Cross-sectional Profitability of Namibian Formal Small-scale Mining Firms in 1990

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ABSTRACT. Namibia considers formal small-scale mining firms (FSSMFs) as an important part of the solution to the problems of high unemployment, poverty, and the diminishing role of large-scale mining firms facing the country. However, to be a solution FSSMFs must be profitable first. This paper examines and presents simple estimates and tests of the probability of 25 Namibian SSMFs being profitable. The results suggest that in terms of productivity, specialization, size and structure, small is not as beautiful as generally presented. The findings recommend capital formation and competitive diversification of production and products.

Introduction

Over the years industrialized countries (ICs) have upheld small-scale mining firms for their importance to national security and economic well-being (Fitzroy, 1989; Rothwell, 1985; Sato, 1989; Voutilainen and Diehl, 1983). Policies favoring small-scale mining firms became especially popular with increased concerns over rising unemployment and the concentration of mining activities and mining properties in the hands of a few larger firms. High concentration of mining activities and properties was understood to reduce competition and to lead to suboptimal product pricing and factor allocation with further implications for income and wealth distribution. Moreover, larger mining firms were viewed as ill-equipped to operate small, complex, and low volume ore deposits. Therefore, given small but high ore grade deposits, small-scale mining firms (SSMFs) were "just what the doctor ordered".

Incidently the call for smallness in the ICs also suited the aspirations of developing countries (DCs) yearning for freedom from apparent exploitation by large multinational corporations. Not surprisingly the United Nations Department of Economic and Social Affairs (UNDESA) reports, *Small-Scale Mining in Developing Countries* (1972) and *Small-Scale Mining Prospects in Developing Countries* (1988), were received by the DCs with great enthusiasm as blueprints for the promotion of small-scale mining.[1] The high energy costs of the 1970s, and the recessions that followed, further cemented the negative attitudes towards capital (K)-intensive large-scale mining *vis-à-vis* labor (L)-intensive small-scale mining. Under these circumstances "small" was considered both "necessary" and "beautiful" (Voutilain and Diehl, 1983; Yascir, 1988).[2]

Despite the research lead taken in the ICs (Acs and Audretsch, 1990; Bethlehem, 1979; Storey, 1992; Variyam and Kraybill, 1993), however, policy-makers in the DCs have maintained that SSMFs could contribute to the economic growth of developing countries without regard for problems facing these firms (Helmsing and Koltsee, 1993; Alpan, 1986; Hollaway, 1991; Davidson, 1993; Anderson, 1982; World Bank, 1992a, b; Taubunan, 1992). With the exception of a global overview given by Ghose (1994), for example, little has been done to measure the performance – profitability – of SSMFs in the DCs. But clearly in order to play a significant role in the economic performance of DCs, SSMFs have to be profitable first, a task complicated by the limited data availability, and associated aggrega-

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tion and mismeasurement problems. Available data sources are normally descriptive, and in the present case only sales (price times quantity) are handy. The wage data as outlined in Pekkela and Ruotsi (1991) and the World Bank (1992a) are questionable and may not reflect production costs sufficiently. Capital costs, and indeed capital itself, are almost never published. Measurement difficulties in relation to inputs arise because of the nature of small firms. Often a miner is the laborer, the entrepreneur, and the capitalist. The shovel used to till land in the morning is used later in the day to dig for gold or whatever the case might be (Amavilah, 1996). Thus, without production cost data there is no usual way of estimating profit for these firms. Measurement problems clearly arise from available data, while their paucity makes the binary qualitative response methodology employed in this analysis appropriate.

This paper examines and presents the results of two simple qualitative models used to estimate and test the probability of cross-sectional profitability of 25 Namibian formal SSMFs (FSSMFs) in 1990 given the limited data available. The discussion is organized in five sections. Section 1 briefly describes the structure and activities of formal SSMFs in Namibia, and provides a general definition of such firms. Section 2 states the problem. The methodology is the subject of the third section, followed by Section 4, which presents and discusses the results, and by the conclusions in the final section.

1. Namibia's small-scale industry

The Namibian mining industry divides by scale into approximately three firm groups. Depending on what is used to define scale, there are five to seven large scale mining firms, three to five medium scale mining firms, 30 formal small scale mining firms (FSSMFs), and over 1200 informal small scale mining firms. These firms produce between 40–60 types of minerals (Hangala, 1990; Galloway, 1990).

Figure 1 summarizes the basic activity data on annual production, employment, and gross revenue for 1990. From this figure it is clear that larger (large and medium) firms account for 74.0% of production, 86.7% of employment, and 88.0% of gross revenue. FSSMFs are responsible for 13.5% of production, about 7% of employment, and more than 1.5% of annual gross revenue. The discrepancy is often assigned to informal small-scale firms. Since only FSSMFs' information is known with some limited degree of accuracy, this paper examines the cross-sectional profitability of this group of firms in Namibia.

1.1. *What is an FSSMF?*

An FSSMF is defined as a firm characterized by any one of the following criteria:

- Maximum number of employees is 100;
- Concession size is less than 100 hectares;
- Reserve size is 1×10^6 m^3 or less;

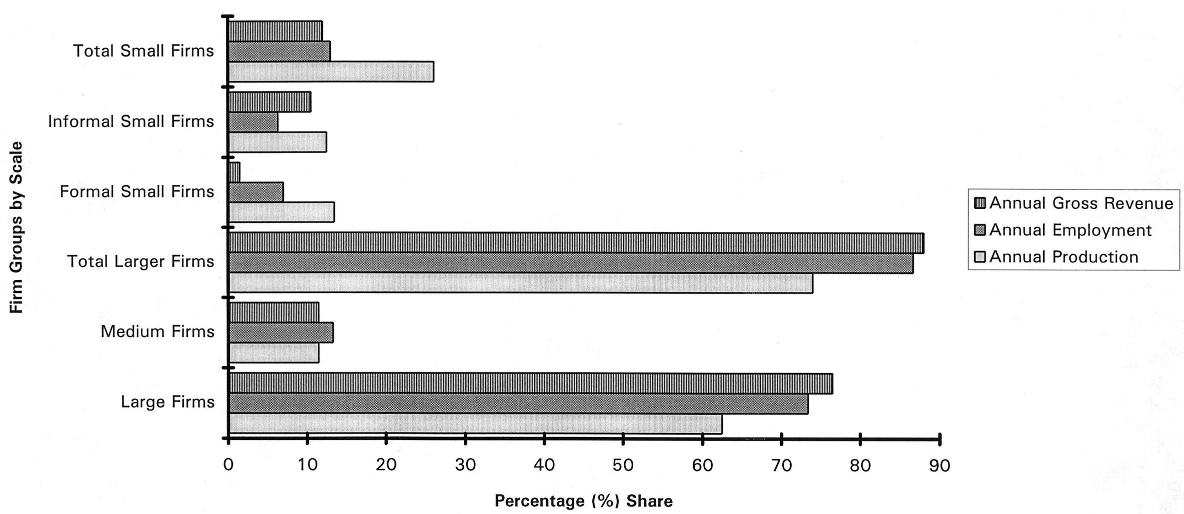

Fig. 1. The basic structure of the mining industry in Namibia, 1990.

