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in a Two-sector Model of Productive Matching
– with an Application to the Natural Resource Curse

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No 796

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF
WARWICK

Moral Hazard and Entrepreneurial Failure in a Two-sector Model of Productive Matching – with an Application to the Natural Resource Curse*,†

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This version: April 2007

Abstract

We analyze a two-sector, general-equilibrium model of productive matching and sorting, where risky production is carried out by pairs of individuals both exerting effort. Risk-neutral (entrepreneurial) individuals can match either with other risk-neutral individuals, or – acting as employers/insurers – with risk-averse (nonentrepreneurial) individuals. Although the latter option has the potential to generate more surplus, when effort is unobservable and risk is high, the moral hazard problem in mixed matches may be too severe for mixing to be attractive to both risk aversion types, leading to a segregated equilibrium in which risk-averse individuals select low-risk, low-yielding activities. An increase in the return associated with the riskier sector can then trigger a switch from a mixed to a segregated equilibrium, causing aggregate output to fall.

KEY WORDS: Entrepreneurship, Matching, Natural Resources

JEL CLASSIFICATION: C78, J41, O12, 013

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*We are grateful to Chuck Blackorby, Patrick Legros, Marcus Miller, Andrew Newman, and Herakles Polemarchakis for comments and suggestions. All errors are our own.

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1 Introduction

Does the extractive sector in a natural resource rich country drain risk-taking entrepreneurs from the rest of the economy? An affirmative answer to this question could provide an explanation for the so-called "natural resource curse"– the consistent finding in cross-country regressions that a country's share of natural resources in GDP is a strong (negative) predictor of economic performance.[1]

In this paper, we propose a new, contract-theory based explanation for this negative relationship between resource abundance and economic performance, and, more generally, for the entrepreneurial "failure" that afflicts less developed economies – beyond the specific case of natural-resource abundant countries. The essence of our argument is as follows. Absent complete insurance markets, productivity differentials across sectors depend on the intersectoral allocation of entrepreneurial risk-taking across sectors. Such allocation, in turn, depends on intersectoral risk differentials. Large risk differentials can lead to a concentration of entrepreneurial risk-taking in the riskier sectors (such as mining) and a consequent reduction in entrepreneurial risk-taking, and hence in productivity, in the rest of the economy.

To formalize this argument, we develop a two-sector model of productive matching and sorting, where risky production is carried out by teams of two individuals both exerting effort. Risk-neutral, entrepreneurial type individuals can either match with other risk-neutral individuals in symmetric contractual arrangements or with risk-averse individuals in asymmetric arrangements whereby they assume risk in exchange for an implicit insurance premium – thus acting as employers/insurers. The latter option can potentially generate extra surplus; but in a setting of high uncertainty and incomplete information about individual effort, the severity of the associated moral hazard problem might prevent this surplus from materializing. We show that if production risk is sufficiently high, risk takers will opt to undertake the risky activity with other risk takers rather than acting as employers/insurers; and, left without insurance, risk-averse indi-

[1]Gelb (1988), Sachs and Warner (1995, 1997a,b), Lane and Tornell (1996), and Gylfason, Herbertsson and Zoega (1999), among others.

viduals will select low-risk, low-yield activities. The economy will then reach a type segregated, low-output equilibrium, where individuals match assortatively with respect to risk attitudes, and where the resulting type-homogenous matches sort themselves across sectors by risk-aversion type – risk-neutral matches in the high-risk sector, risk-averse matches in the low-risk sector.

The characterization of entrepreneurs as risk-taking insurers can be traced back to Knight (1921);[2] but there has been less attention in the literature on the role of risk-taking entrepreneurs in projects that need to be carried out by teams.[3] Once we characterize entrepreneurs in this way, entrepreneurial failure can be thought of as an outcome where risk takers do not act as partners/insurers in mixed-type production teams, preferring instead to team with other risk takers in higher-yield, riskier projects, and thus leaving the other individuals with no option but to self-insure by selecting low-risk, low-yield activities.

Segregation by risk-aversion type might provide an explanation for the persistently low levels of labor productivity commonly observed in the manufacturing sectors of less developed economies. Empirical evidence shows that this observation cannot be fully accounted for by low levels of workers' human capital; Fafchamps and Soderbom (2005) suggest that inefficient management, rather than a lack of human capital, may be to blame[4] – a conjecture similar in spirit to our own argument.

Literature on the relationship between entrepreneurship and underdevelopment has traditionally emphasized the role of wealth constraints in preventing new entrepreneurial activity (e.g. Evans and Jovanovich, 1989). However, a number of recent empirical contributions have cast doubt on this interpretation:

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[2]Khilstrom and Laffont (1979) show that, in a model of general equilibrium, less risk-averse individuals become entrepreneurs and more risk-averse individuals become laborers. For a more recent statement and critique of this idea, see Newman (2007).

[3]The idea that insurance can be gainfully combined with another type of transaction in an incomplete market setting is an old one in the literature (Stiglitz, 1974) but its general-equilibrium implications have not been fully recognized.

[4]Moreover, Bigsten at al (2000) show that the increase in the schooling rates fail to result in an increase in productivity in African countries and Eicher (1985) and Seernels (1999) notice that African economy are often characterized by high levels of graduate unemployment.

Bhide (2000) shows that the start-up capital for successful projects is usually very low; and Hurst and Lusardi (2004) find that initial wealth is not significant in explaining entrepreneurial choices for low levels of income.[5] Our characterization of entrepreneurial failure does not hinge on the presence of wealth constraints; rather, in our model entrepreneurial failure can arise whenever insurance markets are incomplete and there are significant intersectoral risk differentials.

