Performance, Technical Progress and Investment in Tunisian Manufacturing Firms: Evidence from Firm-Level Panel Data

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Abstract

In order to contribute to the understanding of some of the microeconomic forces driving overall growth performance in Tunisia, this paper aims to develop an econometric analysis of firm performance determinants. For this purpose, and unlike the conventional methods where the analysis of firm performance has been done using conventional financial ratios, frontier methodology is adopted to measure firm performance relative to best practice frontiers consisting of other firms in the industry. Such measures summarize firm performance in a single statistic that controls for differences among firms in a sophisticated multidimensional framework that has its roots in economic theory. A panel of 265 firms in manufacturing industry, drawn from the Annual Firm Survey carried out by the National Statistics Institute of Tunisia (1984-1994), with detailed information on output and input factors and firm ownership is used to estimate a translog stochastic production function for the period 1984-94. By adopting the time-varying inefficiency model developed by Battese and Coelli (1995), the paper seeks to identify the determinants of technical inefficiency for each of the six manufacturing sectors. This study also enables the examination of industry-level total factor productivity performance, and to investigate the relationship between technical efficiency change, openness and firm investment decision.

الأداء، التقدم التقني والاستثمار في منشآت الصناعة التحويلية في تونس: دليل من بيانات على مستوى المنشأة

رياض بن جليلي

الملخص

مـن أجـل المساهمة بفهم بعض القوى الاقتصادية الجزئية التي تقود مجمل أداء النمو في تونس، فإن هذه الورقة تهدف إلى تطوير تحليل اقتصـادي قياسـي لمحـددات أداء المنشأة. من أجل هذا الغرض، وعلى خلاف الطرق التقليدية التي كانت متبعة في تحليل أداء المنشأة باستخدام النسب المالـية التقليدية، فقد تم تبني منهجية رائدة لقياس أداء المنشأة نسبة إلى أفضل ما تم تطبيقه متضمناً منشآت أخرى في الصناعة تلخص مثل هكذا مقاييس أداء المنشـأة بإحصـاء مفرد يراقب الاختلافات بين المنشآت في إطار عمل متطور ومتعدد الأبعاد له جذور في النظرية الاقتصادية. لقد تم سحب قائمة مـن 265 منشأة من منشآت القطاع الصناعي التحويلي من المسح السنوي للمنشآت الذي قام به معهد الإحصاء الوطني التونسي، في الفترة 1984-1994، بمـا يتضمنه من بيانات تفصيلية عن عناصر المدخلات والمخرجات وملكية المنشأة، وقد تم استخدامها لتقدير معادلة الإنتاج العشوائية عبر اللوغاريتمية للفـترة 84-1994. من خلال تبني نموذج عدم الكفاءة ذات المتغير الزمني، الذي تم تطويره من قبل باتسي وكولي (1995)، تسعى الورقة إلى تشخيص المحـددات الفنية لعدم الكفاءة لكل من القطاعات الصناعية الستة. كما تمكن هذه الدراسة من إختبار مستوى المنشأة من خلال أداء جميع عناصر الإنتاج، وكذلك من تشخيص العلاقة بين الكفاءة الفنية والإنفتاح وقرار الاستثمار في المنشأة.

Introduction

The idea that differences in firms are important to understanding economic growth and the performance of economies is not new. The Schumpeterian approach (Schumpeter,1934 and 1942) describes the process by which competition produces economic growth and improvements in living standards as one of "creative destruction." Firms constantly search for new products and new ways of doing things to try to gain competitive advantage.

While Schumpeter's view of the competitive process is compelling, it has not been the primary foundation for empirical research in economics. Indeed, academic research has been structured around the "representative firm" model. In this model, firms in the same industry use the same production processes, produce identical products, and face identical costs. Thus, all firms react similarly to shocks and the "industry" becomes the effective unit of analysis. The lack of statistics at the business unit or plant level constitutes a principal impediment for the paucity of micro approaches to the study of competition and economic growth. Indeed, most governmental statistics, especially in less developed countries, are provided at aggregate levels broader than firms or plants.

With new empirical research possibilities, the past 20 years have seen a number of new models in the economic literature describing firm behavior and the associated industry dynamics. A common feature of these models is that uncertainty and limited information cause firms to take different approaches to common problems, thereby generating heterogeneity among firms, even within the same industry or product grouping. These theoretical developments, coupled with new databases, have led to a flood of empirical studies of firm behavior and performance which confirm the relevance of the new theoretical approaches. The behavior of firms within industries differs

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dramatically and it is a well known stylized fact that there are persistent differences in performance among firms in an industry (Mueller. 1986; Geroski and Jacquemin, 1988).

It may be argued that the question of firm performance is more in the realm of strategic management. However, in order to conclude anything relevant about industries, economists need to understand the behavior of firms and how industries change over time. Indeed, a large part of economic environment is determined by the performance of firms. Macroeconomic growth rate, unemployment and standards of living are highly correlated with the economic performance of firms. Accordingly, to explain the performance of the economy in general and to conclude anything relevant about industries, the composite has to be analyzed, and hence the microeconomic agents, of the economy.

In Tunisia, private manufacturing sector has been called upon to play a key role in the transformation and development of the Tunisian economy since the launching of market oriented reforms fifteen years ago. In order to contribute to the understanding of some of the microeconomic forces driving overall growth performance in Tunisia, this paper aims to develop an econometric analysis of firm performance determinants. For this purpose, and unlike the conventional methods where the analysis of firm performance has been done using conventional financial ratios (return on equity, return on assets, expense to premium ratios, etc), frontier methodology is adopted to measure firm performance relative to best practice frontiers consisting of other firms in the industry. Such measures summarize firm performance in a single statistic that controls for differences among firms in a sophisticated multidimensional framework that has its roots in economic theory.

In this paper, a panel of 265 firms in manufacturing industry, drawn from the Annual Firm Survey carried out by the National Statistics Institute of Tunisia (from 1984 to 1994), with detailed information on output and input factors and firm ownership is used to estimate a translog stochastic production function for the period 1984-94. By adopting the time-varying inefficiency model developed by Battese and Coelli (1995), the paper seeks to identify the determinants of technical inefficiency for each of the six manufacturing sectors. This study also enables the examination of industry-level total factor productivity performance, and to investigate the relationship between technical efficiency change and firm investment decision.

Business Environment, Contracting Impediments and Firms Performance in Less Developed Countries

The expansion of manufacturing sector is usually viewed as the leading edge of modernization, technological diffusion and skilled job creation, as well as a fundamental source of numerous positive spill-overs and competitiveness at various levels (firm, industry and national level). Consequently, although many Less Developed Countries (LDCs) have scaled back trade barriers over the past 20 years the manufacturing sector remains relatively protected in a typical country (Schiff and Valdez, 1992; Erzan, et al., 1989; Ng, 1997). They have also been subject to heavy regulation, much of which is biased in favor of large enterprises. The bias against small entrepreneurs is exacerbated when financial repression is a problem, since credit rationing typically excludes the smallest borrowers first (Levine, 1997; Little, 1987; Tybout, 1984).

Therefore, three arguments or basic features have been commonly prominent in policy discussions of the performance problems facing manufacturers in LDCs:

- Firstly, markets tolerate inefficient firms, so cross-firm productivity dispersion is high. In addition, firms in LDCs lack the technical capacity to perform well. Pack (1993) declares that “without an increase in proficiency, the responsiveness of output to even the best designed structural adjustment program is likely to be limited. Prices are one-half of a scissor, the other being technical skill.”
- Secondly, small groups of entrenched oligopolists exploit monopoly power in product markets.
- Thirdly, many small firms seem to be unable or unwilling to grow, so important scale economies go unexploited. Moreover, larger firms are more capital-intensive than smaller ones, so such factor choices are inappropriate for the factor endowment of many LDCs (Little, Mazumdar and Page,1987).

These basic features raise a number of fundamental empirical issues related to dynamism (or lack of dynamism), technical efficiency and competitiveness either at the firm level or industry level. However, in many LDCs, information on the producers themselves is very limited. The coverage of detailed studies of producer pricing behavior, investment decision and efficiency is occasional, and many empirical issues remain completely unexplored.

Nonetheless, evidence provides some of the distinctive features of the business environment in which LDCs manufacturers generally operate. Reviewing these features will help to distinguish differences in the LDCs firms performance that trace to structural differences in their economies rather than to the policies designed to influence their behavior (Tybout, 2000), even if these features will not be directly evaluated in the rest of the paper.

Business Environment Features

A variety of features distinguish the business environment in developing countries which, according to Tybout (2000), the most striking and widely acknowledged are:

- **Market size:** Although some developing economies are quite large, most are not. Hence, excepting some countries, the size of the domestic market for manufactured products is relatively limited.

- **Access to manufactured inputs:** The menu of domestically produced intermediate inputs and capital equipment is also often limited in developing countries. Indeed, the vast majority of machinery and equipment deployed in developing countries is imported.

- **Human capital:** Lack of technical and managerial skill, inadequate organizational adaptability and ability to acquire or use new technology affect the mix of goods manufactured and the factor proportions used to produce them. There are considered also as impediments to growth as well as barriers to entry (Jones, 1992). Similarly, many have argued that flexibility in production processes and the ability to absorb new technologies is directly related to the stock of indigenous human capital (e.g., Nelson and Phelps, 1966; Evenson and Westphal, 1995; Keller, 1996).

- **Infrastructure:** Roads, ports, airports, communication facilities, power, and safe water access also tend to be relatively limited in LDCs. Production techniques are directly affected, and so are the costs of servicing distant markets.

- **Financial markets:** Credit markets are also relatively thin, and heavily skewed toward short-term instruments. Excepting some of the newly industrialized countries, stock markets are nearly irrelevant as a source of new equity funds (Levine, 1997). The financing constraint binds especially for small firms, which are relatively likely to fail, and which banks find relatively costly to service per unit of funds lent.

- **Volatility:** Macroeconomic and relative price volatility is typically more extreme in developing countries. Latin America and Sub-Saharan Africa stand out among the developing countries as the most volatile, but all developing regions do worse than the industrialized countries (World Bank, 1993; Hausmann and Gavin, 1996).

- **Governance:** Finally, legal systems and crime prevention are also relatively poor in developing countries, and corruption is often a serious problem (World Bank, 1997; Brunetti et al, 1997). Hence the protection of property rights and contract enforcement can be problematic. Anti-trust policy is also often weak, as are environmental standards (Brunetti et al., op. cit.).

Contracting Impediments and Firms Performance

The term "contracting impediments" refers to a variety of market imperfections that firms in developing countries are especially prone to, that are sought to be overcome by various non-market institutions. These include distinct contracting arrangements and organizational forms, formal institutions of the state, informal institutions such as family and community networks, and related social norms.

A very large literature has traditionally been devoted to the topics or features quoted in the previous section both from a positive and normative standpoint. This section will be concerned instead on organizational innovations and informal institutions that have spontaneously evolved in the absence of formal state support, partly because they have not received adequate emphasis in traditional literature. Two kinds of impediments, which are likely to achieve greater significance in the post-1990s environment of substantive deregulation and liberalization of free market forces, will be discussed below: financial constraints and problems of contract enforcement. They respectively give rise to two alternative solutions, involving contractual payment of informational rents and relying greatly on reputational considerations.. All of them raise the costs of dealing with the moral hazard problem, creating an institutional source of lack of competitiveness of firms in developing countries (Mookherjee, 1999).