- Production capacity is less than 100 MT/day;
- Daily labor productivity is no greater than 50 MT/person;
- Annual gross revenue is less than or equal to US$1,000,000;
- Degree of capitalization and mechanization is less than US$200,000; and
- Maximum annual production is 50,000 MT or less.

This analysis accepts these general criteria. However, while indicative, these criteria are less definitive. For example, in Namibia's case, Pekkala and Ruotsi (1991) argue that the employment criterion alone defines a Namibian FSSMF. Many Namibian FSSMFs appear as well described by other criteria as they are by the employment criterion. In fact Pekkala and Ruotsi's (1991) own data (Appendix 3:4) offer a good example of the low degree of capitalization and mechanization for a typical FSSMF in Namibia.

1.2. *Activities of FSSMFs in Namibia*

Pekkala and Ruotsi (1991), the World Bank (1992), and Amavilah (1996) give further details about the activities of FSSMFs in Namibia. Table I exhibits a cross-section of formal SSMFs for 1990. The aggregate annual activity is valued at N$25.0 million. Within that activity diamond FSSMFs account for N$7.00 million representing 1.2% of total annual diamond production in the country. Excluding the four diamond and three metallics FSSMFs, the remaining 23 non-metallics FSSMFs generate more than half of gross revenue and employment. What is important to note here is that non-metallics dominate the small scale activity in Namibia, about as much as in the large scale activity if only diamonds are considered (Schneider, 1993).

2. Problem

The potential role of FSSMFs in Namibia is popularly and frequently alleged. Yet, little is understood about the profitability of these firms. Given limited information on wages, revenues, production, and employment, what is the probability of 25 Namibian FSSMFs being profitable? This is the research problem.

The problem is important for three main reasons. First, to contribute to the economy requires that FSSMFs be profitable. Second, since the 1980s large-scale mining firms in Namibia have faced rising production costs due to reserve depletion, falling ore grades, and poor mineral market conditions. Poor performance by larger firms has meant a reduced role for mining in the economy. Third, as in other developing countries, larger mining firms are often criticized for being foreign-owned K-intensive enclaves which use too few local inputs, leading to the outflow of income in the form of factor and dividend payments abroad (Curry and Stoneman, 1993; Hermann and Silfverstolpe, 1993). All these issues have engendered an interest in FSSMFs as potential players. Yet only *three* studies (Collet, 1980; Pekkala and Ruotsi, 1991; De Waal and Galloway, 1993), and

TABLE I
Activities of formal SSMFs in Namibia, 1990

Activity	Number of firms	Annual production	Number of workers	Annual revenue, N$1 × 10^6
Diamonds	4	9607 CT	101	7.200
Semi-precious stones	11	2593 MT	184	2.235
Industrial minerals	4	16417 MT	203	7.785
Industrial rocks	8	20251 MT	195	6.864
Nonmetallics	*27*	*9607CT + 39261 MT*	*683*	*24.084*
Copper	1	80 MT	13	0.001
Tin	1	100 MT	17	0.389
Gold+Silver	1	0.002 MT	27	0.042
Metallics	*3*	*180.002 MT*	*57*	*0.432*
Total	30	9607 CT + 39441.002 MT	740	24.516

two commentaries (Van Schalwyk, 1993; Tjihuiko, 1992/93) so far have focused on FSSMFs in Namibia, and *none* have considered profitability.

3. Methodology

Clearly the standard microeconomic examination in which individual firms are units of analysis is the appropriate approach to the stated problem. Just as clearly, when data is limited, qualitative response models have proven useful as alternative tools for advancing understanding of the profitability of FSSMFs and for modeling policies that are empirically relevant to the behavior of FSSMFs. In this analysis logit and probit (normit) models are used to estimate and test by the maximum likelihood functional approach the probability of 25 Namibian FSSMFs being profitable.

3.1. *Models*

Assume that each Namibian FSSMF is faced with a discrete choice of either being profitable or unprofitable. Let π_{it} be a dichotomous dependent variable taking on a value of one ($\pi_{it} = 1$), if the ith firm is profitable in time t, and a value of zero ($\pi_{it} = 0$), if otherwise, given the explanatory variables (X_{it}) in Table II.1, and variable definitions and restrictions summarized in Table II.2 below. Further assume that the ith firm's profitability is distributed as either a logistic curve or a normal function. If logistically distributed, then the logit model can be specified as,

$$\begin{aligned}\text{Prob}(\pi_{it} = 1) &= \frac{e^{X_{it}\beta_i}}{1 + e^{X_{it}\beta_i}} = [1 + e^{-\beta_i X_{it}}]^{-1} \\ &= \Theta(X_{it}\beta_i) + \mu_{it} \qquad (1)\end{aligned}$$

TABLE II.1
Basic data for small-scale mining firms in Namibia, 1990

Firm[a]	π_{it}	q_{it}	L_{it}	R_{it}	ρ_{it}	κ_{it}	D_{it}	σ_{it}	η_{it}
NW	1	3792	45	5323	84.3	0.67	0	0	0
TDM	1	5814	20	1715	290	0.56	0	0	0
SPM	0	1	15	0.5	0.1	0.08	0	1	0
ONG	0	80	13	25	6.2	0.05	1	1	0
CHT	1	10	17	389	5.9	0.35	1	1	0
OTJ	1	351	42	886	8.3	0.06	2	1	0
USM	0	0.7	6	195	0.1	0.11	2	1	0
PLV	0	45	14	33	3.2	0.20	2	1	0
DM	1	27	13	179	2.1	0.21	2	1	0
OKH	1	35	10	108	3.5	0.21	2	1	0
BR	1	309	10	240	30.9	1.07	3	1	0
MCB	0	160	10	90	11.0	0.58	3	1	0
SIN	0	35	5	5	7.0	0.33	3	1	0
ROS	0	1552	11	7	14.0	3.40	3	0	0
YTZ	1	72	25	425	2.9	0.15	3	1	1
OM	0	8.3	5	16	1.7	0.18	4	1	1
SG	0	5632	5	236	1127	–2.2	4	1	1
RUB	1	1272	106	700	12.0	0.32	4	0	1
BRG	1	3366	41	636	82.1	0.93	4	0	1
KM	1	2098	59	2401	35.6	0.61	4	0	1
AM	1	1972	28	442	70.4	0.36	4	0	1
AG	1	3659	54	1405	87.1	0.72	4	0	1
PAL	1	8896	21	1980	423	0.96	4	0	1
SC	0	1183	71	4672	1600	11.0	4	0	1
SS	0	3871	21	2177	1844	2.37	4	0	1

[a] Full company names for this and subsequent tables are given in the appendix.
π_{it} = proxy for profitability, q_{it} = quantity produced in metric tons, L_{it} = number of workers employed, R_{it} = annual gross revenue in Namibia dollars, ρ_{it} = apparent labor productivity = quantity produced in metric tons (MT) per worker, k_{it} = relative production cost per metric ton produced, D_{it}, σ_{it}, η_{it} are sectoral dummies, firm type, firm size, and structure respectively, i = ith firm, t = 1990. See also Table II.2 next.

