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# The Dutch Disease, Learning by Doing and Public Policy: Evidence from the United Arab Emirates

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The effects of a natural resource boom have been well studied by the Dutch Disease literature. Deindustrialization has been one of its undesirable effects. This prompted public policy intervention to neutralize such impact, which many viewed as an intervention against market forces in a structural adjustment process. However, the existence of learning-by-doing induced technological progress that is characteristic of the manufacturing sector has been introduced as an externality that theoretically justifies public intervention. Sectoral Evidence from the United Arab Emirates supports such presumption and shows that significant learning-by-doing growth effect exists in the manufacturing sector.

## I . Introduction

The effects of natural resource expansion on the local economy has been well studied and analyzed through the Dutch Disease models. These effects include real appreciation (a rise in the price of nontradeables relative to tradeables) and a decline in the output of tradeable sectors (other than the natural resource sector).[1] Since these sectors usually include agriculture and manufacturing, the latter effect is termed deindustrialization (or deagriculturlization if the agriculture sector is the dominant one).[2]

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[1] The term "Dutch Disease" was first introduced by *The Economist* November 26th 1977 (pp. 82-83) in discussing the effects of oil discoveries in the Netherlands on its manufacturing sector. For references on the Dutch Disease model, see Corden and Neary (1982), Corden (1984), and Neary and van Wijnbergen (1986).

The basic mechanics of the Dutch Disease model are briefly explained here (For a formal presentation and variation of the model see Corden and Neary (1984) and Neary and van Wijnbergen (1986)). The Dutch Disease analysis begins with a rise in wealth due to a boom in the natural resources sector (due to new discoveries or due to significant rises in the price of its output). Such shock raises real income level and, thus, increases domestic demand for all normal goods, which include tradeable goods (produced by the agricultural and manufacturing sectors) and nontradeable goods (produced by the service sector). By the assumption of a small open economy, higher demand for tradeable goods can be satisfied immediately through imports. On the other hand, due to the nature of nontradeable goods, their demand can only be satisfied locally. But given the pressure of higher demand coupled with limited production capacity in the short run, the price of nontradeables must increase to preserve market equilibrium. This rise in the price of nontradeables relative to the price of tradeables is called the real appreciation effect.[3] Furthermore, higher prices for nontradeables will bid factors of production (specially labor in the short run) away from the tradeable sector to be drawn into the nontradeable sector. Such resource movement will cause a decline in the production level of tradeables. This is known in the literature as the deindustrialization effect. Real appreciation and deindustrialization are two undesirable effects that instigated the term "Dutch Disease" as a label for the analysis of natural resource booms.

Public policy response to the effects of natural resource booms has been mixed. While some countries allowed nontradeable sectors to grow at the expense of tradeable sectors, others have intervened by subsidizing tradeable sectors to prevent the inevitable decline in their output. This was the response of many developing countries who experienced natural resource booms.[4] In particular, their intervention was

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2. However, Fardmanesh (1991) shows that for a small open economy, a rise in the "world-price of manufactured goods relative to agricultural goods" as a result of an oil boom can lead in the final analysis to an expansion in the manufacturing sector despite the initial contraction in its output. This is true if the country is a net importer of manufacturing goods.

3. Real appreciation refers to appreciation of the real exchange rate which can reduce domestic production of tradeable goods due to cheaper imports.

in the form of subsidizing the manufacturing sector which has been viewed as source of economic growth and prestige. Critics of such policy consider government actions as an intervention with efficient economic adjustment governed by market forces as a result of the resource boom. They contend that these countries should move in industries related to the resource boom and into the production of nontradeable goods and ignore their manufacturing sector until the natural resource is exhausted or the true boom is halted. This view has been challenged theoretically by van Wijnbergen (1984, 1985) who introduced "learning by doing" into the analysis. He argues that stylized facts show that technological progress is faster in the tradeable sectors of the economy, primarily the manufacturing sector, than in its nontradeable ones. Augmenting this fact with the hypothesis that technological progress is not merely a function of time but also of accumulated experience, the underlying concerns of developing countries become clearly understandable. Given that a significant portion of economic growth is caused by technological progress in the from of learning by doing, then a decline in the output or in activity of the tradeable sector (even if temporary) can be translated into a permanent decline in per capita income thus hampering economic growth.

The purpose of this paper is to investigate whether indeed there is learning-by-doing-induced technological progress in the tradeable (in particular manufacturing) sector as opposed to the nontradeable sector. This is done by examining sectoral production functions in a small oil-producing country, namely, the United Arab Emirates (UAE). Our findings could have far reaching policy implications in a country with a heavily subsidized manufacturing sector and a labor market that is dominated by guest workers.[5] Section II presents the theoretical background of the econometric model. Section III describes the data

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4. As matter of fact, their response was not well measured to combat the deindustrialization effect. It was only done for the purpose of industrial development.

5. Subsidies to the sector are in the form of subsidized capital, exemptions from custom duties, donated lands and subsidized electricity, water and other services. There are no taxation incentives since the country has no direct income taxation system. In 1990, it is estimated that guest workers make up 90% of the country's labor force [see Al-Mutawa (1991) for a description of the UAE economy]. This makes learning by doing an important policy issue in the UAE.

and the empirical methodology. Section Ⅳ reports the empirical findings. Finally, section Ⅴ concludes the paper.

## Ⅱ. Theoretical Foundations

A form of an aggregate production function is needed to implement our econometric investigation. In economic application, most functions in this area are variants of the general type:

$$Q_t = A_t f(K_t, L_t) \tag{1}$$

where $Q$ is the level of output, $K$ is capital stock, $L$ is employment (labor) and A is a scale parameter that represents the level of technology at time t. However, as it stands, equation (1) cannot be estimated unless the functional from of the relationship between the inputs and output is explicitly specified. In addition, and specially for the purpose at hand, assumptions about the types of technological change must be clearly spelled out.

In recent years there have been numerous studies estimating production functions.[6] These studies utilized many forms for the production function such as the Cobb-Douglas, the constant elasticity of substitution (CES), the variable elasticity of substitution (VES), the translog, etc. To concentrate on sources of technological change, we adopt the traditional Cobb-Douglas approach.[7]

$$Q_t = A_t K_t^{\alpha} L_t^{\beta} \tag{2}$$

where $\alpha$ and $\beta$ are the elasticities of output with respect to capital and labor, respectively. These elasticities represent the shares of the two inputs in production.

The subscript t of the technological change parameter indicates

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[6] For some of the very recent studied, see Bairam (1989), Grant (1993), Monga and Singh (1992), Anderson and Moroney (1993), Hasan and Mahmud (1993), and Kalirajan and Obwona (1994).

