply iterative elimination further and since the convergence $(\underline{z}_n)_{n\in\mathbf{N}}$ is increasing and $(\bar{z}_n)_{n\in\mathbf{N}}$ is decreasing there exist limit values $\underline{z}^\star = \lim_{n\to\infty}\underline{z}_n$ and $\bar{z}^\star = \lim_{n\to\infty}\bar{z}_n$. For these values it holds that

$$\underline{z}^\star = \min\{z \mid \Pi(z, I_z) = 0\} \qquad \text{and} \qquad \bar{z}^\star = \max\{z \mid \Pi(z, I_z) = 0\}.$$

The values $\underline{z}^\star$ and $\bar{z}^\star$ are the lowest and the highest solution of the equation $\Pi(z, I_z) = 0$. This equation can also be written as

$$[\pi(1) - \pi(0)]\text{prob}(z^j \leq z^\star \mid z^i = z^\star) + \pi(0) - E[C(z) \mid z^i = z^\star] = 0. \tag{7}$$

$z^j \mid z^i$ is triangular distributed between $(z^i - 2\epsilon, z^i + 2\epsilon)$ and therefore $\text{prob}(z^j \leq z^\star \mid z^i = z^\star) = \frac{1}{2}$. Thus (7) can then be written as

$$\pi(1) - \pi(0) = 2E[C(z) \mid z^i = z^\star] \tag{8}$$

The left hand side of (8) is constant while the right hand side is strictly decreasing. Therefore it exists a unique value of $z^\star$. ■

7.2 Proof of Lemma 2

Proof. The proof follows the logic in Heinemann and Illing (2002). The unique equilibrium switching signal $z^\star$ in our model is characterized by the equation

$$\begin{aligned}&\Pi^i(z^\star, I_{z^\star}) = \tfrac{1}{2\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}[\pi(\alpha(z)) - C(z)]dz = \\ &\tfrac{1}{2\epsilon}\int_{z^\star-\epsilon}^{z^\star}\pi(1)dz + \tfrac{1}{2\epsilon}\int_{z^\star}^{z^\star+\epsilon}\pi(0)dz - \tfrac{1}{2\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz = \\ &\tfrac{\pi(1)-\pi(0)}{2} - \tfrac{1}{2\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz = 0.\end{aligned} \tag{9}$$

Total differentiation of this equation yields

$$\frac{1}{2\epsilon}[-C(z^\star+\epsilon) + C(z^\star-\epsilon)]dz^\star$$

$$-\frac{1}{2\epsilon}[C(z^\star+\epsilon) + C(z^\star-\epsilon)]d\epsilon + \frac{1}{2\epsilon^2}[\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz]d\epsilon = 0.$$

Rearranging terms and using $\frac{1}{\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz = \pi(1)+\pi(0)$ gives

$$\frac{dz^\star}{d\epsilon} = \frac{\pi(1)+\pi(0) - [C(z^\star+\epsilon) + C(z^\star-\epsilon)]}{C(z^\star+\epsilon) - C(z^\star-\epsilon)}. \tag{10}$$

The denominator of (10) is positive. To determine the sign of $\frac{dz^\star}{d\epsilon}$ we need to determine the sign of the numerator. We know that $\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z^\star+\epsilon)dz > \int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz$ and that $\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z^\star-\epsilon)dz < \int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz$ because $C(\cdot)$ is a strictly increasing function. Adding up the left hand sides of the last two inequalities and dividing by 2 gives $\epsilon[C(z^\star+\epsilon)+C(z^\star-\epsilon)]$. Adding up the two right hand sides and dividing by 2 gives $\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz$. But since $C(\cdot)$ is a convex function we have

$$\epsilon[C(z^\star+\epsilon) + C(z^\star-\epsilon)] > \int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz.$$

Since $\frac{1}{\epsilon}\int_{z^\star-\epsilon}^{z^\star+\epsilon}C(z)dz = \pi(1)+\pi(0)$ we have established that

$$\pi(1)+\pi(0) < C(z^\star+\epsilon) + C(z^\star-\epsilon).$$

Thus, the numerator of (10) is negative which proves that $\frac{dz^\star}{d\epsilon} < 0$. ■

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