

SUPPLEMENT TO “WHY DOESN’T TECHNOLOGY FLOW FROM RICH TO POOR COUNTRIES?”

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THIS SUPPLEMENT CONTAINS TWO APPENDICES, namely, Appendix A and B. Appendix A deals with theoretical aspects of the analysis. In particular, it provides the proofs for all of the lemmas in the paper. Appendix B pertains to the empirical work and discusses the data used.

APPENDIX A: THEORY

A.1. *Proofs for the Contract Problem (P2)*

Some lemmas and proofs describing the structure of the optimal contract are now presented. All lemmas and proofs apply to the appended version of problem (P2), where the no-retention constraints (12) and (13) have been added.

A.2. *Proof of Go All In*

PROOF OF LEMMA 1: Let λ be the multiplier associated with the zero-profit constraint (10) and ξ be the multiplier connected with the self-financing constraint (11). The first-order condition linked with \tilde{f} is

$$-1 + \lambda - \xi = 0.$$

If $\xi > 0$, then the constraint (11) is binding, and the result holds automatically. Alternatively, if $\xi = 0$, then $\lambda = 1$. In this situation, the firm is indifferent between investing in its own project or placing the funds in a bank. On the one hand, by giving \tilde{f} to the intermediary the firm lowers its payoff in the objective function by \tilde{f} . On the other hand, this is exactly compensated for by loosening the zero-profit constraint that will result in a decrease in the payments from the firm to the intermediary (or the $x(s, t)$'s) in the capitalized amount \tilde{f} . *Q.E.D.*

REMARK 1: Since $\lambda = 1 + \xi$ and $\xi \geq 0$, it must transpire that $\lambda \geq 1$. This makes intuitive sense. When the entrepreneur hands over wealth to the intermediary, the lowest expected gross return that he can receive is $1/\beta$. This is what a saver earns from depositing funds with the intermediary. This is worth exactly 1 in present-value terms.

A.3. Transformation of Problem (P2) With Self-Financing to Problem (P5) Without It

Lemma 1 allows problem (P2) with self-financing to be converted into an equivalent problem (P5) without self-financing. The latter problem has a smaller value for the fixed costs, $\widehat{\phi}$; specifically, $\widehat{\phi} = \phi - f$:

$$(P5) \quad v = \max_{\{k(s,t), x(s,t), p(s,t)\}} \sum_{t=1}^T \sum_{s=0}^{\min\{t,S\}} \beta^t [\theta_s k(s,t)^\alpha - x(s,t)] \Pr(s,t),$$

subject to (6) to (9), the new zero-profit constraint (22), and the no-retention constraints (12) and (13). Note that the self-financing constraint (11) has now been eliminated:

$$(22) \quad \sum_{t=1}^T \sum_{s=0}^{\min\{t,S\}} \beta^t [x(s,t) - C(p(s,t), k(s,t)) - qk(s,t)] \Pr(s,t) - \underbrace{(\phi - f)}_{\widehat{\phi}} \geq 0.$$

LEMMA 6—Conversion of Problem With Self-Financing to One Without Self-Financing: *The problem with self-financed start-up funds (P2) reduces to problem (P5), where the fixed cost is $\widehat{\phi} = \phi - f$.*

PROOF: Focus on problem (P2). In line with Lemma 1, set $\widetilde{f} = f$. Use this fact to eliminate $f - \widetilde{f}$ in the objective function and to replace \widetilde{f} with f in the zero-profit condition. *Q.E.D.*

REMARK 2: All that matters for the contract is $\phi - f$, given the above lemma. That is, what matters for the contract is the amount of initial funds that the intermediary must put up, and this is consistent with many different combinations of ϕ and f . Thus, a project with a fixed cost of ϕ , where the entrepreneur has f in start-up funding, will have the same allocations as one where the fixed cost is $\phi - f$, but where the entrepreneur has no start-up funds. Therefore, without cross-country data on ϕ and f separately, it may be difficult to ascertain how much start-up funds matter.