[7] Such a form is similar to that adopted by Bahk and Gort (1993) for examining learning by doing at the firm (microeconomic) level.

that it is not a constant and further presumptions should be made regarding its specification. In many previous empirical works, technological change was treated as "manna from heaven". However, since Arrow's (1962) introduction of the concept, learning by doing has been considered a major part of growth in labor productivity or technological change. The basic idea behind learning by doing is that as workers gain experience at producing something, they become increasingly efficient at it. The repetition of the process inspires labor to find new ways of doing things so that relatively minor modifications to plant and production methods can contribute to higher and higher levels of productivity. This argument suggests that cumulative output rather than a simple time trend should be adopted as a proxy for technological change.[8] Adopting this assumption, the index of labor efficiency can be expressed as a strictly increasing function of cumulative output, that is

$$A_t = A_o D_t^{\theta} \qquad (3)$$

where $A_o$ is the initial level of technology, $D$ is an index of learning by doing and $\theta\,(>0)$ is the learning coefficient. Alternatively, $\theta$ is the elasticity of the level of technology with respect to changes in the learning index. The two widely used indices for learning are cumulative output (Bairam (1987)) and cumulative gross investment (Arrow (1962)). Therefore, both measures will be utilized in our empirical investigation.[9]

However, one can rightfully argue that technological changes do not occur purely as a result of learning by doing. Disembodied and Hicks-neutral technological progress can occur exogenously, as a function of time. In this case equation (3) can be modified as:

$$A_t = A_o e^{\delta t} D_t^{\theta} \qquad (4)$$

where $\delta$ represents the exogenous growth rate of technology.

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[8] Note that in this case cumulative output is used as a measure of experience.

[9] This issue will be revisited later when discussing the econometric specification of the model.

Combining our assumptions about the sources of technological change in the context of the adopted form of the production function gives:

$$Q_t = A_0 e^{\delta t} D_t^{\theta} K_t^{\alpha} L_t^{\beta} e^{u_t} \tag{5}$$

where $u$ is an error term that accounts for the contribution of other factors that are not included in our specified production function. Imposing constant returns to scale on the production function (5) gives its intensive form:

$$q_t = A_0 e^{\delta t} D_t^{\theta} l_t^{1-\alpha} e^{u_t} \tag{6}$$

where $q_t = Q_t/K_t$ and $I_t = N_t/K_t$ are the output-capital and the labor-capital ratios, respectively.

## III. Data and Econometric Methodology

Two econometric issues are encountered in attempting to estimate the production function in (6). The first issue relates to the data and the degree of sectoral disaggregation. For one, time series data of the relevant variables are only available annually for the UAE for the period 1974-1991. Such a small sample size (T=16) makes our estimation results and inferences statistically not reliable. This problem may be alleviated by using interpolation methods to generate quarterly data. Thus, Diz (1970) method has been used to distill the quarterly series from the annual figures, stretching our sample to 64 observations (1975:1-1990:4).

In confronting the sectoral disaggregation problem, it is important to identify sectors where significant learning by doing might occur. The literature stresses the manufacturing sector, where production processes and capital intensity are conducive to such type of technological progress. Therefore, for our purpose in this paper, the economic sectors are categorized as: the manufacturing sector, the oil sector, the agricultural sector, the government services sector, and the services sector.[1] "If we exclude the oil sector (since it is an enclave), the agricultural sector (due to its insignificant contribution) and the government sector (due to its special nature), then we need to estimate two production functions and investigate whether or not government policies to subsidize the manufacturing are theoretically justifiable. These functions are:[11]

1. The manufacturing sector's production function, which theory expects to exhibit significant learning by doing coefficient.
2. The nontradeable sector's production function, which is theoretically expected to show no significant learning by doing effects. However, such an aggregate function might not be appropriate since some of the subsectors in the nontradeable sector are to some degree tradeable. Such subsectors might exhibit some learning by doing effects.

Therefore, the nontradeable sector will be disaggregated into subsectors: Electricity and Water sector, Construction sector, Wholesale and Retail Trade sector, Transportation, Storage and Communication sector, Finance and Real Estate sector, and Other Services sector. Accordingly, six production functions will be estimated. The second issue relates to the methodology adopted in estimating equation (6).

Econometrically, it is easier to deal with a (monotonic) logarithmic transformation of (6) as[12]

$$\ln q_t = \ln A_0 + \delta t + \theta \ln D_t + (1-\alpha)\ln l_t + u_t \ . \qquad (7)$$

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[10] Note that the first three sectors are usually referred to in the literature as tradeable sectors. The last two are considered nontradeable sectors.

[11] Note that two tradeable sectors are excluded from our econometric investigations. One is the oil sector which is highly capital intensive and considered an enclave. The other is the agricultural sector, which under the existence of severe water shortages and poor agricultural conditions, in addition to its insignificant contribution to the country's GDP, is an unlikely source of economic growth.

[12] It is theoretically more acceptable to estimate sectoral production functions in the form of equation (5), since equation (6) imposes the *a priori* assumption of constant returns to scale. However, starting in our case with equation (5), initial estimation results yielded unacceptable and counterintuitive results in terms of factor elasticities and returns to scale. In light of such results, equation (6) which yielded more reasonable results has been adopted in this paper.

Given that seven sectors of the economy will be tested for the presence of learning by doing, equation (7) can be written in a representative form for all sectors:

$$\ln q_{ti} = \ln A_{oi} + \delta_i t + \theta_i \ln D_{ti} + (1-\alpha_i)\ln l_{ti} + u_{ti} \tag{8}$$

where $i = m, ew, c, wrt, tsc, f, os.$[13]

As we mentioned earlier, there are two widely used indices for learning by doing. Since no consensus exists as to which concept is preferred, sectoral equations given in (8) should be specified using both notions. The first specification employs cumulative output (Sq) as the learning index.

$$\ln q_{ti} = \ln A_{0i} + \delta_i t + \theta_i \ln Sq_{ti} + (1-\alpha_i)\ln l_{ti} + u_{ti} \tag{9}$$

The second uses cumulative gross investment (Si) as a measure of learning:

$$\ln q_{ti} = \ln A_{0i} + \delta_i t + \theta_i \ln Si_{ti} + (1-\alpha_i)\ln l_{ti} + u_{ti} \tag{10}$$

## Ⅳ. Empirical Results

In this section we investigate the presence of learning by doing in each sector by estimating its associated production function. However, estimating the log-level forms of (10) and (11) using ordinary least squares (OLS) seems inappropriate. As shown by Granger and Newbold (1974) and Lovell (1983), a regression of nonstationary time series lead to spurious correlation and inflated R-squared. In addition, it yields incorrect inferences where t- and F-statistics would not exhibit standard distributions [Phillips (1986) and Stock and 'Watson (1989)]. Therefore, the regression equations (10) and (11) must be estimated

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[13] The notation i is sectoral notation for manufacturing (m), electricity and water (ew), construction (c), wholesale and retail trade (wrt), transportation, storage and communication (tsc), finance and real estate (f), and other services (os).

with the variables in their stationary form, usually after differencing once or twice. However, Engle and Granger (1987) point out that achieving stationarity through differencing before estimation is problematic if the variables are cointegrated.[14] Such regressions ignore the underlying long-run relationships among the levels of the variables. To sum up, we must first check the degree of integration of the time series in equation (7) through unit root tests. If the variables are integrated of the same degree and share a common root, an error-correction production function is the appropriate form.