Several features of our formal analysis relate to the more recent theoretical literature on matching. Legros and Newman (2006) analyze a model of matching in which surplus is not directly transferable, and derive sufficient conditions for positive and negative assortative matching outcomes. One of the applications they explicitly consider is matching for risk sharing purposes;[6] for this case, they show that all equilibria involve nonassortative matching between individuals with different degrees of risk aversion. That result is consistent with our own findings: the presence of a hidden-action problem within heterogeneous teams limits transferability and can thus give rise to assortative matching. Two other related papers by Besley and Ghatak (2004, 2005) examine matching in the presence of moral hazard, as we do here, but do not focus on matching with respect to risk attitudes. Our analysis further adds to this literature by explicitly incorporating sorting choices into a matching problem.[7]

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[5]See also Moore (2004).

[6]See also Chiappori and Reny (2006).

[7]Our paper is also related to the broader literature on contract failures in a development context. The systemic linkages that have been stressed in this literature either revolve around individual specific linkages (e.g. Mookherjee, 1997, on the relationship between agrarian and credit contracts with respect to land sales) – or around dynamic general-equilibrium linkages that operate through asset accumulation (e.g. Banerjee and Newman, 1993; Galor and Zeira, 1993; Proto 2007). The form of systemic linkage we analyze here – the general-equilibrium effects of contractual failures with respect to the allocation of productive factors across competing production activities – has received comparatively less attention. A paper in this literature that is more closely related to ours is Banerjee and Newman (1998), which analyzes a dual-economy model where credit contracts in the traditional sector have an intrinsic informational advantage over credit contracts in the modern sector. In our analysis, as in theirs, the allocation of workers across sectors is determined by informational constraints; but in our model such constraints operate differently in different sectors because of the different degree of production

The remainder of the paper is organized as follows: Section 2 presents our main model, and derives results for the one-sector and the two-sector cases in turn; in Section 3, we look at the effects of introducing parallel insurance markets; finally, we conclude the paper in Section 4 with a discussion of how our model's results can shed light on observed manufacturing productivity patterns.

2 A Two-sector Model of Productive Matching and Sorting Under Risk

2.1 Preferences and Technology

There is an economy populated by finite numbers of individuals of two types, indexed by $i \in \{N, A\}$. The two types differ with respect to their attitudes towards consumption risk: type N is risk-neutral – the Bernoulli utility of consumption, x, for this type is given by $u_N(x) = x$ – whereas type A is risk-averse – with consumption utility $u_A(x) \in (\underline{u}, \infty)$ being continuous, strictly increasing, concave in x, and satisfying $\lim_{x\to\infty} u'(x) = 0$. Individuals of both types are endowed with an amount w of the consumption good. For simplicity, we derive our results in terms of the transformation $v(y) = u_A(w + y)$ and without loss of generality, we assume $v(0) = 0$.[8]

The economy produces a homogeneous good from inputs (labor) supplied by the individuals. We assume that production must be carried out by teams of exactly two individuals. This can be rationalized as follows: a lower bound on the number of workers in a production unit can be associated with the presence of fixed setup costs for each production unit; an upper bound is the limit case of a scenario where there are decreasing returns in the size of a team. Focusing on teams of exactly two is without loss of generality. Also, for expositional simplicity, we shall assume that the numbers of individuals of each type, respectively n_N and

risk associated with each sector, not because of intersectoral informational differentials.

[8]For any given preference ordering represented by an expected utility function with Bernoulli utility $\hat{v}(x)$, one can always define an equivalent expected utility representation with Bernoulli utility $v(x) \equiv \hat{v}(x) - \hat{v}(0)$ such that $v(0) = 0$.

n_A, are both even numbers. We furthermore assume $n_N < n_A$, i.e. risk-neutral individuals are on the short side of the labor market.[9]

There are two production sectors, indexed by $j = 1, 2$. Two alternative production technologies can be endogenously selected by teams in sector 1 – a risky, high-surplus technology and a safe, low-surplus, zero-effort technology. In sector 2 only the high-surplus, high-risk technology is available.

The safe technology (available only in sector 1) simply yields an output S with certainty and with no effort required.

Output from the risky, high-surplus technology (available in both sectors) is a function of individual effort levels, respectively e' and e'' for each of the two individuals in a team, and of individual-specific productivity shocks, respectively θ' and θ''. For a given realization of shocks (θ', θ''), output is

$$f(\theta'_j, \theta''_j) = 2r_j \min\{\theta'_j, \theta''_j\}, \tag{1}$$

where r_j is a sector-specific yield level. Individual effort is a discrete choice with values $\{0, 1\}$ and associated non-stochastic utility costs $\{0, C\}$. Effort levels, e' and e'', affect the distribution of individual-specific shocks:

$$\theta' = \begin{cases} 1 & \text{with probability } e\sqrt{\alpha_j}\,, \\ 0 & \text{otherwise,} \end{cases} \tag{2}$$

where $\alpha_j > 0$ is a sector-specific parameter that captures the degree of riskiness associated with production in a given sector. An analogous relationship exists between e'' and the distribution of θ''. The probability of experiencing a positive level of output for given levels of effort is therefore $\alpha_j(e'e'')$. Expected output in each sector under this technology and with full effort exerted by both team members ($e' = e'' = 1$) is equal to $\alpha_j r_j \equiv \rho_j$.

In our analysis we wish to focus on the effect of moral hazard on insurance opportunities within teams, abstracting from problems related to free riding. The specification we choose for the production function (1) allows us to do just that: perfectly complementarity implies that there are no free-riding incentives – under equal sharing, the efficient level of effort is also individually rational.

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[9] This is not essential to our general argument, but it simplifies exposition.