In what follows, the proofs in Sections A.4, A.5, and A.6 refer to the transformed problem (P5).

A.4. Proof of Trust but Verify

PROOF OF LEMMA 2: (Necessity) It will be shown that the intermediary will monitor the firm at node $(u - 1, t)$ (for all $t \geq u$) only if the incentive constraint

(7) binds at (u, u) . Assume otherwise; that is, suppose to the contrary that the incentive constraint does not bind at (u, u) but that $p(u - 1, t) > 0$ for some $t \geq u$. The term $p(u - 1, t)$ shows up in only two equations in the appended version of problem (P5): in the zero-profit constraint of the intermediary (22) and on the right-hand side of the incentive constraint (7) at node (u, u) . Picture the Lagrangian associated with problem (P5). By setting $p(u - 1, t) = 0$, profits to the intermediary can be increased through the zero-profit constraint (22). This raises the value of the Lagrangian. At the same time, it will have no impact on the maximum problem through the incentive constraint (7) because its multiplier is zero. Therefore, the value of the Lagrangian can be raised, a contradiction.

(Sufficiency) Assume that the incentive constraint (7) binds at (u, u) and that $p(u - 1, t) = 0$ for some $t \geq u$. Note that the marginal cost of monitoring is zero at node $(u - 1, t)$ since $C_1(0, k(u - 1, t)) = 0$. Now increase $p(u - 1, t)$ slightly. This relaxes the incentive constraint and thereby increases the value of the Lagrangian. It has no impact on the zero-profit condition (22) as $C_1(0, k(u - 1, t)) = 0$. This implies a contradiction because the value of the Lagrangian will increase. Q.E.D.

A.5. Proof of Backloading: Lemmas 3 and 4

PROOF OF LEMMA 4, WITH LEMMA 3 AS A SPECIAL CASE: Consider the no-retention constraint (12) at node $(s, s + 1)$. Here a stall has just occurred. To satisfy the no-retention constraint at this point, the present value of the payments to the firm from there onward must be at least as large as $\psi \sum_{t=s+1}^T \beta^t \theta_s k(s, t)^\alpha \Pr(s, j)$. This is what the firm can take by exercising its retention option. This payment, which is necessary, should be made at node (s, T) . Thus, at node (s, T) , pay the amount $N(s, T) = \psi \sum_{t=s+1}^T \beta^t \theta_s k(s, t)^\alpha \Pr(s, j) / [\beta^T \Pr(s, T)]$. Shifting the retention payments along the path $(s, s + 1), (s, s + 2), \dots, (s, T - 1)$ to the node (s, T) , by increasing $x(s, s + 1), x(s, s + 2), \dots, x(s, T - 1)$ and lowering $x(s, T)$, helps with incentives. It reduces the right-hand side of the incentive constraint (7) at node $(s + 1, s + 1)$. This occurs because the firm will not receive the retention payment if it is caught lying at some node $(s, s + j)$ for $j > 1$. It has no impact on the right-hand side at other nodes along the technology ladder's diagonal. This shift does not affect the left-hand side of (7). Moreover, if the payments are set according to point (2) in the lemma, it follows by construction that the no-retention constraint (12) holds at all nodes (s, t) , for $t \geq s + 1$. It is not beneficial to pay a retention payment bigger than $N(s, T) = \psi \sum_{t=s+1}^T \beta^t \theta_s k(s, t)^\alpha \Pr(s, j) / [\beta^T \Pr(s, T)]$, as will be discussed.