Credit Market Imperfections: Evidence clearly suggests that credit markets in the real world operate differently from what is suggested by the standard competitive model. Imperfections in formal credit markets tend to be

more pervasive in developing countries, owing to a poorly developed intermediary sector, weaknesses in information and enforcement of formal credit contracts, and thinness of bond and equity markets. These imperfections raise the cost of 'external' capital in ways that differ with specific borrower characteristics, such as existing wealth and the extent to which these are collaterizable.
Some of the stylized facts about credit markets are:

- Apparent Lack of Arbitrage: There are many countries where one set of people has been earning negative real rates on their savings, while another set of people has been borrowing at very high real rates. Also, there is a wide range of interest rates prevailing in the same area, with no apparent equalization due to arbitrage.

- Rationing: There is evidence from all countries that borrowers are able to borrow only up to a limit for a given interest rate, and are not given a larger loan even if they are willing to offer a higher interest rate.

A firm is credit-constrained if it cannot borrow as much as it wants under the going market rate. An equivalent way of putting it is the marginal product of capital is higher than the market interest rate.

Moreover, in many LDCs, allocational inefficiencies in the distribution of credit across firms tend to be important. All firms are not credit-constrained to the same degree. This aspect is of interest for two reasons. Firstly, it is another way of approaching the question whether credit markets operate with or without friction. Secondly, it is of interest to know how these frictions are distributed across firms because, after all, matching skills and resources is an important function of the credit market. The policy implications are very different if, for example, all firms (holding constant their wealth which affects their ability to post collateral) face the same barriers in the credit market, or those that belong to close-knit social networks face much lower barriers. Indeed, in the presence of credit market imperfections, people would prefer to lend to people they trust, such as their friends and relatives. As a result, those with strong ties with people with more money than investment opportunities, will enjoy easy access to capital and will invest more than others with the same investment opportunities and abilities.

Credit market imperfections and related wealth effects have profound implications for explaining entry into the industrial sector and subsequent investment levels (Banerjee and Newman, 1993; Galor and Zeira, 1993; Aghion and Bolton, 1997; Piketty, 1997; Ghatak, Morelli and Sjostrom, 1998 and Mookherjee and Ray, 1999):

- The existence of large internal investible surpluses, frequently originate in agricultural prosperity or other forms of primitive accumulation, that obviate the need for external capital;

- The importance of affiliation in informal social that fill the void created by formal credit institutions, owing to their superior position with regard to information and enforcement; and

- A positive correlation between internal capital and access to external capital – the phenomenon that the wealthy have better access to external credit. In particular, this implies that wealth inequality matters. The poor cannot get going because they have neither internal nor access to external capital. In addition, the effect of these capital market imperfections on other factor markets will also become obvious in due course.

Problems of Contract Enforcement. The importance of contract enforcement mechanisms in economic development is the subject of a growing literature (Johnson, McMillan, and Woodruff, 1999; McMillan and Woodruff, 1999; World Bank, 2002). Within this field, Williamson (1975) and Klein, Crawford, and Alchian (1978) were the first to emphasize and elaborate the importance of the hold-up problem, i.e. when one party in a contract ex post exploits contractual imperfections to extract quasi-rents after the other party has sunk contract-specific investments, for the analysis of business institutions and practices. The growing interest in the subject has been subsequently marked with important contributions to the literature by Williamson (1983, 1985), Milgrom and Roberts (1992), Shelanski and Klein (1995) and Klein (1996).

Hold-ups and contract enforcement are widely acknowledged as a primary issue in transition of formerly planned economies. The common view is that historically, these countries have relied on state to enforce dealings among state-owned enterprises. Once the economies became decentralized and privatized, there was no mechanism in place to enforce those new agreements. Nevertheless, the issue of contract enforcement is not unique to transition economies. Even in mature market economies, contracts are maintained both by invoking law and informal mechanisms, such as reputation mechanisms or collateral (Ellickson, 1991; Arrighetti, Bachman and Deakin, 1997). Relational contracting, or bilateral reputation, is the most frequently cited variety of such informal mechanisms. Contracting parties expect their partnership to last for a long time and therefore prefer not to renege on agreements.

Contract enforcement and hold-ups have caused additional financial distress and worsened the already severe cash flow and profitability problems in the affected firms. Both partners to the contract suffer the consequences. As suppliers recognize the possibility for continued hold-ups, they become reluctant to invest in activities involving high asset-specificity (or company-specificity). As a result, the supplies to the downstream firms decline both in terms of quantity and in quality, with obvious negative effects on the downstream producers.

In general, the occurrence of hold-ups may affect firm investment in two ways: (a) directly, via the effect of a hold-up on a firm's cash flow; and (B) indirectly, via the recognition of a hold-up potential. Concerns on the above may lead to sub-optimal investment as risk-averse firms, fearing that their investments will leave them vulnerable, refuse to make the efficient investment. Such concerns are especially due in transition countries where a combination of high litigation costs, ineffective contract law, poor third party verifiability, and the potential loss of the only suitable trading partner make the use of legal dispute mechanisms not viable. Even with risk-neutral transactors, however, the presence of possible hold-up behavior, following unanticipated changes in market conditions, will entail costs as real resources are devoted to the attempt to improve post-transaction bargaining positions in the event of a hold-up contingency occurring. In general, less specific investment will be made to avoid being "locked in" (Klein et al., 1978). Agents reduce investments or move resources to sectors with lower asset specificity requirements.

The contract enforcement mechanisms also raise the question of the weakness of reputational forces for producers of experience goods in developing countries. Indeed, stories of adulterated foodstuffs, equipment breakdowns, and delays in delivery are habitual, and constitute a significant drawback in their competitiveness with comparable products from developed countries. The most common explanation of these problems of low quality is that customers in developing countries are less willing to pay for high quality. In many contexts, this explanation is not persuasive. Mookherjee (1999) considers that reputational considerations play a significant role in maintaining quality incentives for experience goods with significant incidence of repeat dealings.

Esfahani (1991) views the key elements of the weakness of reputational forces in the greater variance in the costs of providing high quality products. He developed a reputational model where a sector providing high quality products coexists with a competitive fringe providing low quality products. For reputation to work as an effective carrot, the supplier of high quality needs to be rewarded with a price premium above the cost of supplying high quality, which would be foregone in the future, following an opportunistic deviation to low quality today. Such premiums are consistent with competition which eliminates excess profits for firms. A firm newly entering the market offers an introductory bonus, pricing its product below cost. This initial loss is recouped by premiums earned later. Any deviation to low quality supply will ensure loss of clientele in the future, who will switch to a newly entering firm, or to low quality service produced by a competitive fringe.

In this context, suppose that the marginal cost of producing a high quality product is subject to greater uncertainty, the cost is observed by the producer before making the decision concerning the quality to be supplied in any given period, but cannot be observed by customers. Thus, customers cannot graduate the future punishment for provision of low quality to the current cost of high quality, e.g., make exceptions owing to 'extenuating circumstances'. In other words, the same punishment will be meted out by customers, irrespective of the current cost shock. Therefore, the existence of a reputational equilibrium relies on reining in the incentive to skimp on quality in the worst possible cost state. Widening the range of possible cost shocks however, increases the current temptation to deviate. This may be controlled only if the future quality premium were to increase. This tends to cause customers to switch to low quality substitutes, and the reputational equilibrium threatens to fall apart.

Esfahani points out a number of other implications of his model: (a) Greater capital scarcity in developing countries can induce higher discount rates, reduce the present value of future quality premiums, and thereby undermine incentives to maintain a reputation for quality; (b) Large firms have an advantage over small firms with respect to building a reputation. They can vertically integrate to increase input supply assurance, and have lower discount rates owing to larger reserves of internal finance, and lower turnover rates; and (c) Increased competition on the product market can exacerbate quality problems. Oligoplistic structures help protect quality premiums from the threat of competition by new entrants, at the cost of an increase in prices.

The Tunisian Background

Global Performance

Significant structural changes in the Tunisian economy have taken place since the early 1960s. Between 1960 and 1999, the Tunisian economy grew at an average rate of 5%, quite a reasonable rate by lower middle-income country and regional standards. Today, with a per capita GDP of about $2,200, Tunisians have more than two-and a-half times the real income their parents had 30 years ago, and all indicators of their social and economic wellbeing have improved significantly. Agriculture's share of the GDP declined steadily from about 28% in 1960 to 9% in 1999. At the same time, the manufacturing sector expanded very rapidly, increasing its portion of the gross domestic product (at factor cost) from less then 8% in 1960 to 20% in 1999. However, the impact of fluctuations of agricultural production on overall GDP remains strong and asymmetric. It is stronger during years of agricultural contractions than during years of agricultural expansions. This asymmetry originates from significant indirect effects produced by fluctuations of agricultural output on manufacturing and of activities linked to agriculture.

International trade is vital to the Tunisian economy [(1)]. In 1999, export and import transactions, together, account for about 61% of the gross national product. Moreover, a high degree of diversification took place, enabling Tunisia to boost its export items from a few numbers of commodities in the early 1960s to a wide range of products in 1999. Indeed, the share of the first three commodities in the total exports of goods and services decreased significantly from 37% in the early 1980s to 20.7% in 1999. However, the market for the product, which is also important to evaluate the degree of diversification, remains dominated by three EU countries: France, Italy and Germany monopolizing more than 70% of the Tunisian trading in 1999. Consequently, Tunisia's business cycle has shown a weak link with business cycles in these EU trading partners. In the near future, this link is likely to be stronger because of the expected increase in trade and investment with the progressive implementation of the 1995 Association Agreement.

Manufacturing Sector Performance

Over the past three decades, the manufacturing sector has been comparatively dynamic, growing at an average (real) rate of 6.1% since 1980. In 1999, manufacturing employed about 21% of the entire labor force and accounted for 69% of total merchandise export earnings, making it the second nation's largest sector. However, this sector remains fairly small, particularly when compared to countries that have achieved fast economic growth. This is cause for concern for two principal reasons:

- Firstly, it is well documented that in the process of development, the manufacturing sector usually increases its share in GDP, and often represents the main engine of growth; and

- Secondly, the process of globalization in Tunisia has been accompanied by trade liberalization which has placed additional pressures on industries causing some to decline and others to grow. Contributing to the globalization pressures is the emergence of dynamic new export-oriented economies in Asia that are forcing structural change in order to increase the Tunisian's manufacturing sector ability to expand and adapt to world market conditions.

General Characteristics of the Manufacturing Sector in Tunisia. The structure of manufacturing output deviated from the concentration on consumer goods (food processing) to give more weight to textiles, clothing and leather goods, which belong to an export-oriented industry. Table 1 illustrates this shift.

(1) To meet the terms of the EU Association Agreement, the government is continuing the structural economic reforms initiated in 1987 with the IMF and World Bank. As customs duties are eliminated over a 12-year period for a wide range of imports, Tunisian producers must become more competitive. In conjunction with the Agreement, and in response to World Bank recommendations, the government has vowed to accelerate its privatization program, which has covered nearly 140 companies since it was launched in 1987, and brought in $950 million by the end of 2000. Nearly $660 million was in the form of Foreign Direct Investment (FDI). "Privatization" of a considerable number of state-owned companies has, in fact, only been a partial sale of state-owned shares. With the full privatization of two cement plants in 1998 and two more in 2000, the government has turned its attention to a variety of public assets, and about 40 companies have been selected for privatization in 2001.