Similarly, the probit model, can be stated as,

$$\text{Prob}(\pi_{it} = 1) = \int_{-\infty}^{X_{it}\beta_i} \phi(t)\text{d}t$$
$$= \Phi(X_{it}\beta_i) + \mu_{it} \qquad (2)$$

where $\Theta(.)$ and $\phi(t)$ are logistic and normal density functions respectively. Eqs.(1) and (2) can be estimated as the following general "regression" model:

$$I_{it} = F_{\Psi}(R_{it}, \rho_{it}, \kappa_{it}, D_{it}, \sigma_{it}, \eta_{it}, Z_{it}) + \mu_{it} \qquad (3)$$

where $I_{it} = \log(\text{Prob}(\pi_{it})/\text{Prob}(1 - \pi_{it}))$ is the dependent variable, Ψ is either Θ (for logit) or Φ (for probit), both chosen such that $0 < F(X_{it}\beta_i) < 1$, X_{it} are explanatory variables, β_i are unknown parameters to be estimated, and $\mu_{it} \sim \text{IN}(0, \sigma^2)$ are independently and normally distributed random disturbance terms.

A maximum likelihood (ML) estimation method is then applied to (3). Full discussions of the theory and applications of the ML estimation method to logit and probit models are in Finney (1971), Christensen (1990), Cramer (1991), Gujarati (1995), Greene (1990), Fry et. al. (1993), Pindyck and Rubinfeld (1990), Davidson and Mackinnon (1993), Parikh and Bailey (1990), van der Linden and Humbleton (1997), and Manski and McFadden (1981).

The estimated coefficients of (3) measure the impacts of unit changes in X_{it} on the log of the odds in favor of the *i*th firm(s) being profitable, i.e., $\log(\text{Prob}(\pi_{it})/\text{Prob}(1 - \pi_{it}))$. The associated probabilities, and hence the marginal effects of changes in explanatory variables on the probability of being profitable or unprofitable can be recovered as antilogs of the estimated varying coefficients of (3), β_i^*, i.e.,

$$\frac{\partial E(\text{Prob}(\pi_{it} = 1))}{\partial X_{it}} = \Theta^*[(X_{it}\beta_i)(1 - \Theta)X_{it}\beta_i]\beta_i^*$$
$$\Rightarrow \text{Logit Model} \qquad (4)$$

and

$$\frac{\partial E(\text{Prob}(\pi_{it} = 1))}{\partial X_{it}} = \Phi^*(X_{it}\beta_i)\beta_i^*$$
$$\Rightarrow \text{Probit Model} \qquad (5)$$

where $\Theta^*(.)$ and $\Phi^*(.)$ are estimated antilogs and β_i^*'s are estimated log of odds coefficients from (3). Eqs. (4) and (5) show the marginal effects of changes in X_{it} on the probability of a firm being profitable.

TABLE II.2
Variables and definitions

Variables	Symbols	Conditions
Dependent	π_{it} =	0 if R > N$100K, N$5/MT, L>10 1 if otherwise
Independent	X_{it} =	Exogeneous
• Gross sales	R_{it} =	Million N$ or Rands
• L-productivity	ρ_{it} =	Output/worker/year
• Labour costs	ω_{it} =	Wage/worker/year
• Capital costs	γ_{it} =	1 if ri ≤ 150 2 if otherwise
• Operation dummies	D_{it} =	0 if diamond firm 1 if base metal firm 2 if precious stone firm 3 if semi-precious stone 4 if industrial rock firm
• Firm size	σ_{it} =	1 if L > 50, *q* > 1000MT/year, R > N$200K 0 if otherwise
• Structure of sector	η_{it} =	0 if less than 5 firms 1 if more than 5 firms

Note: In 1990 one Namibia Dollar (N$) = one South African Rand = US$0.3601 in 1990. *q* = production in metric tons (MT), and *L* = labour units.

3.2. *Explanatory variables*

In concept the profitability of a firm is determined by an array of factors such as the nature of production and products, the effectiveness of management, the size of the market, the phase of the business cycle, and so on. The data for these determinants are usually not available in DCs including the present case. Following below and in Table II.1 are some useful proxies for which "stylized facts" and data are available:

• *Gross sales* (log R_{it})
Since a firm's profit is the difference between gross revenue and total cost, revenue is one of the determinants of profitability. An inference that one can make is that for FSSMFs to have positive effects on the economy the relationship between revenue and profitability must be a positive one, implying strictly greater revenue than cost. This seemingly trivial tautology is useful because

beyond short-run factor costs, long-run government tax revenue, investment and savings profiles, foreign exchange earnings, and indeed employment and wages all require a positive (sustainable) revenue stream. Because revenue is by definition a product of output and price, output prices and quantities must be excluded from (3) in order to avoid double accounting (misspecification error).

- *Labor productivity* (ρ_{it})

Labor productivity, defined as annual metric tons (MT)[3] per year per worker, is another relevant explanatory variable. It is generally argued that one of the advantages of FSSMFs is that they are L-intensive. If so, then one would expect a strong and positive correlation between L-productivity and profitability. Such a correlation, however, obtains only if output prices and factor costs are unchanged, or if an increase in factor costs or a decrease in output prices are more than offset by an increase in output, *ceteris paribus*. Thus, even though a positive correlation between L-productivity and profitability can be defended on theoretical grounds, empirically it cannot be ascertained *a priori*.

- *Relative production costs* (κ_{it})

Relative production costs (κ_{it}), defined as the ratio of total capital costs, including materials and energy (γ_{it}), to total labor costs (ω_{it}), influence firm profitability. However, the influence assumes technical efficiency such that ρ_{it} = K-productivity, and ρ_{it} is a function of the K/L-ratio.[4] The assertion that FSSMFs are L-intensive can then be interpreted as meaning low K/L-ratios. This raises an important question about whether K is scarce, or the production technology is such that certain activities can only be performed efficiently with relatively more labor than capital. For mining in developing countries K-scarcity is more likely than not. Likewise, K is likely to be more productive than L (Cortes, 1987; Notstaller, 1987; World Bank, 1992a, b). Therefore, the average product of labor will depend on the K/L-ratio and a negative relation between profitability and relative factor costs can be expected.

In the absence of data, total capital costs (γ_{it}) were set equal to a value of one wherever $\rho_{it} \leq 150$ MT per year per worker, and to a value of two if otherwise (see Table II.2). The ratio of capital cost dummies (γ_{it}) to the log of labor costs then becomes the relative factor cost index (κ_{it}) to be employed in this analysis, i.e., $\kappa_{it} = \gamma_{it}/\log \omega_{it} = 1/\log \omega_{it}$ for $\rho_{it} \leq 150$ MT and $\kappa_{it} = \gamma_{it}/\log \omega_{it} = 2/\log \omega_{it}$ for $\rho_{it} > 150$ MT.