For both risk-aversion types, the risky technology is assumed to yield a higher risk-free surplus under high effort than the alternative risk-free technology does, i.e., for homogenous teams of N- and A-type individuals respectively, we assume

$$\begin{aligned} &\rho_1 - C > S; \\ &v(\rho_1) - C > v(S). \end{aligned} \tag{3}$$

Sector 2 is assumed to be a comparatively higher-risk, higher-yield sector relative to sector 1. Accordingly, we assume that $\alpha_1 > \alpha_2$ – i.e. the probability of a good outcome in sector 2 is lower for any level of effort – and that

$$\rho_1 < \rho_2, \tag{4}$$

(also implying $\rho_2 - C > S$ and $v(\rho_2) - C > v(S)$ by (4), as well as $\rho_j > S$, $j = 1, 2$.) These assumptions together imply that the high-risk technology is an efficient choice under perfect risk sharing, although, in risk-adjusted terms, it might be dominated by the risk-free technology from the point of view of the risk-averse type.

Finally, and without loss of generality, we normalize $\rho_1 = 1$.

2.2 Contracts

For the time being, we shall maintain the assumption that the only available contractual arrangements are between individuals within a production team, i.e. individuals cannot enter into parallel insurance contracts; as we shall discuss in Section 3, this is not crucial for many of our derivations, although it is central to our main argument. There are otherwise no capacity constraints in each sectors, and individuals are free to move between sectors and to select technologies. Output is observable and verifiable.

Without loss of generality, a contract for a mixed team in sector j will be represented in terms of non-negative state-contingent payments from the risk-neutral team member to the risk-averse team members, respectively equal to $\overline{L}_j \leq w + 2r_j$ if the output realization is positive, and to $\underline{L}_j \leq w$ otherwise. In order to focus only on imperfections stemming from risk aversion, we wish to abstract from the possibility of imperfect insurance deriving from wealth constraints; we therefore assume that w is large enough for the above two constraints never to be binding.

As risk-neutral individuals constitute the short side of the market, equilibria featuring mixed-type teams will involve contracts that maximize the surplus of the risk-neutral type.

If effort is fully observable and verifiable, payments can be conditioned on it. Full effort in a mixed match ($e_A = e_N = 1$, implying a probability of success equal to α_j) can then be supported by a contract that yields zero to the risk-averse individual if her effort is low and positive amounts otherwise. An optimal, individually-rational contract for the risk-neutral type must then solve

$$\max_{\overline{L}_j, \underline{L}_j} 2\rho_j - \alpha_j \overline{L}_j - (1-\alpha_j)\underline{L}_j - C, \tag{5}$$

subject to

$$\alpha_j v(\overline{L}_j) + (1-\alpha_j)v(\underline{L}_j) - C \geq \underline{U}_A, \tag{6}$$

$$2\rho_j - \alpha_j \overline{L}_j - (1-\alpha_j)\underline{L}_j - C > \rho_2 - C. \tag{7}$$

Constraint (6) is the participation (individual rationality) constraint for the risk-averse type, where $\underline{U}_A$ represents the risk-averse type's best outside option – the maximum payoff a risk-averse individual can obtain in a non-mixed contract:

$$\underline{U}_A \equiv \max\{v(S),\, \alpha_1 v(r_1) - C,\, \alpha_2 v(r_2) - C\}. \tag{8}$$

Constraint (7) is the corresponding individual rationality constraint for the risk-neutral individual.

If the shock realizations and individual effort levels are not observable, or if they are observable but not verifiable, payments cannot be conditioned on effort. The contract must then insure that a choice of high effort is optimal for the risk-averse type individual, i.e., it must also satisfy the following incentive compatibility constraint:

$$\alpha_j v(\overline{L}_j) + (1-\alpha_j)v(\underline{L}_j) - C \geq v(\underline{L}_j).[10] \tag{9}$$

We can disregard arrangements under which either e_A or e_N, or both, are zero, since they are all dominated by the above contract or by outside options for at least one individual type.

[10]The incentive compatibility constraint for the risk neutral is always trivially statisfied and is therefore omitted.

2.3 Matching Equilibria: One-sector Economy

Let us initially focus on an economy with only one sector, sector 1 (therefore omitting the subscript 1), with $\alpha r = \rho = 1$, and consider stable matching equilibria, in which no two individuals wish to abandon their respective matches to rematch with one another in a new team.

In all types of matches, the risk-averse individuals will obtain a surplus $\underline{U}_A$. Thus, the matching outcome will be dictated by the matching choices of the risk-neutral individuals.

Consider first scenarios where, for the risk-averse type, the no-insurance, risk-adjusted surplus is highest under the high-risk technology, i.e., scenarios with $\alpha v(\rho/\alpha) - C > v(S)$. Focusing on such scenarios implies the following lower bound on α: $\alpha \geq \tilde{\alpha}(\rho)$, where $\tilde{\alpha}(\rho)$ solves

$$\tilde{\alpha} v(\rho/\tilde{\alpha}) - C = v(S); \tag{10}$$

$\tilde{\alpha}(\rho)$ exists and is less than unity by (4) and by strict concavity of v.[11] Concavity of v also implies $d\left(\alpha v(\rho/\alpha)\right)/d\alpha > 0$, and thus we can conclude that the expression $\alpha_1 v(\rho_1/\alpha_1) - C$ is less than $v(S)$ for any value $\alpha < \tilde{\alpha}(\rho)$, and greater than $v(S)$ otherwise, i.e.

$$\underline{U}_A = \begin{cases} v(S) & \text{if } \alpha \in (0, \tilde{\alpha}(\rho)), \\ \alpha v(\rho/\alpha) - C & \text{if } \alpha \in [\tilde{\alpha}(\rho), 1]. \end{cases} \tag{11}$$

Finally, given that the LHS of (10) is increasing in α and in ρ, we can conclude that $d\tilde{\alpha}(\rho)/d\rho > 0$.