Table 1. Structure of Manufacturing Value Added, 1972-1999 (%)

	1972 - 1979	1980 - 1989	1990 - 1994	1995	1996	1997	1998	1999
Food processing	36	26	20	17	17	18	17	18
Construction materials and glass	8	12	11	11	10	9	9	9
Mechanical and electrical goods	14	15	14	13	13	13	13	13
Chemical and rubber	10	9	9	11	11	11	11	11
Textiles, clothing and leather goods	20	24	32	35	36	36	36	36
Woodwork, paper and diverse	11	12	13	13	13	13	13	13
Total	100	100	100	100	100	100	100	100

Part of this shift resulted from a widespread concern in the late 1970s over limited demand in the domestic market. Additionally, conducive circumstances in the world market at that time called for a shift in policies from producing for domestic markets to producing for export.

The manufacturing activities that experienced the highest rates of growth (at constant prices) were those related to chemicals and rubber, construction materials and glass, woodwork, paper and diverse, and textiles, clothing and leather goods. Table 2 illustrates this evolution.

Table 2. VA Real Growth Rate of Different Groups of Industries, 1973-1999 (%)

	1973-1979	1980-1989	1990-1994	1995-1999
Food processing	0.3	3.0	2.2	4.7
Construction materials and glass	16.6	9.6	4.3	3.0
Mechanical and electrical goods	9.9	8.8	4.0	5.1
Chemical and rubber	8.4	19.0	7.8	4.5
Textiles, clothing and leather goods	10.0	6.1	10.0	5.4
Woodwork, paper and diverse	12.1	8.8	7.1	5.3
GDP real growth rate	5.7	6.8	6.0	4.8

The story of the real growth in manufacturing output of the period 1973-1999 reports that capital contribution to the sector growth amounted to 43% while that of labor was 35%. As regard TFP(2), it registered a significant growth rate of 22% (50%). In the 1990s, growth in technology contributed relatively strongly to growth in real value added in four sectors: (a) Construction Materials and Glass (91%); (b) Chemical and Rubber (83%); (c) Woodwork, Paper and Diverse (52%); and (d) Textiles, Clothing and Leather Goods (32%). Growth in the capital input contributed negatively to growth in only one sector: Chemical and Rubber (-11%); and growth was driven by growth in factor inputs in Food Processing and Mechanical and Electrical Goods sectors. The latter has recorded the worst technology contribution to value added growth (-61%)(3).

The summary evidence in Table 3 suggests the presence of a structural break and strong sectoral differences in terms of the decomposition of the real output growth. While in the 1970s, output growth in the considered sector was driven by growth in factor inputs, the 1990s witnessed a growing reliance on technological improvements. Part of the reason for this evidence is that the 1990s saw a comparative decline in formal sector employment. The declining contribution of capital to the growth performance of the Tunisian manufacturing sector is due to the declining accumulation rate that the sector has experienced (Figure 1).

(2) The computations were by means of the standard primal estimate given by: $TFP = \frac{\dot{Y}}{Y} - s_K \frac{\dot{K}}{K} - s_L \frac{\dot{L}}{L}$ where s_K and s_L denote the shares of capital and labor in output respectively. The factor shares are provided by data on Gross Operating Surplus and the Real Wage Bill respectively.
(3) Source of the percentages: Evaluation of the author on the basis of the above standard primal estimate of TFP.

Table 3. TFP Growth in the Tunisian Manufacturing Sector (%)

	Real Output Growth	Of which			Contribution coefficient		
		Capital	Labor	Technology	Capital	Labor	Technology
Manufacturing Sector							
1972-1979	5.7	2.4	1.3	2.0	42.9*	22.4	34.8
1980-1989	6.8	5.1	3.0	-1.3	75.0	44.3	-19.3
1990-1999	5.4	0.6	2.1	2.7	10.5	39.6	49.9
Food processing							
1972-1979	0.3	2.2	0.2	-2.1	797.4	57.0	-754.4
1980-1989	3.0	-0.5	-1.6	5.0	-15.5	-54.9	170.4
1990-1999	3.4	1.1	1.7	0.6	33.3	50.1	16.6
Construction Materials and Glass							
1972-1979	16.6	13.2	6.2	-2.8	79.7	37.4	-17.1
1980-1989	9.6	4.4	2.8	2.4	46.1	28.9	25.0
1990-1999	3.6	0.3	0.0	3.3	8.3	0.7	91.0
Mechanical and Electrical Goods							
1972-1979	9.9	2.8	6.2	0.9	28.2	62.7	9.1
1980-1989	8.8	-1.1	2.2	7.8	-12.7	24.8	87.9
1990-1999	4.6	0.6	6.7	-2.8	13.9	146.7	-60.5
Chemical and Rubber							
1972-1979	8.4	23.1	2.1	-16.7	273.6	24.4	-198.0
1980-1989	19.0	6.3	10.4	2.2	33.2	55.0	11.8
1990-1999	6.2	-0.7	1.7	5.1	-10.9	27.7	83.1
Textiles, Clothing and Leather Goods							
1972-1979	10.0	16.0	6.2	-12.2	159.9	62.5	-122.4
1980-1989	6.1	2.9	3.8	-0.6	47.6	63.0	-10.6
1990-1999	7.7	2.7	2.5	2.4	35.2	33.2	31.6
Woodwork, Paper and Diverse							
1972-1979	12.1	23.6	19.6	-31.1	195.0	162.3	-257.3
1980-1989	8.8	5.6	6.5	-3.3	63.6	74.3	-37.9
1990-1999	6.2	1.9	1.1	3.2	30.5	17.5	52.0

* 42.9% corresponds to the contribution of capital to the real output growth (2.4% from 5.7% of GPD real growth rate).

Source: National Statistics Institute (INS, Les Comptes des la Nation, 1983 to 1999), Budget Economique (from 1972 to 1982)and author computation.

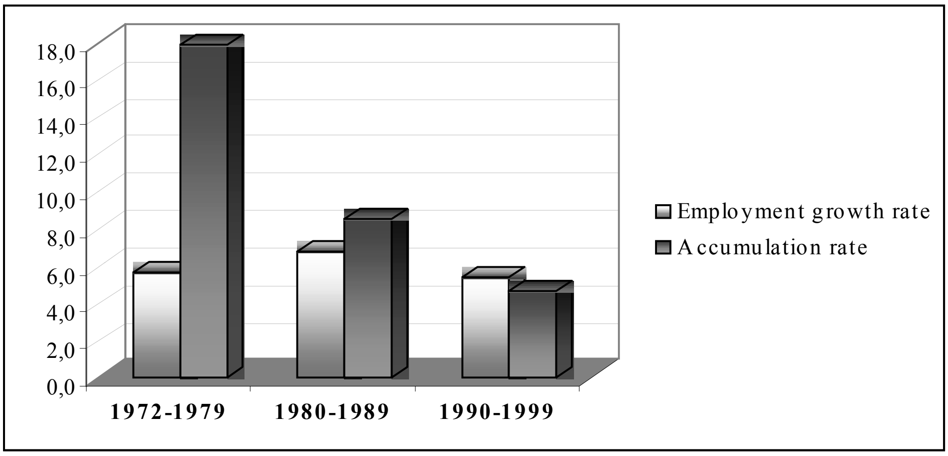

Figure 1. Employment and accumulation rate evolution in the manufacturing sector

Table 4 shows private firm contribution to manufacturing value added. In 1998, this contribution amounted to about 66%. It reached almost 90% in Textiles and 70% in Mechanical and Electrical goods.

Table 4. Private Firm Contribution to Value Added (%)

	1983-1989	1990-1994	1995	1996	1997	1998
Manufacturing Sector	50.1*	59.6	62.6	64.1	70.7	65.8
Food Processing	36.2	41.8	42.5	45.6	38.7	49.6
Construction Materials and Glass	35.0	34.7	37.9	39.1	42.3	48.0
Mechanical and Electrical Goods	62.8	69.6	78.0	80.0	91.1	69.4
Chemical and Rubber	47.4	49.6	43.4	44.3	53.2	44.8
Textiles, Clothing and Leather Goods	67.4	82.0	84.1	84.2	97.0	88.5
Woodwork, Paper and Diverse	47.8	50.0	51.8	53.6	58.8	51.0

* During the period 1983-1989, private firms contributed in average to about 50.1% of the total manufacturing sector value added.

Source: National Statistics Institute (INS, Les Comptes de la Nation, 1983-1999).

Table 5 provides evidence, taken from the Directory of Enterprises of the National Statistics Institute, about the prevalence of small enterprises in the Tunisian manufacturing sectors in 2000. Indeed, small, medium and large firms constitute 52.5, 36.7 and 10.8%, respectively, of the firms present in the directory. The size distribution varies by sector: firms in Chemical and Rubber, Woodwork, Paper and Diverse, and Food Processing sectors tend to be smaller; firms in the textile sectors are larger.

Table 5. Size* (Number of Employees) Distribution in the Tunisian Manufacturing Enterprises (%)

	Small	Medium	Large	Total
Food Processing	66.1	25.8	8.1	100
Construction Materials and Glass	55.1	34.8	10.1	100
Mechanical and Electrical Goods	63.9	26.0	10.1	100
Chemical and Rubber	69.4	27.1	3.5	100
Textiles, Clothing and Leather Goods	33.6	51.5	14.9	100
Woodwork, Paper and Diverse	68.4	26.3	5.3	100
Manufacturing Sectors	52.5	36.7	10.8	100

* Large firms are those having more than 200 permanent workers. Small firms are those having less than 20 permanent workers. Firms that are neither larger nor small are defined as medium size.

Several arguments have been advanced as to why smaller firms might have more problems than larger firms:

- Economies of Scale and Entry Costs: Business obstacles may be particularly severe for small firms because they represent fixed costs that a large firm can absorb more easily. It is useful to distinguish between market and government-induced obstacles. An example of a market-based obstacle for small firms could be financing, since there are fixed costs associated with loan review. Government-induced obstacles could include bureaucratic discretion, since small firms may be unable to bribe their way through bureaucracy.

- Political Influence: Large firms may have more possibilities of collusion, with other firms as well as with the public sector. This means that larger firms might be more successful in influencing politics and obtaining new rules in their favour, and thus gaining advantage over smaller firms.

Conversely, there are several good arguments as to why larger firms may have more problems than smaller firms:

- Informality: Small firms can more easily slip into informal arrangements, thereby avoiding taxes and regulations.

- Exposure: Large firms may be more exposed to corruption since they usually have higher profits than small firms, they are more visible, and they may be more interesting targets for blackmailing and kickbacks.

- Flexibility: Small firms are adept at ascertaining changing consumer tastes with regards to the amount of services that are bundled with a product, or being flexible with regards to other aspects of the product offering.

A number of empirical studies suggest a negative relationship between performance and size, indicating that smaller firms have higher and more variable growth rates which reduce their survival rate (Mansfield, 1962; Hall 1987, Mata, 1994) while other studies (Singh and Whittington, 1975) have found a positive relationship. Indeed, there is no clear picture in support of the views of any theoretical approach concerning the relationships between size and performance emerges.

Between other firm characteristics, the ownership structure and the legal status may be particularly relevant to evaluate economic performances. Table 6 illustrates the legal status of Tunisian manufacturing firms.