Recently there have been many unit-root tests developed in the literature. The most commonly used ones are the Dicky- Fuller (DF) and the Augmented Dicky-Fuller (ADF) tests. The two tests are considered conservative and they tend to accept the null hypothesis of unit root (nonstationarity) more often, specially in positive moving average processes [Banerjee et. al. (1993)]. Therefore, it is advisable to employ another test, in addition to DF and ADF, to confirm the stationarity status of our time series. We use the recently developed Phillips-Perron (PP) nonparametric test (Phillips (1987) and Phillips and Perron (1988)).[15]

Table (1) reports the results of applying ADF and PP tests to the log-level of the variables of each sectoral equation as given in (10) and (11).[16] However, since almost all variables appear nonstationary in their log-levels, Tables (2) and (3) summarize the results of nonstationarity tests for the I (1) and I (2) series, respectively.[17] The strategy of interpreting tests results is as follows: (1) if a series proves stationary in log-level, it will enter the regression equation in log-level, regardless of being stationary either in first-and/or second-difference form,[18] and

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[14] For two variables to be cointegrated, they need to be integrated of the same order.

[15] The DF and ADF tests are more powerful in the case of autoregressive and negative moving average errors. See Banerjee et al. (p. 108-113) on such issue and an elaborate discussion of the PP test.

[16] Since most time series are generally autocorrelated, and since we use another test here, only ADF has been employed to test for stationarity. The ADF is a generalization of the DF test. The latter is usually utilized in testing for cointegration.

[17] If variable X does not contain a unit root in the level form, then X is said to be integrated of order zero [X~I(0)], i. e., stationary in its level. If X is said to be integrated of order one [X~I(1)] or of order two [X~I(2)] then it is stationary in its first difference or second difference form, respectively.

(2) a series is considered stationary if its tests statistics of ADF and PP (in their 4 and 8 lag levels) are statistically significant except for one lag.[19] In light of these guidelines, the notation √ in Tables (1) - (3) is used to indicate the stationary form for each series.

If the variables of a certain sectoral production function in Table (1) - (3) are nonstationary in levels but integrated of the same order then it is possible that they are cointegrated and possess a long-run relationship among them. Such long-run production function, which represents steady-state equilibrium, is given by equation (9) when Sq is used and by equation (10) when Si is used.[2] “However, even if we can estimate this long-run relationship directly, it is also of interest to us to understand the short-run evolution of the variables under consideration. Short-run dynamics is of interest because economic agent are unable to adjust instantaneously to new information which makes not only the current values of the explanatory variables a important but also the lagged ones. In addition, as the dependent variable evolves through time in reaction to current and previous values of the explanatory variables, past (lagged) values of the dependent variable itself will also enter the short-run (dynamic) model. A suitable approach to estimate this dynamic short-run model is the error-correction model adopted in this paper. For example, if all the variables in equation (9) are integrated of order 1, then it can be written in the form of an error-correction model as:

$$\triangle \ln q_{ti} = \pi \triangle \ln D_{ti} + \beta \triangle \ln l_{ti} - \gamma\ [\ln q_{t-1,i} - \theta \ln D_{t-1,i} - (1-\alpha) \ln l_{t-1,i}] + u_{ti} \qquad (11)$$

where △ means first difference of the variable. The third term in equation (11), which is the error of the long-run relationship, represents

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[18] For example, table (2) shows that $Si_{EW}$ is stationary in first-difference, but table (3) shows it is stationary in second-difference. To avoid the problem of over differencing we conclude that $\triangle Si_{ew}$ is the stationary form of the series. Therefore, it will enter the regression equation in such form.

[19] For example, table (2) shows that stationarity test statistics for $\triangle q_m$ are all statistically significant except for ADF at lag = 8. In this case the series is considered stationary in first difference. On the other hand, stationarity test results in table (1) are all significant for $Si_m$ except the $Z_k$ of the PP test. In this case the series is considered nonstationary in log-level.

[20] In both cases we exclude the constant and trend variables.

how far the dependent variable and the independent variables were away from equilibrium in the previous period. Thus, it is called equilibrium error or the "error-correction mechanism" since it indicates that economic agents will adjust their behaviour in this period in light of information about their diversion from equilibrium in the previous period. The coefficient $\gamma$ measures the speed of such adjustment toward long-run equilibrium. However, an error correction model can be estimated for equation (9) only if: (a) all of its variables are integrated of the same order and (b) the residuals from its estimated form are stationary. In this case the variables are said to be cointegrated and a dynamic short-run production function in the form of (11) can be estimated for the sector. If the variables in (9) are integrated of the same order but the residuals obtained from the estimated long-run production function are not stationary, then a long-run relationship does not exist and, thus, we can only estimate a short-run production function of the form:

$$\triangle \ln q_{ti} = \pi \triangle \ln D_{ti} + \beta \triangle \ln l_{ti} + u_{ti} \tag{12}$$

Finally, if the variables in equation (9) are integrated of different orders, only a short-run production can be estimated in which each variable must enter its stationary form.

Unit-root tests results summarized in Table (1) - (3) show that a *long-run* production function of the forms of (9) or (10) possibly exists only for three sectors of the UAE economy.[21] They are the manufacturing sector, the finance sector and the other services sector.[22] Thus, dynamic error-correction production functions may be estimated for these sectors.[23] On the other hand, no long-run production function exists

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[21] Stationarity of the estimated residuals from the long-run production function is still required to prove that the variables are cointegrated.

[22] Note that for the manufacturing sector, the variables in the production function are possibly cointegration when using accumulated output as the learning index. However, when accumulated investment is used as the learning index, the variables in the manufacturing production function cannot be cointegrated since they are of different orders of integratedness. The same argument also applies to the production function of the finance sector.