For scenarios where effort is fully observable, it can be readily shown that a nonsegregated outcome will also be the only possible equilibrium even when the risk-free technology offers the best outside option for the risk-averse type (i.e., for $\alpha < \tilde{\alpha}$) :

Proposition 1 *With reference to a one-sector economy with full information, a mixed-team contract satisfying individual rationality for both types always exists, and the only possible matching equilibrium is a non-segregated equilibrium with* $\overline{L} = \underline{L} < 1$.

[11] This follows from $v(1) - C > v(S)$ and $\partial\left(\alpha v(\rho/\alpha)\right)/\partial\alpha > 0$.

Proof: In scenarios where $\alpha \geq \tilde{\alpha}$, a mixed-type contract will always (weakly) dominate a segregated contract: no-insurance mixed-type contracts can never do worse for either type than a segregated contract – the parties to a mixed match can always fall back on the equal-split contract, obtaining no less than in segregated matches – and will typically yield a higher surplus to risk-neutral individuals. So, for $\alpha \geq \tilde{\alpha}$, the only possible equilibrium will be a non-segregated equilibrium. Considering next scenarios with $\alpha < \tilde{\alpha}$, concavity of v implies that surplus is maximized when payments are state-independent, i.e. for $\overline{L} = \underline{L} \equiv L$. The minimum state-independent payment level $\check{L}$ that induces participation satisfies (6) with equality, i.e. $v(\check{L}) - C = v(S)$. Since $v(1) - C > v(S)$ by (3), we can conclude that $\check{L} < 1$. The corresponding payoff for the risk-neutral type is $2\rho - \check{L} - C = 2 - \check{L} - C > 1 - C$, which is greater than the segregation payoff, $\rho - C = 1 - C$. ■

The intuition for this result is simply that full insurance, when possible, makes payoff concavity irrelevant and thus restores transferability. This is consistent with general results in the theoretical literature on matching, and with Chiappori and Reny (2006) in particular, who demonstrate that even in an environment where surplus can be transferred only indirectly because of payoff concavity, like in the present one, mixing always occurs.

In contrast, if effort is unobservable or unverifiable, the risk-neutral type cannot insure the risk-averse type efficiently (in a first-best sense), and hence may be unable, in a mixed-type contract, to secure a surplus above that which it can obtain by segregating. Then, two kinds of matching equilibria are possible: a non-segregated equilibrium such as the one described above; and a segregated equilibrium, where all risk-neutral individuals team with one another and adopt the risky, high-surplus technology (which, by (3) gives them a higher surplus than the risk-free technology) and where the risk-averse individuals team with one another and adopt the risk-free technology. We will see that which type of equilibrium prevails in this case depends on the risk characteristics of the high-surplus technology: if α is large enough (i.e. the bad outcome has low probability), there will be scope for extra surplus being obtained in mixed teams through the provision of insurance within the contractual arrangement – the risk-neutral individual insuring the risk-averse individual; but if the the risk of a bad outcome is too high, the the moral-hazard problem stemming from the non-verifiability of effort will undermine the possibility of generating surplus through insurance in mixed-type matches. The former scenario will result in a non-segregated equilibrium, while the latter will lead to type segregation.

In order to state this result formally we first need to derive conditions for the existence of an optimal incentive compatibility contract between a risk-averse and risk-neutral individual. Given assumptions (3) and (4), contracts offered by risk-neutral individuals must solve the following problem:

$$\max_{\overline{L},\underline{L}} \; 2\rho - \alpha\overline{L} - (1-\alpha)\underline{L} - C, \tag{12}$$

subject to

$$\begin{aligned} &\alpha v(\overline{L}) + (1-\alpha)v(\underline{L}) - C \geq v(S), && \alpha \leq \tilde{\alpha}, \\ &\alpha v(\overline{L}) + (1-\alpha)v(\underline{L}) - C \geq \alpha v(\rho/\alpha) - C, && \alpha > \tilde{\alpha}, \end{aligned} \tag{13}$$

$$2\rho - \alpha\overline{L} - (1-\alpha)\underline{L} - C \geq \rho - C, \tag{14}$$

$$\alpha v(\overline{L}) + (1-\alpha)v(\underline{L}) - C \geq v(\underline{L}); \tag{15}$$

where (14) and (13) are the participation constraints for the risk-neutral and the risk-averse type, and (15) is the incentive compatibility constraint for the risk-averse type.

Such a contract will only be feasible if production is not too risky:

Proposition 2 *An incentive-compatible and individually rational mixed-type contract – supporting a mixed-type matching equilibrium – exists if and only if $\alpha \geq \alpha^*$, with $\alpha^* \in (0,1)$.*

Proof: Let us begin with the case $\alpha \leq \tilde{\alpha}$. The right-hand side of (13) then equals $v(S)$, and an optimum always involves (15) and (13) both binding – a contract that leaves (15) slack could always be improved upon by another that features a lower $\overline{L}$ and a higher $\underline{L}$. This implies $\underline{L} = S$ at an optimum, and therefore

$$v(\overline{L}) = v(S) + \frac{C}{\alpha}. \tag{16}$$

Continuity of v in R^+ ensures the existence of a value of $\overline{L}$ satisfying (16) for any $\alpha \in [0, \tilde{\alpha})$, and for any combination of S and C consistent with the restrictions defined by (3). Equation (16), in turn, implies $\overline{L} > S$. We can rearrange constraint (14) as $\frac{\rho-S}{\alpha} + S - \overline{L} \geq 0$, and notice that this is equivalent to

$$v\left(\frac{\rho - S}{\alpha} + S\right) - v(\overline{L}) \geq 0. \tag{17}$$

Combining (16) and (17) and multiplying all terms by α, we obtain

$$\alpha v\left(\frac{\rho - S}{\alpha} + S\right) - C - \alpha v(S) \equiv \Omega(\alpha) \geq 0. \tag{18}$$