Table 6. Legal Status of Tunisian Manufacturing Enterprises (%)

	Uni-corporated	Corporation	Limited liability enterprises	Cooperative or SNC	Total
Food Processing	31.4	20.8	39.8	8.1	100
Construction Materials and Glass	36.0	15.7	48.3	0.0	100
Mechanical and Electrical Goods	14.9	32.8	51.3	0.9	100
Chemical and Rubber	8.2	42.4	47.1	2.4	100
Textiles, Clothing and Leather Goods	8.1	15.4	75.5	1.0	100
Woodwork, Paper and Diverse	23.7	25.7	47.4	3.3	100
Manufacturing Sectors	17.6	22.4	57.8	2.2	100

In terms of legal status, 57.8% of manufacturing firms are limited liability companies (SARL in French) and 22.4% are corporations (SA in French); 17.6% are unincorporated, and 2.2% of firms have another legal status (cooperative or SNC in French). As may be expected, large firms are more likely to have a corporation status; small firms are more likely to be unincorporated (Figure 2).

According to the Tunisian Industry Promotion Agency, in 2002, the total number of enterprises with foreign participation is 1 654 (31.4% of manufacturing firms having 10 or more employees). Of this number, more than half are totally foreign owned and 1 370 (83%) are totally exporting enterprises. Table 7 describes the structure of partnership in manufacturing sectors by countries.

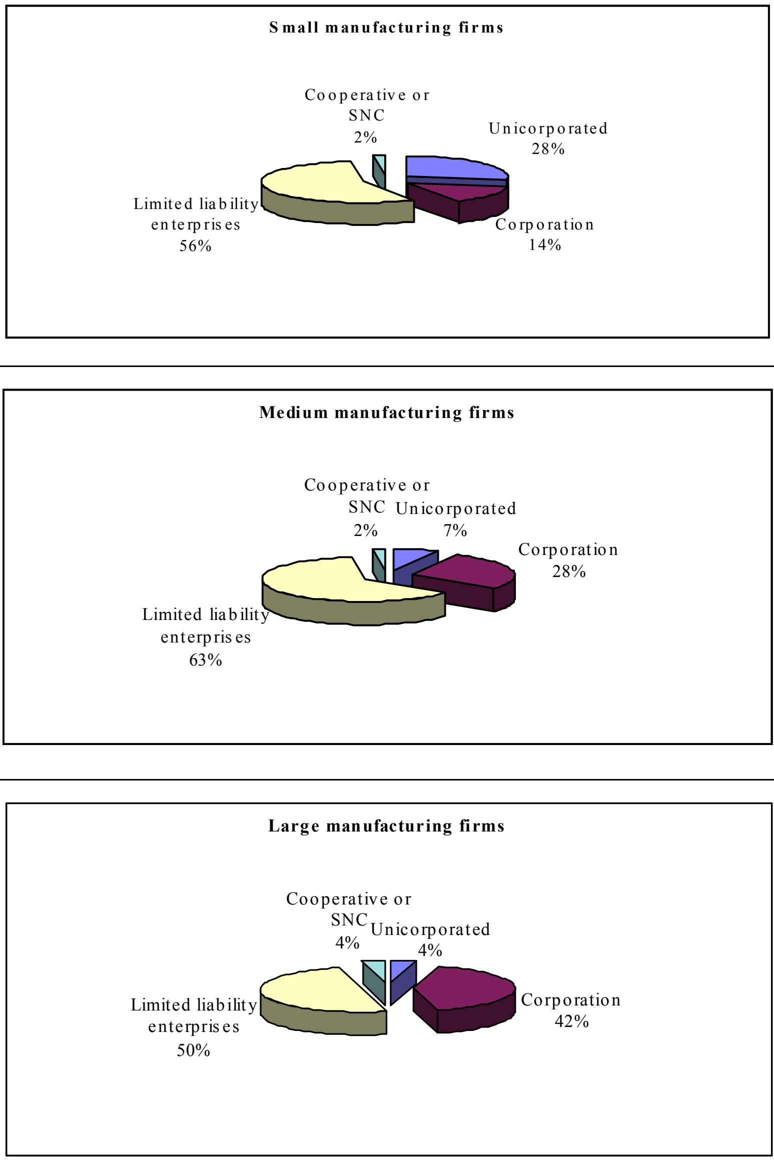

Figure 2. Legal status and size of Tunisian manufacturing firms

Table 7. Structure of Partnership in the Manufacturing Sectors*, 2002

Sectors \ Countries	France	Italy	Germany	Belgium	Other	Total
Food Processing	28	23	1	4	42	98
Building Materials	16	14		2	27	59
Mechanical, Metal	37	20	3	3	34	97
Electrical, Electronics	48	42	30	3	32	155
Chemical Industries	31	9	4	1	30	75
Textiles and Clothing	399	213	139		227	1103
Leather and Shoes	44	48	7	7	26	132
Wood Industries	12	8	1	4	7	32
Diverse Industries	42	19	12	5	23	101
Total	657	396	197	154	448	1852

* N.B. An enterprise may be counted for a number of times.

Source: Industry Promotion Agency (API, 2002)

Trade liberalization has placed additional pressures on industries pushing many manufacturing firms to open their capital to investors particularly in terms of partnership with foreign firms.

Econometric Approach

Efficiency and Performance

Traditionally, the analysis of firm performance has been done using conventional financial ratios such as the return on equity, return on assets, expense to premium ratios, etc. With the rapid evolution of frontier efficiency methodologies, the conventional methods are rapidly becoming obsolete. Frontier methodologies measure firm performance relative to "best practice" frontiers consisting of other firms in the industry. Such measures dominate traditional techniques in terms of developing meaningful and reliable measures of firm performance. They summarize firm performance in a single statistic that controls for differences among firms in a sophisticated multidimensional framework that has its roots in economic theory.

Efficiency is normally defined as comprising of two components: (a) productive or technical efficiency; and (b) economic efficiency. Productive efficiency examines levels of inputs relative to levels of outputs. To be productively efficient, a firm must either maximize its outputs given its input quantities, or minimize its inputs given outputs. Productive inefficiency occurs if a firm is not obtaining maximal output from a set of inputs. Economic efficiency is somewhat broader in that it involves optimally choosing the levels and mixes of inputs and/or outputs based on reactions to market prices. To be economically efficient, a firm seeks to optimize some economic goal, such as cost minimization or profit maximization. In this sense, economic efficiency requires both productive efficiency and allocative efficiency. Allocative inefficiency occurs when a firm fails to choose the optimal balance of inputs given inputs prices, even though it may be obtaining maximal output from the inputs actually used.

Thus, it is quite plausible that some productively efficient firms are economically inefficient, and vice versa. Such efficiency mismatches depend on the relationship between the managers' abilities to utilize the best technologies and their abilities to respond to market signals. Productive efficiency requires only input and output data, whereas economic efficiency also requires market price data.

Frontier efficiency methodology was developed specifically to measure relative productive efficiency, which is the focus of this paper. Frontier efficiency methodologies are useful in a variety of contexts:

- Testing economic hypotheses: For example, both agency theory and transactions cost economics generate predictions about the likely success of firms with different characteristics in attaining objectives such as cost minimization or profit maximization under various economic conditions. Firm characteristics that are likely to be important include organizational form, distribution systems, corporate governance, and vertical integration. Frontier methodologies have been used to analyze a wide range of such hypotheses.

- Providing guidance to regulators and policy makers regarding the appropriate response to problems and developments in an industry.

- Informing management about the effects of policies, procedures, strategies, and technologies adopted by the firm. Although firms currently employ a variety of benchmarking techniques, frontier analysis can provide more meaningful information than conventional ratio and survey analysis, which often overwhelms the manager with masses of statistics that are difficult to summarize conveniently in terms of one or a few performance measures. Frontier analysis may be used not only to track the evolution of a firm's productivity and efficiency over time but also to compare the performance of departments, divisions, or branches within the firm.

Frontier Methodologies for Estimating Efficiency: Panel Analysis

The first studies which aimed to investigate the determinants of technical inefficiencies used a two-stage approach in order to estimate the determinants of technical inefficiencies (Pitt and Lee, 1981; Kalirajan, 1981). Hence, in the first stage a stochastic production frontier was estimated and the individual technical efficiencies obtained and, in the second stage, the predicted inefficiency effects were regressed on a set of variables in order to find their determinants.

Several problems with this two-stage approach have been pointed out in the literature: (a) Firstly, whereas in the first-stage the inefficiency effects are assumed to be independently and identically distributed, in the second-stage the predicted values of inefficiency are assumed to be a function of a number of firm-specific factors, which implies that they are not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero (Coelli, Rao and Battese, 1998); (b) Secondly, the standard ordinary least square results in the second-stage may not be appropriate since the dependent variable, i.e. technical inefficiency, is one-sided; (c) Thirdly, the estimated value of technical inefficiency should be non-positive for all observations; and (d) Finally, the residual term in the second-stage regression does not have a clear meaning (Kumbhakar et al., 1991).

Battese and Coelli's (1995) approach takes into account this problem by modelling inefficiency effects as an explicit function of some firm-specific factors and estimating all the parameters in a single-stage analysis, thus avoiding the inconsistency in the assumptions with respect to the independence of the inefficiency effects in the two-stage estimation. The problems associated with the two-stage estimation may be overcome using one-stage estimation with more general specification of the technical inefficiency effects. Hence, in these models, the technical inefficiency effects are specified as having two components: (a) a deterministic component explained by a vector of observable factors; and (b) a random component representing unobserved factors (Kumbhakar et al., 1991).

The study adopts this approach in order to estimate and investigate their determinants. For this purpose, a stochastic frontier production function for panel data is proposed, which has firm effects assumed to vary systematically with time, and in which the inefficiency effects are directly influenced by number of variables.

Assuming that the relationship between inputs (X_{it}) and outputs (Q_{it}) may be approximated by a production function that is known to the firm i for the year t, than the firm-specific production frontier corresponding to the best practice function is defined as follows:

$$Q_{it}^F = F(X_{it}, t), \qquad (1)$$

where Q_{it}^F is the potential output level on the frontier at time t for firm i, given the technology F(.), assumed to be continuous, strictly increasing and quasi-concave, and X_{it} is a k order vector of inputs.

Following Nishimizu and Page (1982), a stochastic element may be introduced in the production function. Then, any observed output Q_{it} using for inputs X_{it} may be expressed as:

$$Q_{it} = F(X_{it}, t)\exp\{v_{it} - u_{it}\} \qquad (2)$$

where $(v_{it} - u_{it})$ is composed error term combining a symmetric component v_{it} capturing random variation across firm and random shocks that are external to its control, and output-based technical inefficiency or efficiency error u_{it}

accounting for production loss due to unit-specific technical inefficiency. u_{it} is always greater than or equal to zero[(4)] and assumed to be and independent of the random error, v_{it}, which is assumed to have the usual properties (~iid $N(0,\sigma_v^2)$).

For the empirical analysis purpose, a parametric approach[(5)] is adopted by considering the time-varying stochastic production frontier in translog form as[(6)]:

$$LnQ_{it} = \alpha_0 + \alpha_L LnL_{it} + \alpha_K LnK_{it} + \frac{1}{2}\beta_{LL}(LnL_{it})^2 + \frac{1}{2}\beta_{KK}(LnK_{it})^2 + \beta_{LK}(LnL_{it})(LnK_{it})$$
$$+ \beta_{tL}(LnL_{it})t + \beta_{tK}(LnK_{it})t + \alpha_t t + \frac{1}{2}\beta_{tt}t^2 + (v_{it} - u_{it}) \qquad (3)$$

where Q_{it} corresponds to the value-added.

The distribution of technical inefficiency effects is taken to be the non-negative truncation of the normal distribution N(m_{it} , σ_u^2), where:

$$m_{it} = Z_{it}\delta , \qquad (4)$$

δ is a 1xp vector of parameters to be estimated, and Z_{it} a px1 vector of variables which may influence the efficiency of a firm i.