- *Subsectoral dummies* (D_{it})

Obviously FSSMFs do not all produce a homogeneous product. In the present case-study there are five broad subsectors: diamonds, base and precious metals, semi-precious stones, and other industrial minerals and rocks (marble, granite, lithium minerals, and salt). The subsectors are designated by dummy values of 0, 1, 2, 3, and 4 as expressed in Table II.2. This distinction is important since some subsectors may be more profitable than others, even under qualitatively similar market conditions, simply because of the type of mineral they produce. Even so, economic theory offers no *a priori* guidance as to the arithmetic signs of sectoral membership. In the presence of a clear comparative advantage one would expect specialization to lead to increased productivity, but it is an empirical question whether or not specialization improves firm profitability.

- *Firm size* (σ_{it})

The relationship between firm size and profitability is well-documented (Knight, 1921; Hall and Weiss, 1967; Ballantine, Cleveland and Koeller, 1993). What remains controversial is the nature and statistical significance of the size-profitability relation. This controversy has produced two opposing conclusions. On the one hand, under competitive assumptions the profit levels apparently tend to be higher for smaller firms than for larger firms. Hence, a lognormal association between size and profitability is often postulated, although there are counter arguments (Anderson, 1982; Storey, 1992). On the other hand, the so-called Gibrat's Law suggests that only cumulative size effects are meaningful to profitability, i.e., firm size and profitability are independent of each other (Bethlehem, 1979).

In general discussions FSSMFs are usually grouped together and compared to larger firms with little regard to their heterogeneous sizes. This assumption of size homogeneity is unrealistic and is relaxed here by dividing the 25 Namibian

FSSMFs covered in this analysis into two sizes, and assigning values of zero and one on the basis of employment, production, and revenue as shown in Table II.2. This provides a testable hypothesis for the maintained lognormal profit-size distribution, since a positive coefficient of σ_{it} would imply that the smallest of FSSMFs dominate the small-scale mining industry.

- *Subsectoral structure* (η_{it})

The number of firms in each sub-sector is an important underlying assumption of competition to the degree to which it defines the structure of an industry within which production occurs. That is structure influences behavior which affects performance (profitability). To proxy this behavior a value of zero was assigned if a sector consists of less than five firms and one if otherwise. Expectations are for profitability to decrease with the increased number of firms (entry). One would like to use conventional concentration ratios such as the Herfindahl ratio to measure structure. However, doing so in this instance risks severe multicollinearity, because a Herfindahl concentration ratio is highly correlated with a revenue variable.

- *Other variables* (Z_{it})

For mining operations geological and technical factors are also important determinants of profitability. Both factor costs and output prices influence and are influenced by the geological characteristics of ore deposits (mines), such as ore grade and tonnage (Harris, 1984). For example, mining and mineral processing technologies affect production costs and recovery rates, as do discount rates, risks and uncertainties, the prices of competing products, by-products or co-products, regulations and taxes. Where production is for export, world market factors, e.g., exchange rates, transport costs, trade barriers, and so on are crucial to profit determination.

Conversely, the average ore grade (g^*) and raw tonnage (T) affect product costs (C). For a given tonnage mined, the higher the grade, other parameters being equal, the lower production costs (at least recovery costs) are likely to be. Furthermore, mine life (n) and cut-off grade (q') are interrelated, as investment decisions based on profitability are simultaneously determined by considering geotechnical factors (n, T, q', g^*) via variations in production costs (Harris, op. cit.). Thus, $C = C(g^*, T)$, $T = T(g^*)$, output (y) = $y(T, g^*)$, $n = n(T, y)$, and $g^* = g^*(q')$, all evaluated at some critical rates of discount (i), recovery (r), and for systems open to foreign trade, of exchange (e). Since T, g^*, n, q, and C can be linked to q', it is the case that $\pi = [Py(q') - Cy(q')] * (1 + i)^{-n}$. Unfortunately, while geotechnical factors influence firm profitability, lack of data does not permit the inclusion of these variables in this estimation; their effects must be understood to be contained in the random error term.

3.3. *FSSMFs versus larger mining firms*

Prima facie comparison of the data about FSSMFs in Tables I and II.1 to those for larger firms in Table II.3 below shows that small-scale mining firms appear to be more productive than large-scale ones. But further analysis reveals that all the difference in labor productivity is attributable to quantity contributions of the salt and dimension stone firms. This observation is implicit also from the fact that only in diamond mining does gross mining revenue exceed one million Namibia dollars. Excluding rock (salt, marble and granite) and stone (dimension) producing firms, labor productivity tends to be higher in large-scale than in small-scale firms. This has direct implications for factor costs. For example, using 150 MT/worker as the cut-off between low and high productivity firms, all larger firms turn out to have relatively low factor costs since $\kappa_{it} = 1/\log \omega_{it}$. It costs a large-scale diamond firm only 11.1 cents to produce one carat of diamond, for instance. The corresponding unit cost for a small-scale firm is 67 cents. There is thus a world of difference between large and small mining firms in terms of both productivity and cost. But that is trivially obvious. What interests this analysis is what the quantitative effects of this world of difference are to profitability in the case of small-scale mining firms in Namibia.

4. Implications of the results

The results of (1) and (2) or (3) are presented in Table III.1 and Table III.2. The left-hand side (LHS) of each column refers to the estimated logit

TABLE II.3
Basic data for large-scale mining firms in Namibia, 1990[a]

	$q_{it} \times 1000$	$L_{it} \times 1000$	$R_{it} \times$ million	$q_{it}/L_{it} = \rho_{it}$	κ_{it} =1/log ω_i
Large					
CDM	757.6 CT	6.33	668.3	119.1	0.100
ROSS	3.3 MT	2.26	400.0	1.5	0.097
TCL	43.4 MT	2.39	333.4	18.2	0.104
KOM	33.5 MT	0.64	308.8	52.3	0.104
OTJ	34.2 MT	0.63	315.3	54.3	0.102
Medium					
ROP	9.5 MT	0.47	125.6	20.2	0.141
UIS	1.3 MT	0.42	12.3	3.1	0.121
NAV	1.4 KG	0.31	43.5	4.5	0.119
OK	27.1 MT	0.14	–	193.6	0.112
NAML	8.1 MT	0.13	9.5	62.3	0.113
Total	753.6 CT + 1.4 KG + 160.4 MT	13.70	1592.6	52.9	0.111

[a] For their full names and what these companies produce, see Appendix.

model and the right-hand side (RHS) to the estimated probit model. This LHS-RHS listing applies to the summary statistics at the bottom of each table. From Table III.1 an increase of N$1000.00 in gross revenue (R_{it}) induces a corresponding rise in the log of the odds favoring FSSMFs profitability of 1.7 (logit) and 1.0 (probit). The log of the odds of being profitable goes up by approximately the same amount following a change in gross revenue even when only revenue, L-productivity, and relative production costs are considered as Table III.2 illustrates. Varying ρ_{it} by a unit reduces the log of the odds favoring profitability by –0.36 (–0.48) and –0.17 (–0.24) for the logit and probit models, respectively.[5] The implication is that policy incentives which promote L-intensive FSSMFs without improving ρ_{it} may be counter productive for the profitability of these firms. More importantly it also raises serious questions about the alleged positive effects of small-scale firms on economic development. The main reason is that since ρ_{it} depends upon K/L ratios, it is questionable if ρ_{it} can be enhanced in the absence of capital formation, which partly explains high labor productivity in K-intensive larger firms. To the extent that K-productivity > ρ_{it}, it is the case that for FSSMFs K-scarcity restricts profitability more severely than labor abundance, and under high unemployment conditions represents a setback on job creating opportunities. That is, the long-run efficiency cost of an L-intensive strategy for FSSMFs, holding K constant,is a decline in L employment opportunities, wages, or both.