Given assumptions (3), we have $\Omega(1) > 0$. Moreover, using de l'Hôpital's Rule, we obtain $\lim_{\alpha\to 0} v\left(\frac{\rho-S}{\alpha} + S\right)/(1/\alpha) = v'\left(\frac{\rho-S}{\alpha} + S\right)(\rho - S) = 0$, and therefore we can conclude that $\Omega(\alpha) \leq 0$ for $\alpha \to 0$. We can also notice that $d\Omega(\alpha)/d\alpha > 0$, since we can write it as

$$\frac{d\Omega(\alpha)}{d\alpha} = \frac{v\left(\frac{\rho-S}{\alpha} + S\right) - v(S)}{\frac{\rho-S}{\alpha}} - v'\left(\frac{\rho - S}{\alpha} + S\right),$$

and since first ratio in this expression – which represents a discrete incremental ratio – is greater than the derivative $v'\left(\frac{\rho-S}{\alpha} + S\right)$, by concavity of v. By continuity, monotonicity then implies that there will exist a value α^* such that

$$\Omega(\alpha^*) = 0, \tag{19}$$

and such that $\Omega(\alpha) \geq 0$ for $\alpha \geq \alpha^*$.

Next, we show that $\tilde{\alpha} > \alpha^*$. Let $\Gamma(\alpha) \equiv v(\rho/\alpha) - C - v(S)$. The condition $\Gamma(\alpha) = 0$ – equivalent to (10) – defines $\tilde{\alpha}$, whereas $\Omega(\alpha) = 0$ defines α^*. The derivative of $\Gamma(\alpha)$ with respect to α is

$$\frac{d\Gamma}{d\alpha} = v\left(\frac{\rho}{\alpha}\right) - \frac{\rho}{\alpha}v'\left(\frac{\rho}{\alpha}\right). \tag{20}$$

For $\alpha = 1$, we have $\Gamma(\alpha) = \Omega(\alpha)$. Moreover, for $\alpha < 1$, we have $d\Gamma(\alpha)/d\alpha > d\Omega(\alpha)/d\alpha$, since $v(\rho/\alpha) > v((\rho - S)/\alpha + S) - v(S)$ and $\frac{\rho}{\alpha^2}v'(\frac{\rho}{\alpha}) < \frac{\rho-S}{\alpha^2}v'\left(\frac{\rho-S}{\alpha} + S\right)$, by concavity of v. We can then conclude that $\tilde{\alpha} > \alpha^*$, and therefore there exists a non-empty interval $[\alpha^*, \tilde{\alpha})$.

Finally, we can note that for $\alpha > \tilde{\alpha}$ an incentive-compatible, individually-rational mixed contract always exists: a no-insurance contract featuring an equal split of the output is always individually rational or both types, as it is equivalent to their respective outside options; and, in a mixed match, the risk-neutral type can do strictly better by offering the risk-averse type a contract with $\overline{L} < \rho$ and $\underline{L} > 0$. ■

Thus, private information about effort limits transferability in a more fundamental way than payoff concavity; and, as Legros and Newman (2005) show, nontransferability can give rise to type segregation. When a risk-free technology is the best outside option for the risk-averse type, an increase in risk in the risky activity does not provide opportunities for greater surplus extraction by the risk-neutral type; on the contrary, it only worsens the moral-hazard problem and makes providing insurance more difficult for the risk-neutral type. Above a certain level of risk ($\alpha < \alpha^*$), entrepreneurial type individuals will prefer not to involve the risk-averse type and will opt to match instead with other entrepreneurial type individuals in a pure-production, no-insurance relationship.

2.4 Matching Equilibria: Two-sector Economy

The introduction of a second sector in the economy enlarges the set of possible configurations of production teams in a matching/sorting equilibrium. The fact that sector 2 yields a higher return means that teams of risk-neutral individuals will always select sector 2 in a segregated equilibrium, whereas in such an equilibrium teams of risk-averse individuals will always select the risk-free technology in sector 1. A non-segregated equilibrium, on the other hand, can have mixed teams operating in sector 1 or in sector 2 depending on the configuration of the parameters ρ_1, ρ_2, α_1 and α_2.

Considering problem (5), we note that a necessary condition for the existence of a mixed contract in sector 1 is

$$\rho_2 < 2 - S, \tag{21}$$

so that the maximum surplus that can be potentially extracted by the risk-neutral type in a mixed contract in sector 1 is larger than the surplus obtainable in a segregated contract in sector 2. Under assumptions (3), (4), and (21), we obtain the following result:

Proposition 3 *There exists a combination of thresholds,* $(\alpha_1^*(\rho_2), \alpha_2^*(\rho_2))$, *with* $\alpha_2^*(\rho_2) < \alpha_1^*(\rho_2)$, *such that, for* $\alpha_j < \alpha_j^*(\rho_2), j = 1, 2$, *the only possible equilibrium is a type segregated matching equilibrium where individuals sort themselves between sectors according to their risk-aversion type – risk-neutral teams selecting sector* 2, *and risk-averse teams selecting the risk-free technology in sector* 1.