Given the estimates of parameters in Equations 3 and 4, the technical efficiency level of firm i at time t is then defined as the ratio of its means, given its realized firm effect, to the corresponding mean potential output,

$$TE_{it} = \frac{E(Q_{it}/u_{it}, L_{it}, K_{it})}{E\left(Q_{it}^F / L_{it}, K_{it}\right)} = \exp\{-u_{it}\}, \qquad (5)$$

The rate of technical progress TP_{it} is defined by:

$$TP_{it} = \frac{\partial LnF(L_{it}, K_{it}, t)}{\partial t} = \alpha_t + \beta_{tt}t + \beta_{tL}(LnL_{it}) + \beta_{tK}(LnK_{it}) \qquad (6)$$

If technical change is non-neutral then TP_{it} may vary for different input vectors. Hence, following Coelli, Rao & Battese (1998), the geometric mean between adjacent periods as a proxy is used:

$$TP_{it} = \sqrt{\left(1 + \frac{\partial LnF(L_{it}, K_{it}, t)}{\partial t}\right)\left(1 + \frac{\partial LnF(L_{it}, K_{it}, t+1)}{\partial (t+1)}\right)} - 1 \qquad (7)$$

Taking logs of Equation 2 and totally differentiating it:

---

(4) If $u_{it} = 0$, then the production activity of the considered firm is achieved at perfectly efficient levels.

(5) There are two principal types of efficiency methodologies – the econometric (parametric) approach and the mathematical programming (non-parametric) approach. While the non-parametric method is attractive in that it does not require any parametric assumptions about the functional relationship between inputs and outputs, an important disadvantage of this procedure is that the computed inefficiency scores are very sensitive to measurement errors either in output or the input variables. Therefore, this method is not very well suited to survey data sets and consequently not used in this paper. The primary advantage of the econometric approach is that it allows firms to be off due to random error as well as inefficiency. However, this methodology is vulnerable to errors in the specification of the functional form or error term(s).

(6) In most industries, the exact functional form is not known. This led economists to use various approximations such as the well-known Cobb-Douglas and constant elasticity of substitution (CES) production functions. One of the most important developments in the evolution of parametric frontier modelling was the introduction of the translog production function by Christensen, Jorgenson and Lau (1973). They reasoned that even though the functional form may be unknown, any function satisfying rather weak regularity conditions may be expanded as a single or multi-variate Taylor series. They proposed the use of a second-order Taylor expansion in natural logarithms as an approximation of the unknown production function.

$$\dot{Q}_{it} = \frac{dLnF(L_{it},K_{it},t)}{dt} - \frac{du_{it}}{dt} + \frac{dv_{it}}{dt}$$
$$== \frac{\partial LnF(L_{it},K_{it},t)}{\partial t} + \sum_{J=K,L} \frac{\partial LnF(L_{it},K_{it},t)}{\partial J_{it}} \frac{dJ_{it}}{dt} - \frac{du_{it}}{dt} \quad (8)$$
$$= TP_{it} + \sum_{J=K,L} e_{it}^{J} \frac{dJ_{it}}{dt} - \frac{du_{it}}{dt}$$

The second term on the right-hand side of Equation 8 measures the input growth weighted by output elasticities e_{it}^{J} with respect to input J.

The conventional conceptualization of total factor productivity growth ($T\dot{F}P$) may be defined as output growth unexplained by inputs, i.e.:

$$T\dot{F}P \equiv \dot{Q}_{it} - \sum_{J=K,L} e_{it}^{J} \frac{dJ_{it}}{dt} \quad (9)$$

In Equation 9, the output elasticities with respect to input J is supposed to be equal to input share in the total production cost under the assumption of perfect competition.

From Equations 8 and 9, TFP growth consists of two components: technical progress, which corresponds to innovation and shifts in the frontier technology, and technical efficiency change or catching-up effect:

$$T\dot{F}P = TP_{it} - \frac{du_{it}}{dt} \quad (10)$$

The technical efficiency change (ΔTE_{it}) denotes movement toward or away from the frontier. It corresponds to the derivative of the negative of the inefficiency measure with respect to time.

The decomposition of TFP growth is useful in distinguishing innovation or adoption of new technology by best practice firms from the diffusion of technology. Coexistence of a high rate of TP and a low rate of change in technical efficiency may reflect the failures in achieving technological mastery or diffusion (Kalirajan, Obwona and Zhao, 1996).

With the translog, the elasticities of output with respect to labor and capital, respectively, may be estimated at each time period and at the mean inputs values across the sample (or sectoral sub-sample), ($\widetilde{L},\widetilde{K}$), as:

$$e_t^{L} = \alpha_L + \beta_{LL} Ln\widetilde{L}_t + \beta_{LK} Ln\widetilde{K}_t + \beta_{tL} t \quad (11)$$

and,

$$e_t^{K} = \alpha_K + \beta_{KK} Ln\widetilde{K}_t + \beta_{LK} Ln\widetilde{L}_t + \beta_{tK} t \quad (12)$$

So, returns to scale may be computed as: $e_t = e_t^{L} + e_t^{K}$. An e_t < 1, = 1, and > 1 indicates decreasing, constant, and increasing returns to scale, respectively.

Taking into account the possibility of increasing or decreasing returns to scale, TFP growth is then the sum of the following three terms:

$$T\dot{F}P = \underbrace{TP_{it}}_{\text{Technological Progress Affect}} + \underbrace{\Delta TE_{it}}_{\text{Catching-up Effect}} + \underbrace{(e_t - 1)\left[\frac{e_t^{K}}{e_t}\Delta K_{it} + \frac{e_t^{L}}{e_t}\Delta L_{it}\right]}_{\text{Returns to Scale Effect}} \quad (13)$$

Increasing K and L by x% will increase output by more than x% if there is increasing returns to scale, and by less than x% if decreasing returns to scale are present. If there are constant returns to scale, then input changes do not affect changes in total factor productivity, and Equation 10 is valid.

Technical Efficiency Change, Openness and Investment

A statistical analysis is performed to identify the determinants of technical efficiency change of the Tunisian manufacturing sector with a focus on the impact associated to investment rate and openness:

Openness and Performance. The relationship between openness and economic performance has long been a subject of controversy. Liberal analysts suggest that free trade would lead to better economic performance, but some economists argue that protectionism may promote faster growth. Recently, while Romer (1986, 1992) and Lucas (1988), among others, propose that openness can have a positive impact on growth, it is sometimes argued that openness may not automatically lead to growth. For instance, Grossman and Helpman (1991) show that whether or not a country gains from openness to trade depends on a number of factors, including its comparative advantage vis-à-vis the rest of the world.

Empirical tests of the openness-performance relationship are usually based on the growth accounting approach. Total factor productivity is estimated from the traditional production function, and then regressed on openness as well as other relevant explanatory variables. The growth accounting approach implicitly assumes economic efficiency, and therefore may be reasonably applied only to equilibrium states and marginal changes over short periods of time. Only some noticeable examples of openness-TFP research include cross-section analyses (Dollar, 1992; Edwards, 1993) and a panel data study (Miller and Upadhyay, 2000).

The current research tries to test the contribution of openness (OPENNESS), based on import penetration ratio by type of manufacturing industry, to gains in efficiency.

Investment and Performance. Accumulation of capital in the manufacturing sector still is of high relevance to the overall growth of a developing economy. Indeed, fixed investment is seen as one of main drivers of factor productivity growth and technological accumulation. Some qualitative case studies of individual firms in developing countries have shown technology accumulation to be positively related to firm performance (Katz, 1987; Dahlman and Fonseca 1987), but wider generalization from these studies is limited.

This paper addresses this gap by investigating the effects of investment effort, evaluated by the ratio of real fixed investment to real value added (INVRATE), on technical efficiency change (ΔTE)[7].

In general terms, and given the previous discussion, the model examining the impact of openness (OPENNESS) and investment effort (INVRATE) on technical efficiency change is specified as follows:

$$\Delta TE_{it} = \gamma_0 + \gamma_1 INVRATE_{it} + \gamma_2 OPENNESS_{it} + \gamma_3 SIZE_{it} + \xi_{it} \ , \qquad (14)$$

where SIZE is the firm size which refer to the number of full-time employees in the firm i at period t and ξ_{it} a classical disturbance term.

Data Issues and Empirical Results

Data Sources and Sample Characteristics

The econometric analysis is applied on a balanced panel of 265 manufacturing firms for which observations exist for all the years because the reliability of the measure of technical efficiency depends crucially upon the length of the time dimension of the panel. Firms are observed for a period of 11 years, from 1984 to 1994. Hence, a total of 2915 observations for 265 firms are used in the analysis. The firms have been selected from the National Annual Survey report on firms carried out by the Tunisian National Statistics Institute (from 1984 to 1994), and data used concerning capital stock, age of capital, and investment, are taken from the Quantitative Economics Institute (IEQ, 2000).

The variables used in the analysis comprise value added, capital stock evaluated at historical values and calculated through perpetual inventory method, total labor used by type of qualification, age of capital, investment, short-term and long-term debts, exports, time invariant characteristics such as activity, whether or not the firm is an exporting. Data were deflated using the appropriate price index, thereby expressing all data in terms of values for 1990. Table 8 provides a descriptive summary of the sample and variables in the data set.

[7] Productivity studies often cover a large sector of the economy, such as the manufacturing sector. These studies then report the impact of aggregate levels of capital investment on the overall manufacturing productivity of the economy.

In empirical studies of production and cost, the use of data aggregated at least to some degree is unavoidable. In order for such aggregation to be consistent with an underlying microeconomic structure that is disaggregated, typically it will be the case that quite severe restrictions must be imposed on the model. The most important types of restriction is separability restrictions ─ he assumption that the production technology is weakly separable may be used to justify the use of value-added measures of output in this paper.

It is important to note that choice between value-added and gross-output production function is nevertheless not innocuous for two reasons: (a) Returns to scale estimated from the value-added production function overstate (understate) the degree of returns to scale in the case of increasing (decreasing) returns. Moreover, differences between estimates may be substantial. For example, Levinsohn and Petrin (1998) estimate value-added production functions for eight Chilean manufacturing sectors and find returns to scale between 1.22 and 1.52. Pavcnik (2002) estimates gross-output production functions and finds returns to scale between 1.06 and 1.13 for the same sectors. (b) Given differences of such magnitude, it might well be the case that a test for constant returns is rejected for the value-added estimates but not for the gross-output estimates.