Suppose that $x(s, t) < \theta_s k(s, t)^\alpha$ at some node (s, t) , for $s \leq t < T$. It will be established that, by setting $x(s, t) = \theta_s k(s, t)^\alpha$, the incentive constraint (7) can be (weakly) relaxed. Suppose $t = s$. Then, increase $x(s, s)$ by $\theta_s k(s, s)^\alpha -$

$x(s, s)$ and reduce $x(S, T)$ by $[\theta_s k(s, s)^\alpha - x(s, s)][\beta^{s-T} \Pr(s, s) / \Pr(S, T)]$. In other words, shift the payment to the firm from node (s, s) to node (S, T) while keeping its present value constant. The left-hand sides of the incentive constraints (7), for $u \leq s$, will remain unchanged. For $u > s$, the left-hand sides will increase. The right-hand sides of the incentive constraints will remain constant, however. Thus, this change will help relax any binding incentive constraints. This shift also helps with the no-retention constraints (13) for $u > s$. Next, suppose that $s < t < T$. Presume that a retention payment is made at (s, T) in the amount $N(s, T)$, as specified by (14). As discussed above, a payment of at least this size must be made at node (s, T) to prevent retention at node $(s, s+1)$. It will be argued below that it is not beneficial to pay a higher amount. For the off-diagonal node (s, t) , raise $x(s, t)$ by $\theta_s k(s, t)^\alpha - x(s, t)$ and reduce $x(S, T)$ by $[\theta_s k(s, t)^\alpha - x(s, t)][\beta^{t-T} \Pr(s, t) / \Pr(S, T)]$. This change can only increase the left-hand side of the incentive constraints for $u > s$ and has no impact elsewhere. It reduces the right-hand side at node (s, s) . The right-hand sides elsewhere are unaffected. This change also helps with the no-retention constraints (13) for $u > s$. Finally, consider the node (s, T) , for $s < S$. A similar line of argument can be employed to show that it is not optimal to set $x(s, T) < \theta_s k(s, T)^\alpha - N(s, T)$, that is, to pay a retention payment bigger than $N(s, T)$. *Q.E.D.*

COROLLARY 1—Lemma 3: *If $\psi = 0$, then $x(s, T) = 0$; that is, it is weakly efficient to take all of a firm's output at every node but (S, T) . Thus, Lemma 3 is a special case of Lemma 4.*

A.6. Proof of Efficient Investment

PROOF OF LEMMA 5: The first step is to define the first-best allocation. The first-best allocation for working capital solves the following time-0 problem:

$$\max_{\{k(s, t)\}} \left\{ \sum_{t=1}^T \sum_{s=0}^{\min\{t, S\}} \beta^t [\theta_s k(s, t)^\alpha - qk(s, t)] \Pr(s, t) \right\} - \phi,$$

subject to the information and irreversibility constraints, (8) and (9). Now, $k(s, t) = k(s, s+1) = k(s+1, s+1)$ for all $t > s$, by the information and irreversibility constraints. This allows the above problem to be recast as

$$\begin{aligned} \max_{\{k(s, s+1)\}} & \left\{ \sum_{t=1}^T \beta^t \sum_{s=0}^{\min\{t-1, S\}} [\theta_s k(s, s+1)^\alpha - qk(s, s+1)] \Pr(s, t) \right. \\ & \left. + \sum_{s=0}^{S-1} \beta^{s+1} [\theta_{s+1} k(s, s+1)^\alpha - qk(s, s+1)] \Pr(s+1, s+1) \right\} - \phi. \end{aligned}$$

Focus on some $k(s, s + 1)$. It will show up in the top line of the objective function whenever $t \geq s + 1$. It appears once in the second line. The first-order condition for $k(s, s + 1)$ is

$$\begin{aligned} & \sum_{t=s+1}^T \beta^t [\alpha \theta_s k(s, s + 1)^{\alpha-1} - q] \Pr(s, t) \\ & + \beta^{s+1} [\alpha \theta_{s+1} k(s, s + 1)^{\alpha-1} - q] \Pr(s + 1, s + 1) = 0, \end{aligned}$$

for $s = 0, \dots, S - 1$. A similar first-order condition holds for the top of the ladder.