[23] Of course, before estimating the dynamic error-correction production function, the

for the other sectors since the variables entering the production function of these sectors are of different orders of integratedness. Therefore, *a short-run* production function will be estimated for the electricity and water sector, the construction sector, the construction sector, the trade sector and the transportation, storage and communication sector.

Tables (4) - (10) summarize estimation results of the seven sectoral production functions. The results of cointegration tests for the manufacturing sector, the finance sector and "other services" sector are stated below their respective tables. Tables (4) - (7) report estimation results of the short-run production functions of the construction sector, the electricity and water sector, the trade sector and the transportation, storage and communication sector, respectively.[24] First, we notice that there appears to be technological progress in form of learning by doing in the construction sector. However, such effect is not statistically significant.[25] Furthermore, the effects of exogenous technological progress are also insignificant. Second, the learning indices give mixed results in the electricity and water sector. While accumulated output shows signifi- cant positive effect, accumulated investment exhibits strong negative effect.[26] Third, there does not seem to be any significant technological progress associated with either learning index in the trade sector. This also applies to exogenous technological advancement. Finally, the learning indices exhibit significant negative effects in the transportation, storage and communication sector.

The dynamic error-correction production functions of the three remaining sector are given in Table (8) - (10).[27] The results for the

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error-correction term obtained from the estimated long-run relationship must be tested for stationarity via the DF test. See footnote 29 on the power of this test.

[24] Note that to avoid problems associated with spurious regressions, the variables included in the estimated production functions appear in their stationary form.

[25] This appears to be the case when either learning index is used.

[26] A negative sign for the labor/capital ratio does not seem counterintuitive. Due to the nature of the electricity and water sector, a rise in such ratio indicates a deterioration in the sector's capital stock and a movement toward labor intensive technology. This can reflect negatively on the sector's output.

[27] There are two ways to estimate error-correction models. One is the two-step procedure suggested by Engle and Granger (1987). The other is the generalized error-correction model which relies on a Hendry-type testing down process. Thomas (1993) and Charemza and Deadman (1992) offer detailed description of both methods. We adopt the Engle-Granger

manufacturing sector are reported in Table(8). Due to autocorrelation of the error term in Model 1, the dynamic error-correction production function is given by Model 2.[28] In both models, the coefficient of the error-correction mechanism (ECM) is as it should be (significant, negative and less than 1 in absolute value).[29] If accumulated investment is used as the learning index, as in Model 3, we can only estimate the short-run production function. Nonetheless, using either index of learning, evidence of technological progress caused by learning by doing in the manufacturing sector appears to be strong.

The estimation of the production functions of the finance sector and the "other services" sector is more complicated since it involves estimating error-correction models for I (2) variables.[30] The methodology of estimation is described in appendix B. However, when the estimated residuals from the cointegrating equation of each sector are tested, they both failed the cointegration tests. The DF and ADF test statistics for the residuals from the long-run production function of the finance sector are -1.84 and 1.50, which are insignificant when compared with the critical values in table 2 in appendix A. The DF and ADF cointegration test statistics for the "other service" sector, when $Sq_{os}$ is used, are -1.80 and -1.70, respectively. When $Si_{os}$ is used, similar tests yielded -1.91 and -1.58.

The above mentioned cointegration testing results indicate that no

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methodology in our analysis. The explanation of the process is embedded in the discussion of Appendix B which outlines the estimation of error-correction models when the variables are I (2).

[28] Thomas (1993) offers excellent explanation on the use of lagged dependent and independent variables within the error-correction framework to correct for serial correlation. Due to the appearance of these variables lagged-once in the model, the error-correction (ECM) term should be lagged twice.

[29] As required in estimating error-correction models, ECM is tested for stationarity using the DF test for unit root. The obtained t-value for the lagged ECM is -8.002 which rejects the null hypothesis of a unit root. However, Kremers, Ericsson and Dolado (1992) point out that the DF test applied to the residuals of the static relationship has a non-standard asymptotic distribution. This is due to the fact that the test imposes a possibly invalid common factor restriction. On the other hand, the test of significance of ECM in the error-correction model is approximately normally distributed and, thus, a more powerful test of cointegration.

[30] Few authors discuss the estimation of these models. Engle and Yoo (1991) elaborate on such issues, and their results are briefly presented in Appendix B.

error-correction (long-run) production function can be estimated for the finance and other services sectors. Thus, estimation results of the short-run production functions for the two sectors are offered in Tables (9) and (10). The obvious conclusion is that neither sector exhibits significant learning by doing effects. This is true when either learning index is used. However, since the t-value of cumulative output in the finance sector is greater than one (equals 1.37 in Model 2)[31], we suspect the existence of some learning by doing technological progress related to the process of providing more and more financial services.

To sum up, Table (11) summarizes our findings on the existence of learning by doing technological progress in the seven sectors. First, strong evidence of learning by doing exists only in two sectors: the manufacturing sector and the electricity and water sector. The effect of such learning in the manufacturing sector is greater with the experience generated from the production process. In addition, the gain in growth from learning by doing seems to be of a long-term nature. However, Bahk and Gort(1993) point out that such a gain approaches zero with the passage of time. In the case of the electricity and water sector, cumulative investment as an index of learning produces puzzling results. This is due to the negative sign of $Si_{ew}$ which indicates that growth in the sector's output is negatively affected by new additions to its capital stock. Thus, such result must be viewed cautiously.

Second, while the variable $Sq_i$ appears with only one negative sign, this seems to be the dominant case for the variable $Si_i$. This casts some doubt on the use of cumulative investment as a learning index, specially in the case of developing countries where investment and capital data are of poor quality. Furthermore, an econometric problem of multicollinearity that is inherent in the specification of the model might be the culprit in rendering counterintuitive results for some of the coefficients of Si. Since Si index is constructed as cumulative gross investment and current capital stock (K) is calculated as the integration of gross investment minus depreciation, the two variables can be highly correlated by definition. Thus, their appearance in the same equation can yield counterintuitive results due to high degree of linear

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[31] Which is statistically significant at 80% confidence level.

dependence between the two explanatory variables. A better approach and a solution to this problem, if data is available, is to use an index of the average vintage of sectoral capital stock as a measure of learning by doing (Bahk and Gort (1993)).

## V. Concluding Remarks

The main purpose of this study has been to test the theoretical justification of the public policy response to booms in the natural resource sector. The study implements that on a sectoral level. In specifying the production functions of the economic sectors, we take into account recent econometric developments of cointegrated systems and error correction models. This avoids the effects of a spurious regression which plagued previous studies and casted doubts on their econometric findings. In addition, we utilize recent advances in unit root tests to carefully detect the stationarity status of our time series. At the end such scrutiny is hoped to improve our results and solidify our empirical findings.