It is found that in general it does not matter in what subsector an FSSMF is involved. Each additional step taken toward complete specialization (D_{it}) reduces the log of the odds favoring the profitability of any small-scale firm that behaves *logistically* by –0.31, and *normally* by –0.24. In other words, specialization is negatively related to the profitability of FSSMFs in Namibia. The implied strategy is competitive diversification. Empirical evidence also shows that the log of the odds favoring profitability tends to fall by –1.3 as a small-scale firm up-scales.[6] The implication is that small tends to remain small.

Finally, the log of the odds favoring profitability is lowered by competition. This is an expected result. As more firms enter the production of the same commodity, assuming equal market access, technology, and identical cost structures, increased competition tends to lower the profitability of the average FSSMF in Namibia. In the full model version (Table III.1) the subsectoral structure, firm size, and factor costs are the major constraints on small-scale firm profitability, while factor costs and low labor-productivity are the obstacles in the short model version (Table III.2). In either case gross sales

TABLE III.1
Logit (LHS) and probit (RHS) regression results for FSSMFs in Namibia, 1990

Variables	Coefficient		Asymptotic std. error		T-ratios		Weighted aggregate elasticity[a]	
log R_i	1.7452	0.9850	0.9893	0.5474	1.7641	1.774	1.7332	1.7250
log ρ_i	–0.3552	–0.1662	0.4079	0.2007	–0.8708	–0.8279	–0.2017	–0.1583
κ_i	–0.9338	–0.5208	0.8622	0.4806	–1.0831	–0.0837	–0.0691	–0.0626
D_i	–0.3066	–0.2432	1.4237	0.8138	–0.2153	–0.2989	–0.1625	–0.2241
σ_i	–1.7437	–0.8672	2.8858	1.6996	–0.6042	–0.5102	–0.1541	–0.1317
η_i	–2.1042	–1.2484	2.6030	1.5692	–0.8084	–0.7956	–0.2516	–0.2666
Constant	–4.6535	–2.5643	6.5486	3.7829	–0.7106	–0.6779	–0.8171	–0.7955

[a] Sum of mean elasticities weighted by probabilities, for reference see e.g. Kenneth J. White et al., Shazam: Econometrics Computer Program,User's Reference Manual, Version 6.2, McGraw-Hill Book Company, New York, 1990, Chapter 21, pp. 137–140.

Sample size	25.0	25.0
Log-likelihood function	–7.7425	–7.7398
Likelihood ratio test	18.812 (6 df)	18.817 (6 df)
Adjusted McFadden R^2	0.398	0.3982
McFadden F	1.417 (6.7df)	1.418 (6.7 df)
Number of correct predictions	22.0	21.0
Percentage of correct predictions	88.0	84.0
Sum of squared residuals	2.3722	2.5064
Weighted sum of residuals	20.066	16.300
Normalized success index	0.608	0.597
Mean dependent variable	0.560	0.555
Std. deviation	0.3927	0.3928
Variance	0.1543	0.1543
Interval (Min)	0.0007	0.00002
Interval (Max)	0.9999	1.00000

TABLE III.2
Logit (LHS) and probit (RHS) regression results for FSSMFs in Namibia, 1990

Variables	Coefficient		Asymptotic std. error		T-ratio		Weighted aggregate elasticities	
log R_i	1.7583	1.0162	0.7380	0.4010	2.3759	2.5341	1.8817	1.9387
log ρ_i	–0.48115	–0.2351	0.3363	0.1541	–1.4316	–1.5262	–1.3169	–1.2604
κ_i	–0.6088	–0.3683	0.4113	0.2249	–1.4801	–1.6377	–0.0669	–0.0725
Constant	–7.6014	–4.5689	3.5686	2.0633	–2.1301	–2.2144	–1.408	–1.4971

Sample size	25.0	25.0
Log-likelihood function	–8.2759	–8.2595
Likelihood ratio test	17.745(3 df)	17.778(3 df)
Adjusted McFadden R^2	0.449	0.4495
McFadden F-distribution	1.4294(3,4df)	1.4349 (3,4df)
Number of correct predictions	21.0	20.0
Percentage of correct predictions	84.0	80.0
Sum of squared residuals	2.5296	2.6820
Weighted sum of residuals	22.559	18.037
Normalized success index	0.584	0.574
Mean dependent variable	0.560	0.555
Std. deviation	0.3855	0.3870
Variance	0.1486	0.1498
Interval (Min))	0.0004	0.00001
Interval (Max)	0.9998	1.00000

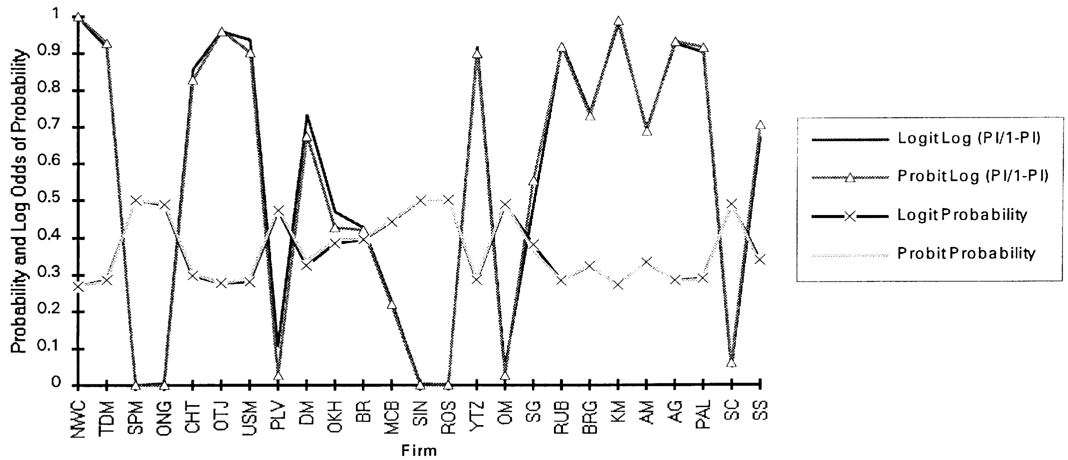

Fig. 2a. Probability and log odds favoring profitability/loss – all firms.