Proof: As we did earlier for the one-sector case, we can identify a value $\tilde{\alpha}_1 \in (0,1)$ such that, for $\alpha_1 < \tilde{\alpha}_1$, the risk-free technology dominates the risky technology in sector one for the risk-averse type in a segregated match; and, assuming $\alpha_1 < \tilde{\alpha}_1$, we can identify a corresponding value $\tilde{\alpha}_2 \in (0,1)$ such that, for $\alpha_2 < \tilde{\alpha}_2$, the risk-free technology also dominates the risky technology in sector 2 for the risk-averse type. Then, for $\alpha_j < \tilde{\alpha}_j, j = 1, 2$, we can, for each sector, proceed as in the proof of Proposition 2, to derive the following conditions for an incentive-compatible mixed contract in each of the two sectors to be individually rational *relative to segregation* (i.e. when separately comparing mixed contract in each sector with segregated contracts):

$$\alpha_1 v\left(\frac{2-\rho_2-S}{\alpha_1}+S\right) - C - \alpha_1 v(S) \equiv \Omega_1(\alpha_1, \rho_2) \geq 0; \tag{22}$$

$$\alpha_2 v\left(\frac{\rho_2-S}{\alpha_2}+S\right) - C - \alpha_2 v(S) \equiv \Omega_2(\alpha_2, \rho_2) \geq 0. \tag{23}$$

As in the proof of Proposition 2, we can conclude that there exist values $\alpha_1^*(\rho_2)$ and $\alpha_2^*(\rho_2)$ such that $\Omega_1(\alpha_1^*(\rho_2), \rho_2) = 0$ and $\Omega_2(\alpha_2^*(\rho_2), \rho_2) = 0$, and such that, respectively, $\Omega_1(\alpha_1^*(\rho_2), \rho_2) < 0$ for $\alpha_1 < \alpha_1^*(\rho_2)$, and $\Omega_2(\alpha_2^*(\rho_2), \rho_2) < 0$ for $\alpha_2 < \alpha_2^*(\rho_2)$, i.e. such that a type-segregated match dominates mixed contracts in either sector for the risk-neutral type. Moreover, for $\alpha_1 = \alpha_2 = \alpha$, we have $\Omega_1(\alpha, \rho_2) < \Omega_2(\alpha, \rho_2)$, since $\rho_2 - S > 2 - \rho_2 - S$. Given that $\partial\Omega_1/\partial\alpha_1 > 0$ and $\partial\Omega_2/\partial\alpha_2 > 0$, we can therefore conclude that $\alpha_2^*(\rho_2) < \alpha_1^*(\rho_2)$. ■

Let us then consider a situation where $\alpha_1 \geq \alpha_1^*(\rho_2)$ and $\alpha_2 < \alpha_2^*(\rho)$, so that mixed teams in sector 1 are chosen over segregated teams or mixed teams in sector 2. What we want to focus on here is the possibility that, starting from such a scenario, an increase in the profitability of sector 2 might trigger a switch from a non-segregated to a segregated equilibrium:

Proposition 4 *For any given level of $\rho_2 > 1$, there exist combinations $(\hat{\alpha}_1(\rho_2), \hat{\alpha}_2(\rho_2))$, for which an increase in ρ_2 can trigger a switch from a non-segregated to a segregated equilibrium in which the low-yield, risk-free technology is adopted in sector 1.*

Proof: As shown in the preceding proof, we have $\partial\Omega_j(\alpha_j, \rho_2)/\partial\alpha_j > 0, j = 1, 2$. One can also verify that $\partial\Omega_1(\alpha_1, \rho_2)/\partial\rho_2 < 0$, $\partial\Omega_2(\alpha_2, \rho_2)/\partial\rho_2 > 0$, and that $\partial\Omega_2(\alpha_2, \rho_2)/\partial\rho_2$

is bounded. Let $\hat{\alpha}_1(\rho_2) = \alpha_1^*(\rho_2) < \tilde{\alpha}_1$, and select an arbitrarily small but positive value $\hat{\alpha}_2(\rho_2) < \alpha_2^*(\rho_2)$ (as we argued earlier, $\alpha_2^*(\rho_2) \in (0, \alpha_1^*(\rho_2))$, and is continuous in ρ_2 for all $\rho_2 \in [1, 2-S]$.) Then, in an economy characterized by $\alpha_1 = \hat{\alpha}_1(\rho_2)$ and $\alpha_2 = \hat{\alpha}_2(\rho_2)$ (which support a non-segregated equilibrium), we can identify a right-hand neighborhood of ρ_2, $\mathcal{N}^+(\rho_2)$, such that, for $\rho_2' \in \mathcal{N}^+(\rho_2)$, we have $\alpha_1 < \alpha_1^*(\rho_2') < \tilde{\alpha}_1$ and $\alpha_2 < \alpha_2^*(\rho_2')$ (by boundedness of $\partial\Omega_2(\alpha_2, \rho_2)/\partial\rho_2$), giving rise to a segregated equilibrium. ■

From the above, we also obtain a clearcut prediction about the effect of such a switch on aggregate productivity:

Proposition 5 *The switch described in the previous proposition will always result in a decrease in gross labor productivity.*

Proof: This happens if and only if $2n_N + (n_A - n_N)S > n_N\rho_2 + n_AS$, which is always true given assumption (21). ■

The introduction of second, higher-yielding but riskier sector, can trigger segregation. If it does so, it also brings about a fall in aggregate output – an occurrence that can be described as a "high-yield sector curse". This happens because, by (21), the loss of output from switching from mixed matches to segregated matches in sector 1 (which equals $1 - S$) is always larger than the extra output obtained by segregated matches in sector 2 (which equals $\rho_2 - 1$).

Only economies where production in sector 1 is not too risky ($\alpha_1 \geq \alpha_1^*(1)$) can be affected by the curse – for $\alpha_1 < \alpha_1^*(1)$ segregation would occur independently of the level of yield in sector 2. However, sector 1 must be risky enough that the risk-neutral type would, if uninsured, opt to self-insure by adopting the risk-free technology ($\alpha_1 < \tilde{\alpha}_1$). Moreover, the risk differential between sectors must be sufficiently large ($\alpha_2 < \alpha_2^*(\rho_2) < \alpha_1^*(\rho_2) \leq \alpha_1$). These are economies where production risk is present everywhere but is not everywhere high, and where therefore risk-neutral individuals could take on the role of entrepreneurs/insurers in sector 1, were they not drawn to sector 2; and where sector 2 is too risky for risk-neutral individuals to take on an entrepreneurial role there.