Several interesting conclusions emerge from the empirical analysis. First, the theoretical assumption that learning by doing induced technological progress occurs only in the manufacturing sector seems to be valid in the case of the UAE economy. Econometric results show that regardless of the learning index used, such an effect presents a significant source of technological progress in the sector. With the exception of electricity and water, learning by doing productivity gain does not exist in all nontradeable sectors.

Second, public policy responses in the form of direct and indirect subsidies to the manufacturing sector, which have followed booms in the oil sector, appear a rational strategy to avoid future deterioration in the country's welfare level. Allowing the manufacturing sector's output to shrink would lead to a significant loss in productivity and could place the economy at a lower long-run growth path. In the final analysis, this means a lower welfare level for the society. A similar finding, although with a lower likelihood, also applies to the finance and real estate sector. This sector holds the potentials of enhancing gains from growth in productivity through the accumulation of experience in providing financial services.

Third, in a country like the UAE, that is significantly dependent on the supply of foreign labor, our findings add another cost to such reality.[32] If growth in productivity in the manufacturing sector occurs significantly in the form of learning by doing, then the departure of foreign labor employed in this sector means a great loss in terms of technological progress and future welfare level. To avoid such losses, the country must set the employment of nationals in sectors that exhibit learning by doing gains as a priority in its attempts to reduce dependence on foreign labor. In the case of the UAE, these sectors are the manufacturing sector and, to a lesser extent, also the financial sector.

Fourth, in implementing the above mentioned recommendation, learning by doing effects in the manufacturing sector must be investigated further at the industry or plant levels. This would help to decompose it as labor learning, capital learning and organizational learning (Bahk and Gort (1993)). This inquiry, unfortunately, cannot be carried out with the currently available data. The benefits from more efficient data collection efforts, though costly, would lead to more rational public policy decisions and ultimately to a prosperous UAE economy.

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[32] See Al-Mutawa (1991) on the costs of foreign labor in the UAE.

**Table 1 Unit Root Tests of the Basic Variables in Log-Level Form**

| Variables | Augmented Dicky-Fuller(ADF)* | | Phillips-Perron (PP)* | | | |
|---|---|---|---|---|---|---|
| | | | $Z_k$ | | $Z_t$ | |
| | lag=4 | lag=8 | l=4 | l=8 | l=4 | l=8 |
| $q_m$ | $-4.11^a$ | -2.41 | -6.72 | -6.56 | $-3.93^a$ | $-4.04^a$ |
| $l_m$ | -2.24 | $-2.95^b$ | -3.29 | -4.31 | -1.28 | -1.47 |
| $Sq_m$ | $-3.07^b$ | $-4.08^a$ | -3.20 | -3.21 | $-14.76^a$ | $-13.13^a$ |
| $Si_m$ | -2.57 | $-5.78^a$ | -3.14 | -3.15 | $-12.46^a$ | $-10.99^a$ |
| √ $q_{ew}$ | $-2.90^c$ | -1.88 | $-11.60^c$ | $-12.01^c$ | $-7.58^a$ | $-7.02^a$ |
| $l_{ew}$ | $-2.66^c$ | -1.83 | -5.73 | -5.77 | $-9.42^a$ | $-8.65^a$ |
| $Sq_{ew}$ | -1.39 | -0.69 | -4.41 | -4.44 | $-9.16^a$ | $-8.28^a$ |
| $Si_{ew}$ | -2.35 | -1.71 | -7.88 | -8.01 | $-11.59^a$ | -9.82 |
| $q_c$ | -0.89 | -0.36 | -0.42 | -0.99 | -0.24 | -0.49 |
| $l_c$ | -1.07 | -1.10 | -1.10 | -1.97 | -0.54 | -0.81 |
| $Sq_c$ | -0.29 | -2.26 | -5.45 | -5.49 | $-10.64^a$ | $-9.67^a$ |
| $Si_c$ | -0.91 | -2.32 | -5.86 | -5.93 | $-9.61^a$ | $-8.58^a$ |
| $q_{wrt}$ | -2.56 | -2.25 | -5.10 | -5.82 | $-2.96^b$ | $-2.80^c$ |
| $l_{wrt}$ | -2.34 | 0.04 | -5.67 | -6.40 | $-3.81^a$ | $-3.40^b$ |
| $Sq_{wrt}$ | -1.91 | $-6.39^a$ | -7.35 | -6.31 | $-9.84^a$ | $-8.46^a$ |
| $Si_{wrt}$ | -0.53 | 1.08 | -6.21 | -7.41 | $-14.76^a$ | $-12.61^a$ |
| $q_{tsc}$ | $-3.20^b$ | -2.44 | -3.78 | -3.81 | $-7.29^a$ | $-8.11^a$ |
| $t_{tsc}$ | -2.36 | $-3.53^b$ | -2.54 | -2.55 | $-7.89^a$ | $-7.08^a$ |
| $Sq_{tsc}$ | -1.91 | 0.72 | -5.89 | -5.98 | $-9.52^a$ | $-8.27^a$ |
| $Si_{tsc}$ | -0.49 | $-6.77^a$ | -7.42 | -7.51 | $-12.76^a$ | $-10.83^a$ |
| $q_f$ | -0.50 | -0.79 | 0.47 | 0.002 | 0.30 | -0.01 |
| $l_f$ | -0.34 | -0.04 | -2.37 | -3.81 | -1.04 | -1.34 |
| $Sq_f$ | $-2.98^b$ | $-5.74^a$ | -4.94 | -5.01 | $-8.19^a$ | $-7.15^a$ |
| $Si_f$ | -1.23 | $-7.67^a$ | -9.31 | -9.43 | $-14.69^a$ | $-12.46^a$ |
| $q_{os}$ | 0.21 | -0.98 | 0.53 | 0.48 | 0.97 | 0.74 |
| $l_{os}$ | 0.56 | -0.26 | 0.68 | 0.64 | 1.31 | 1.09 |
| $Sq_{os}$ | $-2.64^c$ | $-2.65^c$ | -4.85 | -4.95 | $-7.14^a$ | $-6.26^a$ |
| $Si_{os}$ | -2.55 | -2.05 | -2.97 | -3.03 | $-4.80^a$ | $-4.30^a$ |

a, b and c Indicate significance at the 1%, 5% and 10% level, respectively.

* Critical values and the forms of the ADF and PP tests are given in apendix A.

√ Indicates the stationary form of the variable.