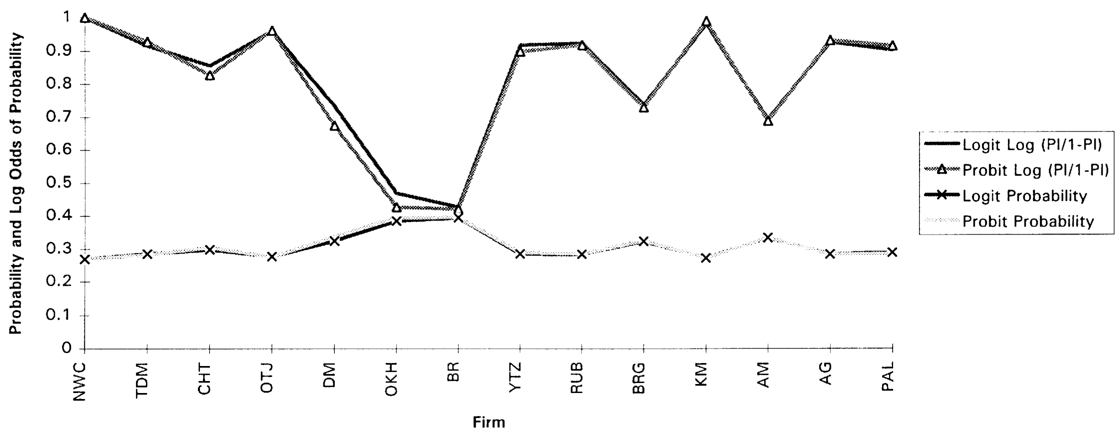

Fig. 2b. Probability and log odds favoring profitability – profitable firms.

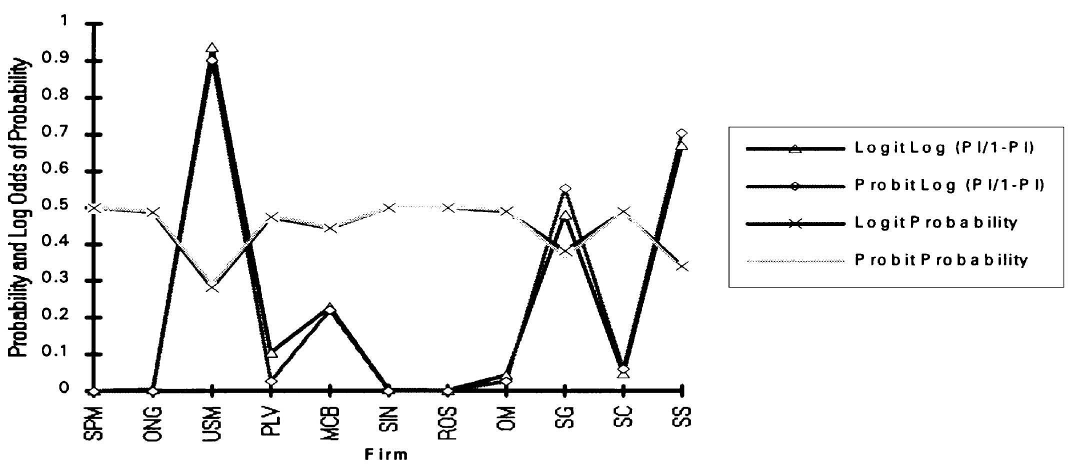

Fig. 2c. Probability and log odds favoring loss.

have expected positive impacts. But both the logit and probit models seem to suggest that in the long-run Namibian promoters of small-scale mining must choose between a few profitable firms with some employment prospects and many unprofitable firms with high potential but low feasible employment chances.

The log-likelihood functions of the two models are significant judging from the high likelihood ratio (> 18.00) tests, taking into account appropriate degrees of freedom. The explanatory power, measured by the McFadden adjusted R^2 of 0.398 (0.449), and the joint significance by χ^2 (approximate McFadden F-distribution of 1.4 with 6 and 7 degrees of freedom) are both reasonable. The McFadden R^2 indicates that about 40–45% of the variations in the log of the odds favoring profitability are explained by the included variables. The approximate McFadden F suggests that it is strongly unlikely that the impacts of the included variables on the log of the odds favoring profitability are jointly nonsignificant (sum to zero). For both models an average of 86% (21.5 of 25) and 82% (20.5 of 25) of the observations are correctly predicted. At the mean of the dependent variable, the success indexes of the log of the odds in favor of profitability are 61% (58%) and 60% (57%) for the logit and probit models respectively.[7]

Again the slope coefficients in Tables III.1 and III.2 measure the changes in the log of the odds favoring probability of mean profitability following corresponding changes in the explanatory variables. Given these coefficients and specific levels of any explanatory variable(s), the probability that a firm can be profitable or unprofitable can be estimated. At the mean of the dependent and independent variables the probability of Namibian FSSMFs being profitable is only 0.363548 for the logit model and 0.364705 for the probit model (both very low). Figure 2a shows the probability as well as the log of the odds favoring profitability and loss (unprofitability) across all 25 firms. An important observation is that as probability rises the log of odds favoring profitability falls. Figures 2b and 2c, focusing on small-scale firms' probability of being profitable and unprofitable respectively, suggest one important general conclusion: the probability of being profitable is lower than the probability of being unprofitable.

Table IV presents the marginal impacts of changes in X_{it} on the probability of FSSMFs being profitable. These marginal estimates are inverse transformations of the β coefficients obtained from equations (4) and (5) at the mean of each variable. They represent incremental effects of changing X_{it} on the probability of FSSMFs being profitable. For example, if gross sales go up by a unit, the probability of being profitable increases by 0.43 (logit) and 0.40 (probit). The chances of being profitable almost doubles as revenue increases. But increased specialization and L-productivity on average reduce the probability of FSSMFs being profitable by –0.06 to –0.12. If correct, the former recommends diversification, while the latter points to the need for capital formation in small-scale mining. Moreover, as expected, increasing the number of firms in one activity and relative factor costs reduce the probability of being profitable significantly. The result also seems to show that the optimal number of firms (η_i^*) per subsector is $2 < \eta_i^* < 5$.

It is important to note that marginal effects vary with changes in the regressors. On average, the marginal effect on the probability of being profitable of the change in sales is 0.37 for the probit and 0.41 for the logit, i.e. the marginal change in the probability of being profitable as sales revenue increases is 0.39 on average. However, the positive effect of revenue on the probability of success is offset (certainly neutralized) by the negative effects due to labor productivity and relative factor costs which range from –0.086 to –0.14 individually. Figures 3.1a–c plot the marginal effects of

TABLE IV
Marginal impacts on the probability of profitability

Variables	Logit #1	Logit #2	Probit #1	Probit #2
log R_{it}	0.4300	0.4320	0.3885	0.4008
log ρ_{it}	–0.0875	–0.1186	–0.0655	–0.0927
κ_{it}	–0.23301	–0.1500	–0.2054	–0.1453
D_{it}	–0.0755		–0.0959	
σ_{it}	–0.4296		–0.3420	
η_{it}	–0.5185		–0.49545	

Probability critical value (P(Z)) = –0.15096.
Probability density function value = 0.39442.
Variance = 0.2568.
Std. deviation = 0.5066.
Bounds (min = 0, max = 1).