Table 8. Descriptive Summary of the Sample and Variables

	Industry	Code	Number of firms	Mean Foreign Partici-pation %	Mean Private Local Partici-pation %	Mean State Partici-pation %
Food processing (FPI)	Milk Industry	121	3	38	34	18
	Grain Milling	131	3	0	100	0
	Pasta and Couscous	132	4	0	100	0
	Bread and Pastries	133	8	0	100	0
	Biscuits	134	1	0	100	0
	Canned Vegetables and Fruits	151	4	0	100	0
	Canned Fish	152	1	0	100	0
	Sugar Industry	161	3	22	42	36
	Miscellaneous Food Industries	171	6	12	74	6
	Animal Feed	172	2	0	100	0
	Non-alcoholic Beverages	181	5	46	52	3
	Wine	182	1	0	100	0
Construction materials and glass (CMGI)	Quarry Products	211	2	50	50	0
	Stone and Marble Polished	212	7	0	100	0
	Cement and Plaster	221	1	0	1	99
	Cement-based Products	222	8	0	100	0
	Brick Industry	231	6	8	86	4
	Tile Industry	232	3	10	46	45
	Glass Industry	241	4	0	100	0
Mechanical and electrical goods (MEGI)	Iron and Steel	311	1	0	100	0
	Metal and Semi-products Non-ferrous	312	1	72	28	0
	Foundries	313	1	37	0	9
	Forge Products	321	4	0	100	0
	Metallic Construction and Boilerworks	322	9	0	88	0
	Quincaillerie	324	5	0	100	0
	Metallic Household Appliances	325	3	0	67	0
	Agricultural Machinery	331	1	0	100	0
	Industrial Machinery	332	3	0	100	0
	Spare Parts For Cars	341	1	0	100	0
	Boats And Repairing	351	1	1	1	98
	Electrical Equipment	361	4	0	96	0
	Miscellaneous Electrical Equipement	362	3	0	100	0

	Electronic Professional Equipement	371	3	33	67	0

Chemical And Rubber (CRI)	Fertilizers	411	2	47	10	40
	Base Chemical Products	422	2	0	79	0
	Paint, Ink, Glue and Colorants	431	7	0	96	0
	Soap, Detergents and Disinfectants	432	9	0	100	0
	Perfumes and Toiletry	433	7	0	100	0
	Miscellaneous Para-Chemicals	434	1	0	100	0
	Tires and Rubber Products	451	2	0	100	0
Textiles, Clothing And Leather Goods (TCLGI)	Textile Spinning	511	5	0	100	0
	Textile Weaving	512	23	1	96	1
	Other Textiles	513	4	0	99	0
	Carpet	521	1	0	100	0
	Underwear	531	7	0	90	0
	Apparel	541	31	0	63	0
	Leather and Skin Work	551	2	0	100	0
	Other Leather and Plastic Products	552	3	33	67	0
	Footwear	553	6	0	67	0
Woodwork, Paper And Diverse (WPDI)	Wood Products	611	2	18	78	5
	Building Carpentry	612	1	0	100	0
	Bedding Furniture	613	7	18	75	0
	Paper Pulp and Cardboard	621	2	0	50	50
	Packaging	622	2	0	96	0
	Paper-Making	623	2	0	100	0
	Printing Works	624	8	4	75	21
	Plastic Products	631	13	0	100	0
	Miscellaneous Products	641	4	0	50	0

Lack of data is one of the reasons behind the measurement of performance based on the value added function. Indeed, construction of data on intermediate inputs of energy and materials by industry is difficult. The problems arise from the low quality of the underlying data. Intermediate inputs into any one sector include inputs from other sectors. To obtain the proper measure of intermediate inputs, the disaggregated intermediate inputs must be weighted by their marginal products in order to calculate the composite intermediate input. The other reason of performance measurement based on the value added approach is that intermediate consumptions compensate themselves in make and use. However the way intermediate consumptions are used is not equal among sectors.

Empirical Results

The parameters of the translog stochastic frontier model, defined by Equations 3 and 4, are simultaneously estimated by the maximum likelihood method using the computer program, FRONTIER Version 4.1, designed by Coelli (1996). The program provides maximum-likelihood estimates of the parameters and predicts technical efficiencies. It uses the following parameterization:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{, and } \gamma = \sigma_u^2 \big/ (\sigma_v^2 + \sigma_u^2) \text{,}$$

The parameter γ must lie between zero and one. If the hypothesis $\gamma = 0$ is accepted, this would indicate that σ_u^2 is zero and thus the efficiency error term, u_{it}, should be removed from the model, leaving a specification with parameters that may be consistently estimated by OLS. Conversely, if the value of γ is one, it is a full-frontier model, where the stochastic term is not present in the model.

Throughout this paper, it is assumed that production function parameters are the same across all the sectors in the manufacturing industry, given data limitations for some sectors. An interesting extension would be to relax this assumption. This maybe done for instance, within a model in which heterogeneity in both the slope coefficients representing the scale properties (random input elasticities) as well as the intercept term is allowed for. However, to do this, a minimum number of observations for each plant is needed to estimate the plant specific parameters properly. Also, it is important to note that for this type of extension (random coefficient approach), and in order to avoid over parameterization and the degrees of freedom problem, specific assumptions have to be made about the distribution from which the plant specific coefficients are drawn.

Hypotheses Tests and Model Selection. For the reason of a high level of multicollinearity due to the presence of the squared and interaction term in the generalized translog function (Equation 3), many parameters could turn to be insignificant to the usual t-test even if they are non-zero. As a consequence, it is preferable not to look at the single t-ratios but to carry out the generalized likelihood-ratio (LR) test to involve more than one parameter at the same time(8). Therefore, several generalised LR tests of null hypothesis involving restrictions on the parameters in both the frontier and the inefficiency models were performed and are presented in Table 9.

Table 9. Likelihood Ratio for Hypothesis Tests

Null Hypothesis	Test Statistic	Critical value at 5%	Decision
Cobb-Douglas production function H_0 : all $\beta_{ij} = 0$	176.54	12.59	reject
No technical change $H_0 : \alpha_t = \beta_{tt} = \beta_{tK} = \beta_{tL} = 0$	37.52	9.49	reject
Neutral technical progress $H_0 : \beta_{tK} = \beta_{tL} = 0$	3	5.99	accept
No technical inefficiency $H_0 : \gamma =$ all $\delta_j = 0$	115.48	7.045*	reject

* The critical value for the test is obtained from Table 1 of Kodde and Palm (1986)

The first three tests consider the frontier function. The first null hypothesis specifies that the second-order coefficients in the translog stochastic frontier function are equal to zero, which means that the Cobb-Douglas technology applies. The value of the generalised LR statistic for this test, as seen in Table 9, is calculated to be 176.54, which is much larger than the critical value of 12.59, the upper 5% point for the chi-square distribution with 6 d.f. Given the assumption of the translog stochastic frontier production function, Cobb-Douglas technology is rejected as an adequate representation of the data on Tunisian manufacturing firms.

The second null hypothesis of no technical change is strongly rejected by the data given the value of LR statistic, 37.52 much larger than the critical value 9.49 for the chi-square distribution with 4 d.f. The third null hypothesis concerns the neutral technical progress. This null hypothesis is accepted (LR statistic, 3, smaller then the critical value 5.99).

The remaining test considers restrictions on the parameters in the inefficiency model. The null hypothesis (no technical inefficiency) states that the inefficiency effects are absent from the model, suggesting that firms are fully technically efficient. This null hypothesis of no inefficiency effects is strongly rejected by the data. Indeed, LR statistic evaluated at 115.48 is much larger than, 7.045, the critical value obtained from Table 1 of Kodde and Palm (1986). Since this hypothesis is rejected, the significance of the variables that explain technical inefficiency is confirmed.

Stochastic Production Frontier Estimation Results. Given the specifications of translog frontier with inefficiency effects expressed as an explicit function of firm-specific variables, and a random error, and given the results

(8) The generalised likelihood-ratio test statistic is defined by $\lambda = -2(\lambda(H_0) - \lambda(H_1))$ where $\lambda(H_0)$ is the log-likelihood value of a restricted frontier model, as specified by a null hypothesis, and $\lambda(H_1)$ is the log-likelihood value of the general frontier model under the alternative hypothesis. This test statistic has approximately a chi-square (or a mixed chi-square) distribution with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypothesis. If the inefficiency effects are not present in the model, as specified by the null hypothesis, H_0: $\gamma = \delta_j = 0$ for j=1,…,p, (p corresponds to the dimension of vector δ) then the statistic, λ, is approximately distributed according to a mixed chi-square distribution. In this case, critical values for the generalised likelihood-ratio test are obtained from Table 1 in Kodde and Palm (1986).

of statistical tests on the estimated parameters, the preferred frontier models are chosen and the estimates of their parameters are given in Table 10.

Elasticities of mean output with respect to two input variables, labor and capital stock, are estimated at the mean values of the variables involved, by using Equations 11 and 12. It should be noted that labor effort is a flow input variable while capital is a stock input variable, which excludes the possibility of direct comparison. Returns to scale range from 1.017 to 1.075. The detailed information on returns to scale is presented in Table 11. It shows that the sum of inputs elasticities is always close to unity and the hypothesis of constant returns to scale is accepted in all years, and for all sectors(9) . Thus, over the full period, it seems unlikely that firm size is a major cause of inefficiency in manufacturing.

The elasticity of output with respect to labor is higher for the Textile, Clothing and Leather Goods firms than the other sectors. It ranges from 0.702 to 0.726, which reflects the high labor-use in this sector.

Although the null hypothesis concerning whether inefficiency effects are non-stochastic and whether technical inefficiency effects are absent is rejected, the estimated value of the parameter γ, which is significantly different from zero at 1% level, is very small. This result indicates that the inefficiency effect explains only a limited fraction of the deviations from the frontier output. Thus, assumption of firms operating at near to full efficiency is not necessarily implausible, particularly in the period 1990-1992 where the mean technical efficiency is situated at 90% (see Figure 3).

Table 10. Maximum Likelihood Estimates of Parameters in Equations 3 And 4

Variable	Parameter	Coefficient	Standard Error	T-ratio
Constant	α_0	4.415	0.233	18.967*
Log(L)	α_L	2.089	0.113	18.530*
Log(K)	α_K	-0.727	0.097	-7.476*
Log(L)²	β_{LL}	0.099	0.028	3.530*
Log(K)²	β_{KK}	0.135	0.011	12.063*
Log(L)*Log(K)	β_{LK}	-0.293	0.029	-10.030*
Time	α_t	-0.070	0.015	-4.621*
Time²	β_{tt}	0.005	0.001	4.561*
Inefficiency determinants				
Constant	δ_0	0.358	0.046	7.860*
Dummy FPI	δ_1	-0.107	0.016	-6.570*
Dummy CMGI	δ_2	0.115	0.017	6.744*
Dummy MEGI	δ_3	-0.100	0.015	-6.509*
Dummy CRI	δ_4	-0.013	0.016	-0.782
Dummy TCLGI	δ_5	0.021	0.014	1.521

(9) In general, the use of individual firm data, instead of the mean values, doesn't yield different results. The firm level returns to scale distribution by year is reported in the following table:

Returns to scale distribution (Frequency in %)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Less than 0.96	5.3	5.3	5.3	5.3	6.0	6.4	6.8	6.8	6.0	6.0	5.7
from 0.96 to 1.08	52.8	51.3	52.8	52.5	52.8	52.5	53.6	54.0	52.8	54.3	54.3
from 1.08 to 1.2	41.1	42.6	40.8	41.5	40.4	40.4	39.2	38.9	40.4	38.9	39.2
more than 1.2	0.8	0.8	1.1	0.8	0.8	0.8	0.4	0.4	0.8	0.8	0.8

So, more than 90 % of firms have an estimated returns to scale between 0,96 and 1,2. Given this distribution, it might well be the case that a test for constant returns is accepted.