## Table 2 Unit Root Tests of the Basic Variables in First-Difference Form

| | Augmented | | Phillips-Perron (PP)* | | | |
|---|---|---|---|---|---|---|
| Variables | Dicky-Fuller(ADF)* | | $Z_k$ | | $Z_t$ | |
| | lag=4 | lag=8 | l=4 | l=8 | l=4 | l=8 |
| √ $\triangle q_m$ | $-3.46^b$ | $-2.58$ | $-15.70^b$ | $-13.28^c$ | $-3.04^b$ | $-2.85^c$ |
| √ $\triangle l_m$ | $-3.95^a$ | $-4.66^b$ | $-11.06^c$ | $-10.08$ | $-2.95^b$ | $-2.89^c$ |
| √ $\triangle Sq_m$ | $-3.25^b$ | $-1.82$ | $-14.18^b$ | $-14.69^b$ | $-5.38^a$ | $-5.28^a$ |
| $\triangle Si_m$ | $-0.95$ | $-1.90$ | $-4.87$ | $-4.90$ | $-2.73^c$ | $-2.73^c$ |
| $\triangle q_{ew}$ | $-5.29^a$ | $-4.07^a$ | $-6.02$ | $-5.07^c$ | $-2.18$ | $-2.11$ |
| $\triangle l_{ew}$ | $-3.78^a$ | $-3.25^b$ | $-4.49$ | $-3.69$ | $-1.96$ | $-1.93$ |
| √ $\triangle Sq_{ew}$ | $-2.93^b$ | $-3.11^b$ | $-22.53^a$ | $-24.29^a$ | $-12.05^a$ | $-10.35^a$ |
| √ $\triangle Si_{ew}$ | $-312^b$ | $-3.40^b$ | $-18.94^b$ | $-19.36^b$ | $-16.98^a$ | $-14.87^a$ |
| $\triangle q_c$ | $-2.17$ | $-1.87$ | $-9.53$ | $-9.46$ | $-2.35$ | $-2.33$ |
| $\triangle l_c$ | $-1.96$ | $-1.96$ | $-8.36$ | $-8.06$ | $-2.14$ | $-2.10$ |
| √ $\triangle Sq_c$ | $-10.04^a$ | $-4.67^a$ | $-24.24^a$ | $-26.14^a$ | $-11.58^a$ | $-10.23^a$ |
| √ $\triangle Si_c$ | $-4.46^a$ | $-3.49^b$ | $-24.55^a$ | $-26.13^a$ | $-13.07^a$ | $-11.43^a$ |
| $\triangle q_{wrt}$ | $-1.47$ | $-1.78$ | $-4.55$ | $-4.45$ | $-1.48$ | $-1.46$ |
| $\triangle l_{wrt}$ | $-1.87$ | $-4.25^a$ | $-1.80$ | $-2.06$ | $-1.07$ | $-1.13$ |
| √ $\triangle Sq_{wrt}$ | $-4.13^a$ | $-2.45$ | $-21.55^a$ | $-22.31^a$ | $-14.22^a$ | $-12.67^a$ |
| √ $\triangle Si_{wrt}$ | $-12.40^a$ | $-8.90^a$ | $-18.82^a$ | $-19.19^b$ | $-10.73^a$ | $-10.21^a$ |
| $\triangle q_{tsc}$ | $-1.46$ | $-2.02$ | $-2.52$ | $-2.23$ | $-1.12$ | $-1.15$ |
| $\triangle t_{tsc}$ | $-1.84$ | $-1.41$ | $-2.97$ | $-2.97$ | $-1.34$ | $-1.34$ |
| √ $\triangle Sq_{tsc}$ | $-4.65^a$ | $-7.37^a$ | $-21.37^a$ | $-22.27^a$ | $-14.45^a$ | $-12.54^a$ |
| √ $\triangle Si_{tsc}$ | $-4.79^a$ | $-1.57$ | $-19.81^a$ | $-20.36^a$ | $-15.25^a$ | $-12.43^a$ |
| $\triangle q_f$ | $-1.95$ | $-2.35$ | $-7.99$ | $-7.08$ | $-2.21$ | $-2.11$ |
| $\triangle l_f$ | $-3.56^b$ | $-4.89$ | $-6.05$ | $-4.84$ | $-3.08^b$ | $-3.71^a$ |
| $\triangle Sq_f$ | $-1.79$ | $-1.24$ | $-21.77^a$ | $-22.75^a$ | $-14.45^a$ | $-12.50^a$ |
| √ $\triangle Si_f$ | $-4.54^a$ | $-1.81$ | $-21.25^a$ | $-21.72^a$ | $-15.25^a$ | $-13.95^a$ |
| $\triangle q_{os}$ | $-1.40$ | $-1.70$ | $-9.28$ | $-8.32$ | $-2.17$ | $-2.06$ |
| $\triangle l_{os}$ | $-1.67$ | $-1.66$ | $-9.66$ | $-8.41$ | $-2.22$ | $-2.07$ |
| $\triangle Sq_{os}$ | $-1.98$ | $-1.22$ | $-23.76^a$ | $-24.76^a$ | $-16.35^a$ | $-14.11^a$ |
| $\triangle Si_{os}$ | $-1.90$ | $-1.91$ | $-27.38^a$ | $-27.38$ | $-19.62^a$ | $-17.14^a$ |