3 Parallel Insurance Contracts

Can the presence of external insurers, not directly involved in production, offset the consequences of adverse type segregation in productive matches? We will see in this section that the answer is a qualified yes.

Suppose there exists a risk neutral agent – an "investor" – willing to insure production units (as many as it is profitable for her to do) without taking part in the production process. We will examine the effect of introducing such an investor in an environment that would feature a segregated equilibrium otherwise. Accordingly, assume $\alpha_1 < \alpha_1^*(\rho_2)$ and $\alpha_2 < \alpha_2^*(\rho_2)$. The investor can then enter into insurance contracts with teams of risk-averse individuals who would be unable to obtain insurance in mixed contracts with risk-neutral individuals and would thus opt for the risk-free, low-yield technology in sector 1.

In order to keep the argument simple, we shall assume that the investor is just as capable at observing output as individuals directly involved in production (i.e. involvement in production does not confer an information advantage). A profitable, incentive-compatible investment contract $\overline{L}_j, \underline{L}_j$, inducing risk-averse individuals to select the higher-yielding technology in sector j over the risk-free technology in sector 1, will exist if and only if

$$\alpha_j v(\overline{L}_j) + (1-\alpha_j)v(\underline{L}_j) - C \geq v(S); \tag{24}$$

$$\alpha_j v(\overline{L}_j) + (1-\alpha_j)v(\underline{L}_j) - C \geq v(\underline{L}_j); \tag{25}$$

$$\rho_j - \alpha_j \overline{L}_j - (1-\alpha_j)\underline{L}_j \geq 0; \tag{26}$$

where (24) and (25) respectively represent the participation and the incentive-compatibility constraint for the risk-averse type, and (26) is the individual rationality constraint for the investor (the contract must yield non-negative profits). We can then show that

Proposition 6 *There exist combinations* $(\breve{\alpha}_1(\rho_2), \breve{\alpha}_2(\rho_2))$*, with* $\breve{\alpha}_1(\rho_2) < \alpha_1^*(\rho_2)$ *and* $\breve{\alpha}_2(\rho_2) < \alpha_2^*(\rho_2)$*, such that the introduction of an external investor induces a switch from the low-yield, risk-free technology to the higher-yield, risky technology in sector 1.*

Proof: Let $(\overline{L}'_j, \underline{L}'_j)$ be the contract maximizing the investor's profits in sector j. We note that this contract is, for all j, the same as that which would be chosen by the risk-neutral type in a mixed match in the absence of an external investor (as described in the previous sections), since $\overline{L}_j$ and $\underline{L}_j$ enter the objective of both the investor and the risk-neutral type linearly and with the same weights. A profitable, incentive-compatible investment contract in sector 2 exists if, at an optimum, it is the case that $\rho_2 - \alpha_2\overline{L}_2' - (1-\alpha_2)\underline{L}_2' \geq 0$ (condition (26)); but since $\alpha_2 < \alpha_2^*(\rho_2)$, the incentive-compatibility constraint (15) for an optimal mixed contract in sector 2, would be violated for $j = 2$, implying $2\rho_2 - \alpha_1\overline{L}_1' - (1-\alpha_1)\underline{L}_1' - C < \rho_2 - C$, which is incompatible with (26). Therefore, if the risk-neutral type does not find mixed matches in sector 2 attractive, then the investor will also not find it profitable to insure risk-averse teams in sector 2. The situation is different for sector 1, since in this case the non-negative profit condition is $1 - \alpha_1\overline{L}_1' - (1-\alpha_1)\underline{L}_1' \geq 0$. This is not incompatible with $\alpha_1 < \alpha_1^*(\rho_2)$, which implies $2 - \alpha_1\overline{L}_1' - (1-\alpha_1)\underline{L}_1' - C < \rho_2 - C$, by (15) (recall that $\rho_2 > 1$). The investor may thus still find it profitable to insure risk-averse teams in sector 1 even when the risk-neutral type opts to segregate in sector 2. This will occur if $\alpha_2 < \alpha_2^*(\rho_2)$ and $\alpha_1^*(1) \leq \alpha_1 < \alpha_1^*(\rho_2)$ – noting that $\alpha_1^*(1)$ coincides with the value of α_1 that solves $1 - \alpha_1\overline{L}_1' - (1-\alpha_1)\underline{L}_1' = 0$. ■

Parallel insurance contracts outside the production unit suffer from the same informational problem as insurance arrangements in mixed matches. However, if risk is not too high, and therefore the moral hazard problem is not too severe, offering insurance can still be profitable for an outside investor even when a risk-neutral individual would opt to segregate. The intuition behind this is simply that, with a second higher-yielding sector, the net value of the outside option for risk-neutral type can be higher than the corresponding net value for investors.

In such scenarios ($\alpha_1^*(1) \leq \alpha_1 < \alpha_1^*(\rho_2)$) the availability of outside insurance can raise productivity in the low-risk sector, breaking the high-yield sector curse. Note that these scenarios are precisely those in which the introduction of a second, higher-yield, higher-risk sector would give rise to segregation: $\alpha_1 \geq \alpha_1^*(1)$ implies that the corresponding single-sector economy would feature mixed matches.[12] If

[12]One could argue, however, that direct involvement in production confers an informational advantage, and that therefore an outside investor would not be as effective as an entrepreneur/insurer at extracting surplus through insurance. If this case, one can show that

risk is too high in both sectors ($\alpha_1 < \alpha_1^*(1)$, i.e. when a single-sector version of the economy would still yield segregation) neither mixed matches nor parallel insurance contracts (a financial sector) can arise.

Thus, financial development can break the curse. But financial development can only occur in economies where informational problems are not too severe – i.e. in those economies that are capable of experiencing a high-yield sector curse. Economies in which production risk is excessively high and widespread are affected by a more fundamental low-productivity curse, which is independent of factor abundance and cannot be broken by financial development.