Rate of skilled workers	δ_6	-0.455	0.038	-12.089*
Dummy FOREIGN	δ_7	-0.097	0.021	-4.524*
Age of capital AGEK	δ_8	0.013	0.002	6.214*
Dummy Firm size<100 employees	δ_9	0.033	0.013	2.455*
Dummy State participation > 25%	δ_{10}	-0.085	0.029	-2.939*
Dummy 1985	δ_{11}	-0.088	0.022	-3.998*
Dummy 1986	δ_{12}	-0.177	0.028	-6.217*
Dummy 1987	δ_{13}	-0.212	0.034	-6.321*
Dummy 1988	δ_{14}	-0.241	0.038	-6.329*
Dummy 1989	δ_{15}	-0.273	0.041	-6.729*
Dummy 1990	δ_{16}	-0.305	0.043	-7.078*
Dummy 1991	δ_{17}	-0.319	0.043	-7.506*
Dummy 1992	δ_{18}	-0.313	0.041	-7.726*
Dummy 1993	δ_{19}	-0.270	0.036	-7.548*
Dummy 1994	δ_{20}	-0.216	0.034	-6.318*
sigma-squared	σ^2	0.038	0.001	35.138*
Gamma	γ	0.062	0.015	4.185*
Log-likelihood		653.629		

* Significant at 5% level.

Table 11. Elasticities and Returns to Scale by Year

	1984	1990	1994	1984-1994
Elasticities with Respect to Labor				
Food Processing	0.566	0.583	0.583	0.576
Construction Materials and Glass	0.574	0.583	0.576	0.575
Mechanical and Electrical Goods	0.657	0.646	0.642	0.648
Chemical and Rubber	0.635	0.618	0.610	0.620
Textiles, Clothing and Leather Goods	0.722	0.718	0.726	0.716
Woodwork, Paper and Diverse	0.669	0.659	0.636	0.655
Elasticities With Respect To Capital				
Food Processing	0.496	0.471	0.469	0.480
Construction Materials and Glass	0.444	0.434	0.452	0.445
Mechanical and Electrical Goods	0.382	0.388	0.397	0.389
Chemical and Rubber	0.423	0.435	0.446	0.437
Textiles. Clothing and Leather Goods	0.352	0.352	0.343	0.356
Woodwork. Paper and Diverse	0.385	0.389	0.408	0.395
Returns to Scale				
Food Processing	1.062	1.054	1.052	1.056
Construction Materials and Glass	1.018	1.017	1.028	1.020
Mechanical and Electrical Goods	1.038	1.034	1.039	1.036
Chemical and Rubber	1.058	1.054	1.057	1.057
Textiles. Clothing and Leather Goods	1.073	1.070	1.069	1.072
Woodwork. Paper and Diverse	1.054	1.048	1.043	1.049

It may be seen that, in accordance with theoretical studies which generally suggest positive externalities from inflows of foreign capital to the host countries, efficiency (inefficiency) of manufacturing firms increases (decreases) with the prevalence of foreign participation (the sign of coefficient of inefficiency effect of FOREIGN is negative and significant at 5% level). The same goes for the effect of training rate variable (TRAIN) which is a highly significant contributor to technical efficiency. Given the absence of data on employees schooling, this variable may be considered as a proxy of human capital in each firm. There is also some evidence, showing that state participation (STATE) is not conducive to technical inefficiency. Furthermore, the result shows small and medium firm size (SMSIZE), likewise age of capital (AGEK), appears to have a negative and significant influence on technical efficiency.

The average technical efficiency, calculated by using Equation 5, ranges from 0.62 to 0.96. Figure 3 shows that the average efficiency score improved at first, recovered to a peak level in 1991, and fell in the last three years.

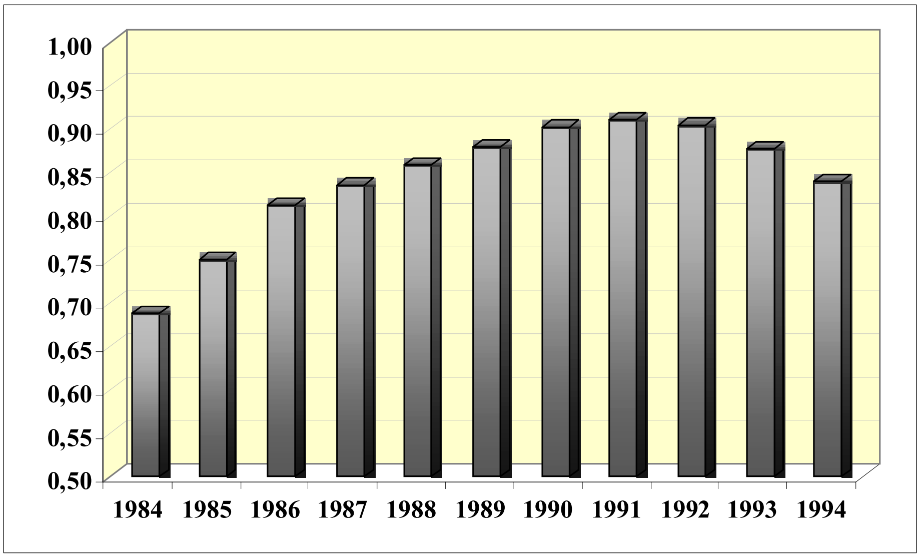

Figure 3. Trend of technical efficiency of Tunisian manufacturing firms

As Figure 4 illustrates, the mean technical efficiency is high for firms belonging to Food Processing and Mechanical and Electrical Goods sectors. The detailed information on mean technical efficiency is presented in Table 12.

The decomposition of total factor productivity change into technical efficiency change and technical change, by using Equation 10, gives the possibility to understand whether the industries have improved their productivity levels simply through a more efficient use of existing technology or through technical progress. Growth in efficiency change may also be considered as an indicator of industry's performance in adapting the technology. The mean changes in efficiency and TFP of manufacturing industries are presented in Table 13.

The results reveal a steady decline in technical efficiency since 1991, which concerns all manufacturing firms and principally firms belonging to Textiles, Clothing and Leather Goods and Woodwork Paper and Diverse sectors.

The average total factor productivity growth for the period 1985-94 has been positive and sluggish across al the industries (mean TFP rate of growth of 0,51%). A comparison of TFP growth over time shows that it improved significantly in the sub-period 1990-1992, for all industries. The end of the period is marked by a decline in TFP growth rate particularly in the industry groups like Textiles Clothing and Leather Goods and Woodwork Paper and Diverse.

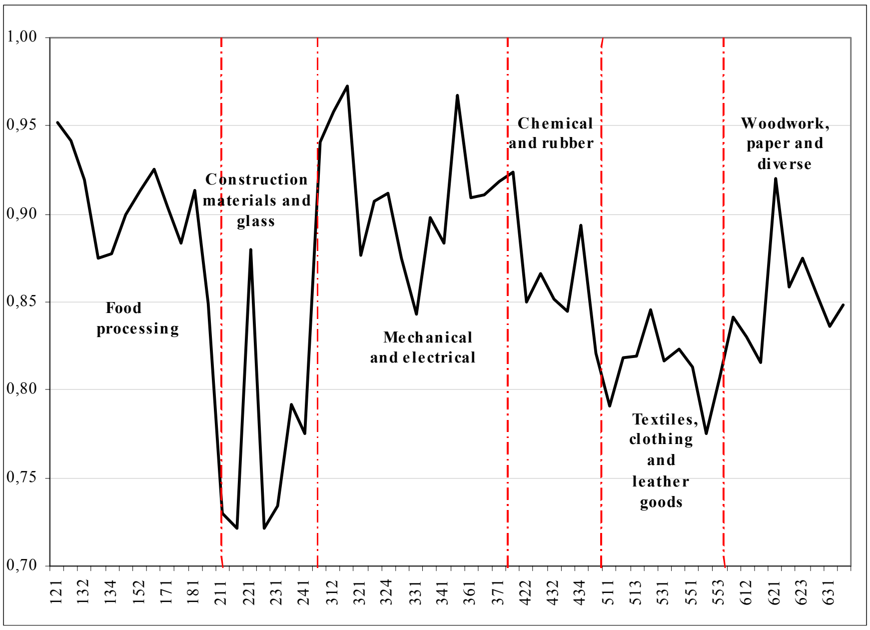

Figure 4. Mean technical efficiency in the Tunisian manufacturing industry by sector 1984-1994

Table 12. Mean Technical Efficiency of Manufacturing Firms by Year (%)

	Mean Technical Efficiency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Food Processing	90	77	83	89	90	92	93	95	96	96	94	89
Construction Materials and Glass	76	62	68	73	75	77	80	82	83	82	79	77
Mechanical and Electrical Goods	91	76	83	89	91	93	94	96	96	96	94	92
Chemical and Rubber	86	68	75	83	86	88	90	93	94	93	91	87
Textiles. Clothing and Leather Goods	81	65	71	77	79	82	85	88	89	88	85	80
Woodwork. Paper and Diverse	85	69	76	82	85	87	89	91	92	92	89	84
Total Manufacturing Sector	84	69	75	81	84	86	88	90	91	90	88	84

Table 13. Efficiency Change and TFP Change in Manufacturing Industries (%)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1985 - 1994
Efficiency Change											
Food Processing	5.6	6.3	0.8	1.9	1.7	1.3	0.9	-0.1	-2.0	-4.2	1.2
Construction Materials and Glass	5.5	5.3	2.3	1.7	3.0	2.5	1.1	-1.2	-3.3	-2.2	1.5
Mechanical and	7.6	5.6	2.1	2.1	1.3	1.9	0.0	-0.5	-1.8	-2.5	1.6

Electrical Goods											
Chemical and Rubber	6.5	8.5	2.3	2.2	2.1	2.6	1.1	-0.6	-2.3	-4.2	1.8
Textiles, Clothing and Leather Goods	5.6	5.8	2.8	2.8	2.6	2.8	0.9	-0.6	-2.8	-4.9	1.5
Woodwork, Paper and Diverse	6.6	6.1	2.7	2.0	2.6	2.2	0.7	-0.3	-3.1	-4.8	1.5
TFP Change											
Food Processing	0.1	1.8	-2.7	-0.6	0.2	0.8	1.4	1.4	0.5	-0.7	0.2
Construction Materials and Glass	0.0	0.8	-1.2	-0.8	1.5	2.0	1.6	0.3	-0.8	1.3	0.5
Mechanical and Electrical Goods	2.1	1.1	-1.4	-0.4	-0.2	1.4	0.5	1.0	0.7	1.0	0.6
Chemical and Rubber	0.9	4.0	-1.2	-0.3	0.6	2.1	1.6	0.9	0.1	-0.7	0.8
Textiles, Clothing and Leather Goods	0.1	1.3	-0.7	0.3	1.1	2.3	1.4	0.8	-0.3	-1.4	0.5
Woodwork, Paper and Diverse	1.1	1.6	-0.8	-0.5	1.1	1.7	1.2	1.2	-0.6	-1.3	0.5

The main results of Ghali and Mohnen[(10)] non-parametric approach are in line with the findings of this study:

- Over the whole sample period of the study of Ghali and Mohnen (2003) of 1983-1996, frontier TFP growth hardly increased in Tunisia (0.2% per year). The mean TFG growth realized in manufacturing industries corresponds to 0.45%. In this paper, this poor global performance is also observed over the period (1985-1994) as described in Table 13. The mean TFP change in manufacturing sector is 0.51% per year.

- The decomposition of frontier TFP growth in Table 1 of Ghali and Mohnen (op. cit) which reveals that the efficiency component rose about 1,6% per year in the sub-period 1986-1991 and then regressed in the sub-period 1991-1996 to reach an annual growth rate of -1,1%. This result which concerns the economy as a whole is in line with the results of study in the manufacturing sector (Table 12 and Figure 3).

- Ghali and Mohnen declare that "…the adjustment program was successful in increasing the efficiency of the Tunisian economy, In 1991-1996, Tunisia moved closer to its efficiency frontier, Changes in the slacks in resource utilization played only a minor role." This statement supports the findings of this study regarding the steady increases in technical efficiency from 1984 to 1991.