## Table 3 Unit Root Tests of the Basic Variables in Second-difference Form

| Variables | Augmented Dicky-Fuller(ADF)* | | Phillips-Perron (PP)* | | | |
|---|---|---|---|---|---|---|
| | | | $Z_k$ | | $Z_t$ | |
| | lag=4 | lag=8 | l=4 | l=8 | l=4 | l=8 |
| $\triangle\triangle q_{m}$ | $-5.61^{b}$ | $-4.87^{a}$ | $-61.70_{a}$ | $-53.41^{a}$ | $-8.85^{a}$ | $-9.44^{a}$ |
| $\triangle\triangle l_{m}$ | $-3.32^{b}$ | $-4.15^{b}$ | $-59.17^{a}$ | $-57.62^{a}$ | $-7.63^{a}$ | $-7.62^{a}$ |
| $\triangle\triangle Sq_{m}$ | $-2.72^{c}$ | $-4.67^{a}$ | $-43.19^{b}$ | $-44.00^{a}$ | $-10.71^{a}$ | $-10.71^{a}$ |
| $\surd\triangle\triangle Si_{m}$ | $-2.97^{b}$ | $-2.78^{c}$ | $-58.01^{a}$ | $-55.16^{a}$ | $-10.08^{a}$ | $-10.47^{a}$ |
| $\triangle\triangle q_{ew}$ | $-3.35^{b}$ | $-3.20^{b}$ | $-53.01^{a}$ | $-53.39^{a}$ | $-7.24^{a}$ | $-7.25^{a}$ |
| $\surd\triangle\triangle l_{ew}$ | $-3.57^{b}$ | $-2.32$ | $-50.33^{a}$ | $-47.24^{a}$ | $-6.77^{a}$ | $-6.72^{a}$ |
| $\triangle\triangle Sq_{ew}$ | $-4.94^{b}$ | $-1.83$ | $-35.30^{a}$ | $-35.93^{a}$ | $-38.88^{a}$ | $-34.17^{a}$ |
| $\triangle\triangle Si_{ew}$ | $-3.96^{b}$ | $-3.95^{a}$ | $-33.27^{a}$ | $-34.29^{a}$ | $-22.86^{a}$ | $-20.07^{a}$ |
| $\surd\triangle\triangle q_{c}$ | $-4.07$ | $-2.93^{b}$ | $-43.96^{a}$ | $-40.92^{a}$ | $-6.08^{a}$ | $-6.02^{a}$ |
| $\surd\triangle\triangle l_{c}$ | $-3.19^{b}$ | $-3.32^{a}$ | $-30.69^{a}$ | $-26.06^{a}$ | $-4.56^{a}$ | $-4.34^{a}$ |
| $\triangle\triangle Sq_{c}$ | $-2.07$ | $-2.98^{b}$ | $-35.54^{a}$ | $-36.16^{a}$ | $-45.15^{a}$ | $-36.80^{a}$ |
| $\triangle\triangle Si_{c}$ | $-2.72^{c}$ | $-2.55$ | $-35.31^{a}$ | $-36.36^{a}$ | $-39.03^{a}$ | $-33.38^{a}$ |
| $\surd\triangle\triangle q_{wrt}$ | $-3.51^{b}$ | $-5.03^{a}$ | $-56.56^{a}$ | $-52.58^{a}$ | $-6.85^{a}$ | $-6.77^{a}$ |
| $\surd\triangle\triangle l_{wrt}$ | $-3.83^{a}$ | $-3.15^{b}$ | $-21.79^{a}$ | $-20.86^{a}$ | $-3.72^{a}$ | $-3.67^{a}$ |
| $\triangle\triangle Sq_{wrt}$ | $-2.66^{c}$ | $-4.12^{a}$ | $-36.15^{a}$ | $-37.74^{a}$ | $-29.54^{a}$ | $-24.94^{a}$ |
| $\triangle\triangle Si_{wrt}$ | $-2.49$ | $-7.29^{a}$ | $-36.21^{a}$ | $-38.95^{a}$ | $-21.91^{a}$ | $-18.68^{a}$ |
| $\surd\triangle\triangle q_{tsc}$ | $-4.01^{a}$ | $-3.34^{b}$ | $-55.41^{a}$ | $-49.82^{a}$ | $-7.39^{a}$ | $-7.42^{a}$ |
| $\surd\triangle\triangle t_{tsc}$ | $-3.22^{b}$ | $-3.83^{a}$ | $-58.97^{a}$ | $-57.89^{a}$ | $-7.79^{a}$ | $-7.79^{a}$ |
| $\triangle\triangle Sq_{tsc}$ | $-4.49^{a}$ | $-2.99^{b}$ | $-35.80^{a}$ | $-37.14^{a}$ | $-30.33^{a}$ | $-25.86^{a}$ |
| $\triangle\triangle Si_{tsc}$ | $-3.21^{b}$ | $-3.11^{b}$ | $-36.01^{a}$ | $-38.12^{a}$ | $-26.44^{a}$ | $-21.99^{a}$ |
| $\surd\triangle\triangle q_{f}$ | $-4.02^{a}$ | $-2.55$ | $-55.76^{a}$ | $-49.66^{a}$ | $-7.42^{a}$ | $-7.46^{a}$ |
| $\surd\triangle\triangle ek_{f}$ | $-4.10^{b}$ | $-2.47$ | $-50.78^{a}$ | $-42.65^{a}$ | $-7.15^{a}$ | $-7.28^{a}$ |
| $\surd\triangle\triangle Sq_{f}$ | $-3.55^{b}$ | $-3.48^{b}$ | $-35.26^{a}$ | $-36.97^{a}$ | $-29.57^{a}$ | $-25.69^{a}$ |
| $\triangle\triangle Si_{f}$ | $-2.83^{c}$ | $-4.67^{a}$ | $-36.68^{a}$ | $-38.70^{a}$ | $-26.52^{a}$ | $-22.41^{a}$ |
| $\surd\triangle\triangle q_{os}$ | $-4.37^{a}$ | $-2.52$ | $-52.85^{a}$ | $-44.25^{a}$ | $-7.21^{a}$ | $-7.32^{a}$ |
| $\surd\triangle\triangle ek_{os}$ | $-4.33^{a}$ | $-3.18^{b}$ | $-53.37^{a}$ | $-44.52^{a}$ | $-7.09^{a}$ | $-7.13^{a}$ |
| $\triangle\triangle Sq_{os}$ | $-3.36^{b}$ | $-3.41^{b}$ | $-35.84^{a}$ | $-36.86^{a}$ | $-33.92^{a}$ | $-29.23^{a}$ |
| $\triangle\triangle Si_{os}$ | $-4.43^{a}$ | $-3.01^{b}$ | $-35.58^{a}$ | $-35.74^{a}$ | $-32.30^{a}$ | $-31.52^{a}$ |

## Table 4 Regression Estimates of the Production Function of the Electricity and Water Sector

**Dependent variable: $q_{ew}$**

| Model | c | t | $\triangle Sq_{ew}$ | $\triangle Si_{ew}$ | $\triangle\triangle l_{ew}$ | Method |
|---|---|---|---|---|---|---|
| (1) | -3.712 | -0.001 | 0.411 | | -0.040 | rls |
| | (-54.58) | (-1.02) | (1.11) | | (-0.59) | |
| (2) | -3.773 | | 0.60 | | -0.038 | rls |
| | (-161.03) | | (2.15) | | (0.57) | |
| (3) | -3.557 | -0.003 | | -1.696 | -0.026 | rls |
| | (-39.91) | (-1.61) | | (-5.14) | (0.45) | |
| (4) | -3.696 | | | -1.779 | -0.025 | rls |
| | (78.21) | | | (5.97) | (0.45) | |

Diagnostics of model (4)

$Adj\text{-}R^2 = 0.99$ $s = 0.09$ $F(3,58) = 138.01$ $BG = 1.48$

ARCH-F(4,49) = 0.25 White-F(4,52) = 0.95 FF-F(5,51) = 1.07

Notes: s is the standard error of regression, BG is Bruesch-Godfrey test, ARCH is the autoregressive conditional heteroskedasticity test, White is for White test of heteroskedasticity, and FF is a general test for functional form mis-specification. Since our sample is relatively small, the F form of these tests is used instead of chi-square. NA indicates the test is not applicable. ols is ordinary least squares and rls is regressive least squares.