For the second step, turn to the appended version of problem (P5). Now, using the information, irreversibility, and zero-profit constraints, (8), (9), and (22), in conjunction with the solution for the $x(s, t)$'s presented in Lemma 4, the contracting problem can be rewritten as

$$\begin{aligned} & \max_{\{k(s, s+1), p(s, t)\}} \left\{ \sum_{t=1}^T \beta^t \sum_{s=0}^{\min\{t-1, S\}} [\theta_s k(s, s + 1)^\alpha - C(p(s, t), k(s, s + 1)) \right. \\ & \quad \left. - qk(s, s + 1)] \Pr(s, t) \right. \\ & \quad \left. + \sum_{s=0}^{S-1} \beta^{s+1} [\theta_{s+1} k(s, s + 1)^\alpha - C(p(s + 1, s + 1), k(s, s + 1)) \right. \\ & \quad \left. - qk(s, s + 1)] \Pr(s + 1, s + 1) \right\} - \phi, \end{aligned}$$

subject to the $2S$ incentive and diagonal-node no-retention constraints:

$$\begin{aligned} & \sum_{t=u+1}^T \beta^t \sum_{s=u}^{\min\{t-1, S\}} [\theta_s k(s, s + 1)^\alpha - C(p(s, t), k(s, s + 1)) \\ & \quad - qk(s, s + 1)] \Pr(s, t) \\ & \quad + \sum_{s=u-1}^{S-1} \beta^{s+1} [\theta_{s+1} k(s, s + 1)^\alpha - C(p(s + 1, s + 1), k(s, s + 1)) \\ & \quad - qk(s, s + 1)] \Pr(s + 1, s + 1) - \phi \\ & \quad - \sum_{s=0}^{u-1} \psi \theta_s k(s, s + 1)^\alpha \sum_{t=s+1}^T \beta^t \Pr(s, t) \end{aligned}$$

$$\begin{aligned} &\geq k(u-1, u)^\alpha \left\{ \sum_{i=u}^S (\theta_i - \theta_{u-1}) \left\{ \sum_{j=i}^T \beta^j \Pr(i, j) \prod_{n=u}^j [1 - p(u-1, n)] \right\} \right. \\ &\quad \left. + \beta^T \Pr(i, T) \prod_{n=u}^T [1 - p(u-1, n)] \left[\psi \frac{\sum_{t=u}^S \beta^t \Pr(u-1, t)}{\beta^T \Pr(u-1, T)} \right] \right\}, \end{aligned}$$

and

$$\begin{aligned} &\sum_{t=u+1}^T \beta^t \sum_{s=u}^{\min\{t-1, S\}} [\theta_s k(s, s+1)^\alpha - C(p(s, t), k(s, s+1)) \\ &\quad - qk(s, s+1)] \Pr(s, t) \\ &\quad + \sum_{s=u-1}^{s-1} \beta^{s+1} [\theta_{s+1} k(s, s+1)^\alpha - C(p(s+1, s+1), k(s, s+1)) \\ &\quad - qk(s, s+1)] \Pr(s+1, s+1) - \phi \\ &\quad - \sum_{s=0}^{u-1} \psi \theta_s k(s, s+1)^\alpha \sum_{t=s+1}^T \beta^t \Pr(s, t) \\ &\geq \psi k(u-1, u)^\alpha \sum_{t=u}^T \sum_{s=u}^{\min\{t, S\}} \beta^t \theta_s \Pr(s, t), \end{aligned}$$

for $u = 1, \dots, S$. Let ι_u and ν_u represent the multipliers attached to the u th incentive and diagonal-node no-retention constraints, respectively. Now suppose that, after some diagonal node (t^*, t^*) , neither the incentive nor diagonal-node no-retention constraints ever bind again; that is, let (t^*, t^*) be the last diagonal node at which one or both of the incentive and no-retention constraints bind. Consider one of the incentive or no-retention constraints up to and including node (t^*, t^*) . The variable $k(s, s+1)$ will not show up on the right-hand side of any of these constraints. Examine the left-hand side. The variable $k(s, s+1)$ appears in the first line whenever $t \geq s+1$ and in the second line once. It does not appear in the third line because $s \leq u-1$. Therefore, the first-order condition for $k(s, s+1)$ is

$$\begin{aligned} &\left[1 + \sum_{j=1}^{t^*} (\iota_j + \nu_j) \right] \left\{ \sum_{t=s+1}^T \beta^t [\alpha \theta_s k(s, s+1)^{\alpha-1} - q] \Pr(s, t) \right. \\ &\quad \left. + \beta^{s+1} [\alpha \theta_{s+1} k(s, s+1)^{\alpha-1} - q] \Pr(s+1, s+1) \right\} = 0, \end{aligned}$$

for $s \geq t^*$. Recall that $p(s, t) = 0$ whenever the incentive constraint does not bind, by Lemma 2, so that $C_2(0, k(s, s + 1)) = 0$.