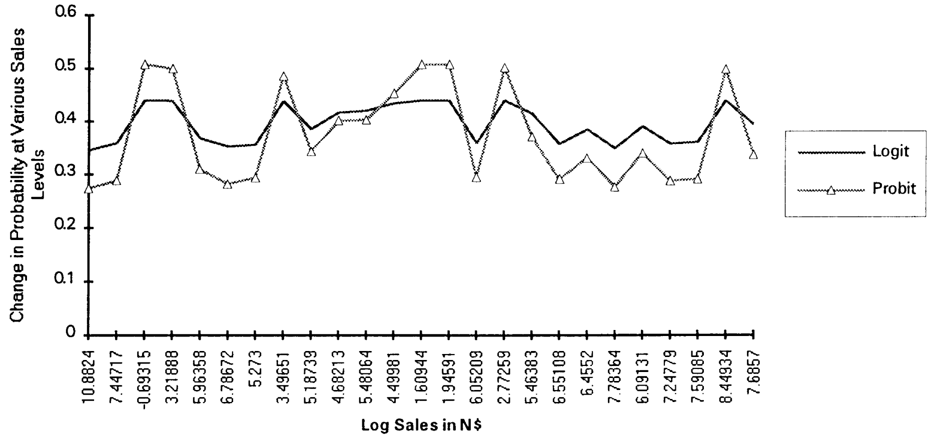

Fig. 3.1a. The change in the probability of profitability/loss at various sales levels – all firms.

Fig. 3.1b. The change in the probability of profitability at various sales levels – profitable firms.

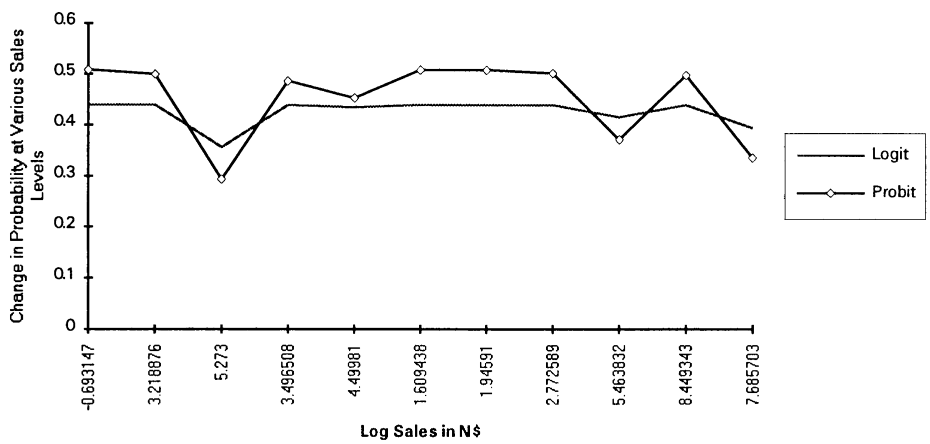

Fig. 3.1c. The change in the probability of loss at various sales levels – unprofitable firms.

Fig. 3.2a. The change in the probability of profitability/loss at various labor productivity levels – all firms.

Fig. 3.2b. The change in the probability of profitability at various labor productivity levels – profitable firms.

Fig. 3.2c. The change in the probability of loss at various labor productivity levels – unprofitable firms.

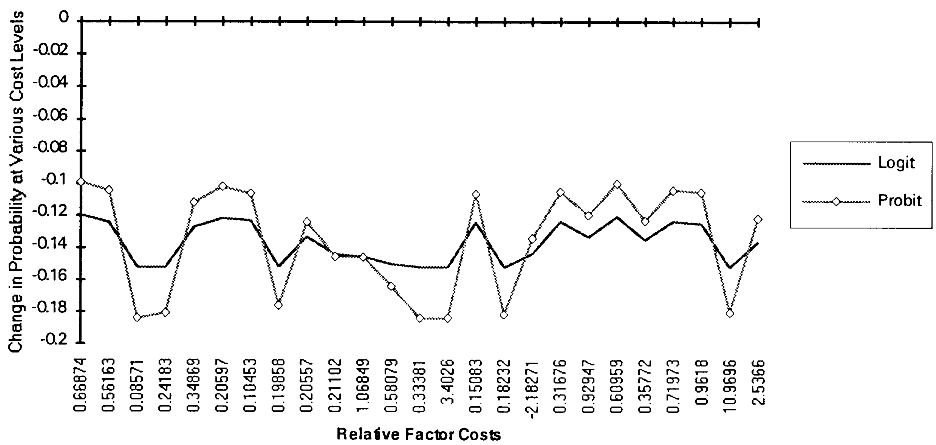

Fig. 3.3a. The change in the probability of profitability/loss at various factor cost levels – all firms.

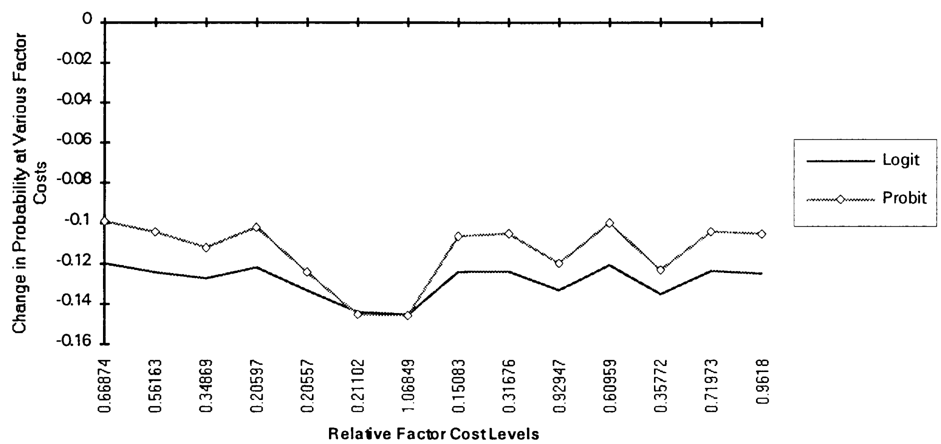

Fig. 3.3b. The change in the probability of profitability at various factor cost levels – profitable firms.