4 Discussion

Our analysis shows that the introduction of a high-yield, risky sector may result in a loss of gross productivity in the other sectors as well as in aggregate. The segregation outcome we have described can be interpreted as an "entrepreneurial drag": high-yield, high-risk activities – such as mining or, even, illegal activities – can divert risk takers from lower-risk activities in which they could take on the role of entrepreneurs/insurers vis-à-vis more risk-averse individuals. The key mechanism at work here is that a given extent of informational asymmetry within a contract has a greater or smaller adverse effect on surplus generation through insurance depending on the degree of production risk. Hence, intersectoral risk differentials can give rise to a segregated, "dual" structure even where there are no intrinsic information differentials across sectors.

As we have argued in the introduction, this mechanism could provide an explanation for the natural resource curse. The argument that has traditionally been invoked to explain this empirical regularity is that the high income generated by natural resources raises the demand for nontradeables and thus their prices, which in turn makes manufacturing sectors uncompetitive.[13] However, as noted

there would still remain scenarios where the introduction of a second sector lowers aggregate productivity even when parallel insurance contracts are available.

[13]Corden and Neary (1982), van Wijnbergen (1984), Krugman (1987), Sachs and Warner (1995), and Baland and Francois (2000).

by Sachs and Warner (2001), this "dutch disease"-type interpretation cannot directly explain why often we also correspondingly observe lower labor productivity (and wages) in the non natural resource sectors, unless we also invoke the idea that the manufacturing sector drives technological progress.[14,15] Our argument can provide an alternative, more direct explanation for the natural resource curse, one that does not hinge on the presence of technological spillovers.

Cross-country evidence on the relationship between sectoral productivity and natural resource abundance (presented in the Appendix) exhibits the following patterns: (i) the gap between non skilled wage in the manufacturing and in the extractive sector is increasing in the size of the (comparatively riskier) non-fuel extractive sector, and only so in the less developed economies; (ii) labor productivity in the manufacturing sector is inversely related to the size of the non-fuel extractive sector. Nonpecuniary compensating differentials could account for (i), but not for (ii); and, taken jointly, (i) and (ii) are inconsistent with a dutch-disease based explanation – without invoking further dynamic linkages. On the other hand, these patterns are directly compatible with a crowding-out effect consistent with our model's predictions.

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[14]On the contrary, a dutch-disease scenario involves a wage increase in all sectors.

[15]The literature has also offered alternative explanations linked to the adverse effects that the rent seeking behavior associated with natural resources can have on institutions (e.g. Collier and Hoeffler (2000), and Lane and Tornell (1996, 1999)).

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Appendix

A.1 Wage Differentials and the Size of the Mining Sector

We consider a panel of twenty-eight countries between 1969 and 2004, with several missing observations, for a total of 605 observations. The dependent variable is the ratio of wages in mining and quarrying sector (data are from ILO 2005 survey: ISIC 2, Major division 2 and ISIC 3 tabulation category C) to wages in the manufacturing sectors (ISIC 2, Major division 3 and ISIC 3 tabulation category D).[16] We focus on "production labor" (i.e. manual labor, sometimes also labeled as "unskilled labor"), in order to abstract from any intersectorial heterogeneity in the skill composition of labor. The variables that refer to natural resources are the share of fuel, FEX, and non-fuel, OME, mineral exports in total exports (World Bank, World Development Indicators 2005).

From Table 1, first regression, we can notice that only OME is statistically significant, while FEX does not seem to have any significant impact on the gap. This is consistent with our predictions, since non-fuel extraction is a comparatively riskier activity relative to oil extraction, which is also less labor intensive. In regression 2 we include per capita GDP (WDI, 2005). We would expect that any misallocation problems associated with inefficient segregation should be mitigated by the presence of developed financial markets; and we would expect financial market development to be positively related to per capita GDP. As expected, the new variable has a negative and highly significant impact, and the coefficient for OME becomes substantially smaller, although it remains significant at the ten percent level.

A.2 Manufacturing Productivity and the Size of the Mining Sector

We consider a panel of thirty countries between 1980 and 2003, for a total of 595 observations. The dependent variable is labor productivity in manufacturing, calculated in terms of gross production over total employees (ILO labor statistics database, 2005). As in the preceding regressions, the variables for natural resources are the shares of fuel, FEX, and non fuel, OME, mineral exports in total exports. We include per capita GDP in the regression to control for technology differentials.

The coefficient for OME is negative and highly significant, which seems to suggest that the presence of non-fuel natural resources has an adverse impact on manufacturing productivity. Interestingly, the coefficient for FEX is positive and significant, suggesting again a difference between oil extraction and riskier, more labor-intensive natural resource sectors.

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[16]The definition of mining and quarrying includes fuel and non-fuel mineral extraction.

Table 1: Intersectoral Wage Gap

	1	2
Years	1969-2004	1969-2004
Non-fuel resource extraction	.012	.008
	(.00435)***	(.00456)*
Fuel resource extraction	.001	.0008
	(.00117)	(.0011)
GDP		-.0000147
		(4.84e-06)***
Country fixed effects	YES	YES
Year fixed effects	YES	YES
No. of observations	612	605
No. of countries	29	28
R^2	.0740	.2564
F test	38.32***	38.59***

Absolute value of Z statistics in parentheses.

*Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 2: Manufacturing Productivity

Years	1980-2003
Non-fuel resource extraction	-1064
	(357)***
Fuel resource extraction	92.755
	(38.79)**
GDP	2.18
	(.1568)***
Country fixed effects	YES
Year fixed effects	YES
No. of observations	595
No. of countries	30
R^2	.534
F test	44.24***

Absolute value of Z statistics in parentheses.

*Significant at 10% level; ** significant at 5% level; *** significant at 1% level.