For the last step, divide the above first-order condition by $1 + \sum_{j=1}^{t^*} (u_j + v_j)$. It now coincides with the one for the planner's problem. Thus, investment is efficient. *Q.E.D.*

APPENDIX B: DATA

B.1. *Section 2*

The data used for real GDP and TFP are derived from Penn World Table 8. For each country, an average value for these series is calculated from 1995 on. The information variable is the FACTOR1 series presented in Bushman, Piotroski, and Smith (2004, Appendix B). Three series from the World Bank's *Doing Business* database are aggregated using factor analysis to obtain an index for the cost of enforcing contracts. The series are time (days), cost (% of claims), and procedures (number). For each country, an average of these series is taken from 2003 on. Last, the series on financial development are taken from the World Bank's *Global Financial Development* data set. The series used for "findev" is "private credit by deposit money banks and other financial institutions to GDP (%)." Here an average from 2005 on is taken. Three other series were also entered as the additional third variable in the regression: viz, firms identifying access to finance as a major constraint (%), loans requiring collateral (%), and the value of collateral needed for a loan (% of the loan amount). These series had no predictive power in the regressions (albeit they reduced the sample size) and so are omitted from the reporting.

B.2. *Table 3*

Average Establishment Size. Data for average establishment size are from different sources for each country. (i) The number for India is based on information obtained from two sources: the Annual Survey of Industries (ASI) for 2007–2008, which gathers data on formal sector manufacturing plants, and the National Sample Survey Organization (NSSO) for 2005–2006, which collects data on informal sector manufacturing establishments. (ii) The figure for Mexico is calculated using data from Mexico's 2004 Economic Census conducted by INEGI. (iii) The number for the United States is derived from figures in the 2002 Economic Census published by the U.S. Census Bureau.

B.3. *Figure 6*

A special request was made to obtain these data. Data for the United States are from the 2002 Economic Census published by the U.S. Census Bureau. They can be obtained using the U.S. Census Bureau's FactFinder.

TABLE B.I
UNITED STATES

	Raw Data		Cumulative Share	
	Estab	Empl	Estab	Empl
All establishments	350,828	14,699,536		
Establishment size				
1 to 4 employees	141,992	279,481	40.5	1.90
5 to 9	49,284	334,459	54.5	4.18
10 to 19	50,824	702,428	69.0	8.96
20 to 49	51,660	1,615,349	83.7	19.94
50 to 99	25,883	1,814,999	91.1	32.29
100 to 249	20,346	3,133,384	96.9	53.61
250 to 499	6,853	2,357,917	98.9	69.65
500 to 999	2,720	1,835,386	99.6	82.13
1,000 to 2,499	1,025	1,494,936	99.9	92.30
2,500 or more	241	1,131,197	100.0	100.00
Mean establishment size		41.9		

B.4. Figure 7

The data for India, Mexico, and the United States displayed in Figure 7 are from Hsieh and Klenow (2014). Table B.II shows the statistics used to construct Figure 7.

TABLE B.II
HSIEH AND KLENOW (2014) FACTS

Establishment Age (yr)	Employment Share		
	U.S. (2002)	Mexico (2003)	India (1994)
<5	0.137	0.280	0.282
5-9	0.110	0.235	0.224
10-14	0.115	0.173	0.155
15-19	0.092	0.100	0.089
20-24	0.074	0.077	0.067
25-29	0.072	0.039	0.043
30-34	0.072	0.035	0.036
35-39	0.049	0.019	0.018
>39	0.280	0.041	0.086

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