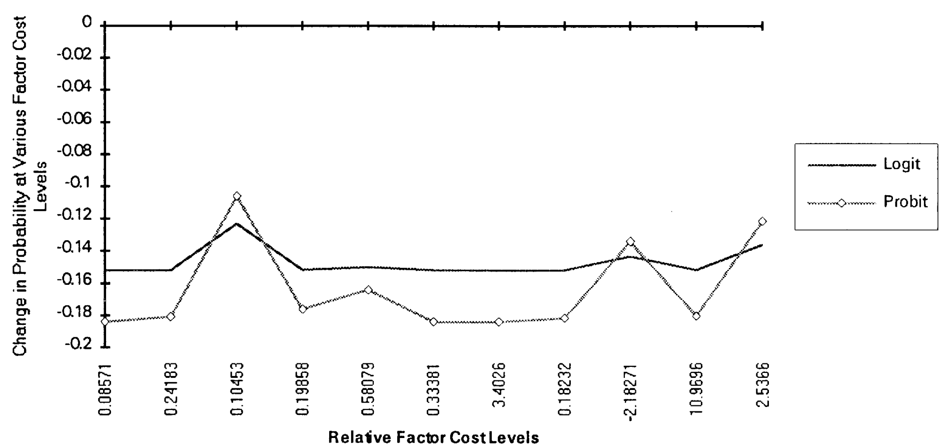

Fig. 3.3c. The change in the probability of loss at various labor factor cost levels – unprofitable firms.

changes in gross sales on the probability of success (profitability) and failure (loss). On average a marginal change of 0.25 to 0.5 follows a change in gross revenue. These effects are about the same for all firms. The implication is that gross revenue is a necessary but not sufficient condition for success. Figures 3.2a–c and 3.3a–c make clear the previous statement for profitability and loss exclusively. The marginal effects of labor productivity and relative factor costs on the profitability of small-scale mining firms in Namibia are both negative. Here high factor costs appear to be more of a constraint on profitability than low labor productivity.[8]

4. Conclusions

This exercise estimated the likelihood of the cross-sectional profitability of 25 formal small-scale mining firms in Namibia. The general finding is that small is not necessarily beautiful. As a group: (a) FSSMFs cannot be entirely L-intensive, because L-productivity depends on K-productivity as in the case of larger firms; (b) full specialization does not seem to be an advantage for the FSSMFs; (c) increased competition narrows the likelihood of large profit margins for small mining firms; (d) respective Namibian small-scale mining sectors can optimally accommodate only two to five firms and still have a reasonable probability for success; and (e) only gross sales support the industry. Perhaps, the comparative advantages of smaller firms lie in geotechnical factors, but these require further investigation.

These conclusions suggest three modest recommendations. First, the hypothesis that FSSMFs can accelerate economic growth and development in Namibia by increasing employment requires knowledge of which FSSMFs actually hold out promise for a significant contribution to the economy and have at least comparative advantages. Further research is needed on this subject. Second, while the level of revenue seems to indicate that Namibian FSSMFs are probably profitable, profitability is reduced by low labor productivity, high factor costs, and increased specialization and competition. The last two factors also limit firm size. By implication this all points out the obvious: government and private firms' objective functions differ. Whereas government may define the advantages of FSSMFs in terms of job creation, FSSMFs themselves look at their profit/loss statements in measuring their performance. The only way these opposing outlooks on performance can be reconciled is through increased investment in competitive FSSMFs. This is important since capital formation and technical change aid labor productivity and make the L-intensive strategy meaningful and feasible. The final recommendation is that under current conditions FSSMFs would do better to avoid full specialization, and attempt instead competitive diversification, which is also a function of capital formation.

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Appendix: Namibian mining firms

A. *Large and medium-scale firms*

CDM	Consolidated Diamond Mines, Ltd., now Namdeb.
ROSS	Rossing Uranium, Ltd.
TCL	Tsumeb Corporation, Ltd.: Copper (Cu) and lead (Pb). At smelter level blister Cu, refined Pb, cadmium (Cd), silver (Ag) and gold (Au) bullion, arsenic (As), and antimony (Sb).
KOM	Kombat, Goldfields, Namibia, Ltd.: Cu, Pb, Ag.
OTJH	Otjihase, Goldfields, Namibia, Ltd.: Cu, Ag, Au, pyrite (FeS_2).
ROH	Rosh Pinah (formerly ISKOR. now in dispute): Zinc (Zn), Pb, Ag.
NAML	Namibia Lead & Zinc: Pb, Zn, Ag.
NAV	Navachab, Anglo-American: Au.
OK	Okurusu Fluorspar: Fluorite (CaF2).
Uis	Closed 1990: Tin (ß-Sn) and tantalum.

B. *Formal small-scale firms*

NWC	Namibia West Coast Diamonds.
TDM	Tidal Diamonds.
SPM	Seven Pillar Diamond Mines
ONG	Onganja WCC Mining: Cu.

CHT	Chrystal Tin Mining
OTJ	Otjua, JA Kleynhaus: Tourmaline, smoky quartz.
USM	S. Pieters Usakos: Tourmaline.
PLV	Plattveld, JA Kleynhaus: Amethyst.
DM	Dan Mines: Amethyst.
OKH	Okaharuiput, JA Kleynhaus: Amethyst.
BR	Bella Rosa, GJ Du Preez: Rose quartz.
MCB	Mickberg: Rose quartz.
SIN	GE Swanson, Sinclair: Rose quartz.
ROS	Rosalies Mining: Rose quartz, beryl.
YTZ	Ysterputz, GE Swanson: Agate.
OM	Omaue, K. Steiner: Dioptase, chrysocolla.
SG	Salz Gossow: Salt
RUB	Rubicon, Namibia Lithium, Ltd.: Li-minerals.
BRG	J. Berger: Marble.
KM	Karibib Marbleworks, also granite.
AM	African Marble.
AG	African Granite.
PAL	Musseti Co: Palisandro marble.
SC	Salt Co.
SS	Snow Salt.

Notes

[1] Following the UNDESA's publications, six international conferences and two seminars were devoted to the problems and prospects of small-scale mining. A quick review of the proceedings of *The Second International Symposium on Small Mine Economics and Expansion* (1983), for example, reveals the rigor and vigor which various experts brought to the discussion of the problems facing small mines and firms worldwide.

[2] The phrase "small is beautiful" is due to E. F. Schumacker (1972); see the references for a complete citation.

[3] All quantities produced are in metric tons (MT); 1 MT = 1,000 kg, 1 carat = 200 milligrams, and the rest follows.

[4] Meaning that production takes place on the production possibility frontier at a point where factor marginal productivities are equated.

[5] The coefficients in parentheses are for the models given in Table III.2.

[6] That is increasing employment, production, and revenues in proportions such that the definition of firm size remains unchanged.

[7] The *T*-values of individual variables hold only in the asymptote. While the *T*-values improve with increased degrees of freedom, the nature of the coefficients remains unchanged and the percentage of correct predictions falls somewhat. This we take to mean models uncorrected for insignificant variables are more powerful (explanatory + predictive) than models corrected for insignificant variables, although *T*-values of the former tend to be lower than those of the latter.

[8] Figure 3 must not be read as goodness-of-fit representations where one would expect a close fit of logit and probit results. These are marginal changes deriving from Eqs. (4) and (5). The logit and probit fits deriving from Eqs. (1) and (2) are in Figure 2.

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