Technical Efficiency Change Determinants. The import penetration rate ─ defined by the ratio of real imports to real apparent consumption of manufactured goods (domestic production minus exports plus imports) ─ is used to measure openness in the considered sector in the current study, Based on disaggregated import penetration rates from 1984 to 1994, the following industries: Mechanical and Electrical Goods (Mean import penetration rate of 1,68), Chemical and Rubber (1,201) and Textiles, Clothing and Leather Goods (0,557) are more exposed to import competition than Food Processing (0,211) ; Construction Materials and Glass (0,198) ; and Woodwork, Paper and

[(10)] The Ghali and Mohnen approach consist of endogenizing commodity and factor prices by finding the frontier of the economy subject to its fundamentals, namely endowments, technology, and preferences. Endowments are represented by the labor force, the accumulated stocks of capital and the trade deficit. Technology is given by the combined inputs and outputs of the various sectors of the economy. Preferences are represented by the commodity proportions of domestic final demand. Compared to frontier analysis approach applied in this paper, the authors use a non-parametric linear programming based technique *a la* DEA, but efficiency change is not based on cross-sectional or intertemporal benchmarking, but on sectoral efficiency-improving reallocations of factors of production within a multi-sectoral economy model. This approach is used to measure, to explain the frontier total factor productivity growth in Tunisia over the period 1983-1996 and to decompose this aggregate TFP growth into changes of technology, terms of trade, efficiency and resource utilization.

Diverse (0,435), Table 14 presents more information about import penetration rate at 3-digit level Standard Industrial Classification (SIC) data in the manufacturing sectors.

Table 14. Import Penetration in the Tunisian Manufacturing Sectors

	Industry	Code	1984-1989	1990-1994
Food processing (FPI)	Milk Industry	121	0.401	0.264
	Grain Milling	131	0.015	0.007
	Pasta and Couscous	132	0.000	0.000
	Bread and Pastries	133	0.000	0.001
	Biscuits	134	0.001	0.003
	Canned Vegetables and Fruits	151	0.024	0.014
	Canned Fish	152	0.005	0.010
	Sugar Industry	161	1.610	2.007
	Miscallaneous Food Industries	171	0.308	0.288
	Animal Feed	172	0.012	0.017
	Non Alcoholic Beverages	181	0.056	0.020
	Wine	182	0.004	0.008
Construction materials and glass (CMGI)	Quarry Products	211	0.439	0.429
	Stone and Marble Polished	212	0.119	0.148
	Cement and Plaster	221	0.027	0.005
	Cement-based Products	222	0.008	0.001
	Brick Industry	231	0.082	0.071
	Tile Industry	232	0.175	0.177
	Glass Industry	241	0.642	0.445
Mechanical and electrical goods (MEGI)	Iron and Steel	311	0.777	0.953
	Metal and Semi-products Non Ferrous	312	1.442	1.866
	Foundries	313	0.487	0.573
	Forge Products	321	0.150	0.124
	Metallic Construction and Boilerworks	322	0.434	0.240
	Quincaillerie	324	0.834	0.533
	Metallic Household Appliances	325	1.168	0.642
	Agricultural Machinery	331	1.417	3.048
	Industrial Machinery	332	9.267	7.695
	Spare Parts for Cars	341	2.814	1.729
	Boats and Repairing	351	0.790	0.970
	Electrical Equipment	361	0.589	0.357
	Miscellaneous Electrical Equipment	362	0.670	0.600
	Electronic Professional Equipment	371	4.049	2.810
Chemical and rubber (CRI)	Fertilizers	411	0.002	0.002
	Base Chemical Products	422	5.459	4.177
	Paint, Ink, Glue and Colorants	431	0.540	0.464
	Soap, Detergents and Disinfectants	432	0.127	0.116
	Perfumes and Toiletry	433	0.227	0.159
	Miscellaneous Para-Chemicals	434	2.514	1.496
	Tires and Rubber Products	451	0.993	0.538
clothing and leather goods	Textile Spinning	511	1.336	1.158
	Textile Weaving	512	1.060	1.495
	Other Textiles	513	0.840	0.912

	Carpet	521	0.002	0.004
	Underwear	531	0.243	0.189
	Apparel	541	0.067	0.070
	Leather and Skin Work	551	1.153	1.197
	Other Leather and Plastic Products	552	0.069	0.123
	Footwear	553	0.049	0.055
Woodwork, paper and diverse (WPDI)	**Wood Products**	611	1.770	1.366
	Building Carpentry	612	0.007	0.002
	Bedding Furniture	613	0.017	0.013
	Paper Pulp and Cardboard	621	0.956	0.953
	Packaging	622	0.093	0.105
	Paper-Making	623	0.063	0.076
	Printing Works	624	0.360	0.426
	Plastic Products	631	0.375	0.367
	Miscellaneous Products	641	0.392	0.482

Source: National Statistics Institute (INS, Statistiques du Commerce Extérieur, 1984-1994)

An extended version of Equation 14, allowing for non-linearity in investment and openness impact on technical efficiency change, for panel data has been estimated including firm-specific fixed-effect α_i, to capture time-invariant influences on a firm's mean level of technical efficiency change over the sample period. To capture economy-wide influences on technical efficiency change that are common to all manufacturing firms in any given year, a set of year time dummies is included.

$$\Delta TE_{it} = \gamma_0 + \gamma_1 INVRATE_{it} + \gamma_2 (INVRATE_{it})^2 + \gamma_3 OPENNESS_{it} + \gamma_4 (OPENNESS_{it})^2 + \gamma_5 (INVRATE_{it})(OPENNESS_{it}) + \gamma_6 SIZE_{it} + \alpha_i + \beta_t + \varepsilon_{it} \quad (15)$$

In this specification, the variable SIZE is defined as a dummy variable equal to 1 if the number of full-time employees in the firm is less than 100 (to characterize small and medium firm in the sample), and 0 otherwise. The variable OPENNESS regards import penetration rate evaluated at a 3-digit level SIC sector-based data.

Fixed-effects OLS estimator is used to obtain estimates of the parameters in Equation 15, the results of which are presented in Table 15.

Table 15. Least Squares with Group Dummy Variables and Period Effects Estimates of Equation 15

Variable	Parameter	Coefficient	Standard-error*	T-ratio	Mean of X
Constant	γ_0	0.016	0.003	5.334	
INVRATE	γ_1	0.007	0.002	4.415	0.347
INVRATE²	γ_2	-0.001	0.000	-3.874	0.5478
OPENNESS	γ_3	0.011	0.004	2.841	0.5499
OPENNESS²	γ_4	-0.001	0.000	-2.303	1.444
INVRATE*OPENNESS	γ_5	0.002	0.001	1.564	0.1813
Small and Medium Firm Size Dummy	γ_6	-0.011	0.003	-3.360	0.6917
Mean of dependent variable				0.01524	
Standard Deviation				0.0393	
Observations				2650	
Degree Freedom				2369	
Adjusted R-squared				0.60559	

* Heteroskedasticity-robust standard errors are reported

The results highlight firstly, the existence of a positive and highly significant association between investment effort of firm and efficiency change. Evaluated at the mean values, the elasticity of efficiency change to investment rate is estimated at 0.174. This suggests that modernity of machinery and installations, caused by investment effort, plays an important role in the growth of the firm efficiency, i.e, more investment effort gives the firm some competitive advantage.

Secondly, a negative correlation is obtained between the dummy indicating small and medium size firm (SIZE) and the efficiency change. This result indicates that large firms are in a better position to improve their efficiency than small and medium firms. This may be the result of large firms having better access to credit than small firms to finance the implementation of new technology or because new technologies (computers) are more profitable when implemented on a larger scale.

Thirdly, there is a positive relationship between the degree of openness of the considered industry and efficiency change. The signs of the openness variable and of its square indicate (as for INVRATE variable) that efficiency increases with openness, reaches a maximum, and than declines. Evaluated at the mean values, the elasticity of efficiency change to openness is estimated at 0.39, which is highly significant. Therefore, the firms that operate in sectors with higher degree of openness, i.e., in more competitive sectors, have greater incentive to improve its efficiency.

Conclusion

In reviewing studies which measure the dispersion of productivity in developing countries, Tybout (2000) argues that “they are not very informative. Most of them are based on outdated methodologies. With a few exceptions they rely on cross-sectional data, and hence must infer efficiency dispersion from the skewness of the production function residuals. Further, because they measure output as real revenue, they misattribute cross-plant mark-up differences to productivity dispersion. Finally, for lack of data, they typically attribute high productivity with superior performance, ignoring many of the costs that firms incur to enhance their technical efficiency.”

This paper has addressed each of these concerns:

- A stochastic frontier production function approach, where firm affects are permitted to vary systematically with time and where inefficiency effects are directly influenced by a number of variables, is used. Frontier methodologies measure firm performance relative to “best practice” frontiers consisting of other firms in the industry. Such measures dominate traditional techniques in terms of developing meaningful and reliable measures of firm performance. They summarize firm performance in a single statistic that controls for differences among firms in a sophisticated multidimensional framework that has its roots in economic theory.

- Panel rather than cross-section data are used, which make possible simultaneous investigation of both technical change and technical efficiency change over time.

- Finally, firm level information on investment, output and size, combined with sector-level information on import penetration rate are used to investigate the determinants of estimated firm technical efficiency change.

What are the implications of this approach when applied to analyze the performance of firms in Tunisian’s manufacturing sector?

- The average technical efficiency is quite high. It ranges from 0,62 to 0,96, The average efficiency score improved at first (1984-1990), recovered to a peak level in 1991, and fell in the last three years (1992-1994).

- The inefficiency effect explains only a limited fraction of the deviations from the frontier output. Thus, assumption of firms operating at near to full efficiency is not necessarily implausible, particularly in the period 1990-1992 where the mean technical efficiency is situated at 90%.

- In accordance with theoretical studies which generally suggest positive externalities from inflows of foreign capital to the host countries, efficiency of manufacturing firms increases with the prevalence of foreign participation. The same goes for the effect of training rate variable which is a highly significant contributor to technical efficiency. Given the absence of data on employees schooling, this variable may be considered as a proxy of human capital in each firm. There is also some evidence showing that state participation is not conducive to technical inefficiency. Furthermore, results show that small- and medium-sized firms, and also age of capital (obsolete or old machinery and installations), appear to have a negative and significant influence on technical efficiency.

- The mean technical efficiency is high for firms belonging to Food Processing and Mechanical and Electrical Goods sectors. Results also reveal a steady decline in technical efficiency since 1991, which concerns all manufacturing firms, and principally firms belonging to Textiles, Clothing and Leather Goods and Woodwork, Paper and Diverse sectors.

- The average total factor productivity growth for the period 1985-94 has been positive and sluggish across all the industries (mean TFP rate of growth of 0.51%). A comparison of TFP growth over time shows that it improved significantly in the sub-period 1990-1992, for all industries. The end of the period is marked by a decline in TFP growth rate, particularly in industry groups like Textiles, Clothing and Leather Goods; and Woodwork, Paper and Diverse.

The results highlight the existence of a positive and highly significant association between investment effort of firm and the degree of openness of the considered industry, on the one hand, and efficiency change, on the other hand. Also, large firms are in better position to improve their efficiency than small and medium firms.

The study has identified some of the very important factors in firm's internal and external environments which are related to their efficiency performances. It contributes to facilitate the process of understanding the movements in efficiency and productivity in Tunisian manufacturing sectors and designing the right policies to enhance them.

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