**Table 5 Regression Estimates of the Production Function of the Construction sector Dependent variable: $\Delta\Delta qc$**

| Model | c | t | $\Delta Sq_o$ | $\Delta Si_o$ | $\Delta\Delta l_o$ | Method |
|---|---|---|---|---|---|---|
| (1) | -0.0007<br>(-0.04) | -0.00003<br>(-0.10) | 0.057<br>(0.68) |  | 0.423<br>(2.82) | ols |
| (2) | -0.0007<br>(-0.04) | -0.00003<br>(-0.10) | 0.057<br>(0.68) |  | 0.423<br>(2.82) | ols |
| (3) | -0.0008<br>(-0.05) | -0.00003<br>(0.10) |  | 0.062<br>(0.78) | 0.426<br>(2.83) | ols |
| (4) |  |  |  | 0.052<br>(1.29) | 0.421<br>(2.86) | ols |

Diagnostics of model 2
$Adj\text{-}R^2 = 0.61$ s = 0.03 F(2,60) = 4.32 BG = 1.21
ARCH-F(4,56) = 0.25 White-F(4,55) = 1.34 FF-F(5,54) = 1.33

**Table 6 Regression Estimates of the Production Function of the Wholesale and Retail Trade Sector Dependent variable: $\Delta\Delta q_{wrt}$**

| Model | c | t | $\Delta Sq_{wrt}$ | $\Delta Si_{wrt}$ | $\Delta\Delta l_{wrt}$ | Method |
|---|---|---|---|---|---|---|
| (1) | -0.009<br>(1.20) | 0.0002<br>(1.18) | 0.036<br>(0.79) |  | 1.611<br>(4.85) | rls |
| (2) | -0.003<br>(-0.67) | 0.0001<br>(0.64) |  | 0.001<br>(0.04) | 1.446<br>(4.85) | rls |
| (3) |  |  | -0.015<br>(0.98) |  | 1.336<br>(5.79) | rls |
| (4) |  |  |  | -0.014<br>(-1.16) | 1.327<br>(5.80) | rls |

Diagnostics of model (1)
$Adj\text{-}R^2 = 0.41$ s = 0.01 F(3,58) = 5.05 BG = 2.89
ARCH-F(4,46) = 0.62 White-F(6,47) = 2.26 FF-F(9,44) = 4.29

**Table 7 Regression Estimates of Production Function of the Transportation, Storage and Communication sector**

**Dependent variable: $\Delta\Delta q_{tsc}$**

| Model | c | t | $\Delta Sq_{tsc}$ | $\Delta Si_{tsc}$ | $\Delta\Delta l_{tsc}$ | Method |
|---|---|---|---|---|---|---|
| (1) | 0.007<br>(2.22) | -0.0001<br>(-1.90) | -0.036<br>(-2.00) | | 0.516<br>(4.33) | rls |
| (2) | 0.004<br>(1.94) | -0.0001<br>(-1.61) | | -0.025<br>(-1.69) | 0.512<br>(4.21) | rls |

Diagnostics of model (1)

$\text{Adj-}R^2 = 0.37$ $s = 0.006$ $F(3,58) = 6.28$ $BG = 3.12$

$\text{ARCH-}F(4,46) = 0.71$ $\text{White-}F(6,47) = 0.43$ $\text{FF-}F(9,44) = 0.95$

Table 8 Regression Estimates of the Dynamic Error-Correction Production Function of the Manufacturing Sector Dependent Variable: $\Delta q_m$

| Independ. Variables | Model 1 (ols) | | Model 2 (rls) | | Model 3 (rls) | |
|---|---|---|---|---|---|---|
| | Coeff. | t-val. | Coeff. | t-val. | Coeff. | t-val. |
| Constant | -0.035 | -3.34 | -0.041 | -3.26 | 0.119 | 3.15 |
| t | - | - | - | - | -0.002 | -2.63 |
| $\Delta l_m$ | 1.141 | 4.73 | 1.358 | 7.84 | 2.070 | 6.00 |
| $\Delta Sq_m$ | 0.707 | 6.71 | 1.134 | 13.75 | - | - |
| $\Delta\Delta Si_m$ | - | - | - | - | 0.584 | 2.27 |
| $ECM_{-1}$ | -0.054 | -3.42 | -0.061 | -2.65 | - | - |

Diagnostics of model 2:

$\text{Adj-}R^2 = 0.94$ s = 0.02 F(6,55) = 206.71 BG(4)=NA

ARCH-F(4,47) = 0.16 White-F(8,47) = 0.25 FF-F(27,27) = 0.30

Notes: DF and ADF test statistic values of cointegration are, respectively, -5.99 and -5.83. Both are significant at the 1% level of significance. Critical values are given in appendix A. ECM is the error correction mechanism.

Table 9 Regression Estimates of the Short-Run Production Function of the Finance and Real Estate Sector
Dependent Variable: $\triangle\triangle q_f$

| Independ. Variables | Model 1 (ols) | | Model 2 (rls) | | Model 3 (rls) | |
|---|---|---|---|---|---|---|
| | Coeff. | t-val. | Coeff. | t-val. | Coeff. | t-val. |
| Constant | -0.001 | -0.14 | - | - | 0.002 | 0.27 |
| $\triangle\triangle l_f$ | 0.870 | 5.85 | 0.867 | 5.94 | 0.877 | 5.79 |
| $\triangle\triangle q_f$ | 0.043 | 1.31 | 0.044 | 1.37 | - | - |
| $\triangle Si_f$ | - | - | - | - | -0.028 | -0.97 |

Diagnostics of model 2:
Adj-$R^2$ = 0.37 s = 01 F(8,10) = 16.36 BG(4)=1.08
ARCH-F(4,50) = 1.71 White-F(6,51) = 0.04 FF-F(9,48) = 0.19

Table 10 Regression Estimates of the Short-Run Production Function of "Other Services" Sector
Dependent Variable: $\triangle\triangle q_{os}$

| Independ. Variables | Model 1 (ols) | | Model 2 (rls) | | Model 3 (rls) | |
|---|---|---|---|---|---|---|
| | Coeff. | t-val. | Coeff. | t-val. | Coeff. | t-val. |
| Constant | -0.0002 | -0.19 | - | - | 0.001 | 0.21 |
| $\triangle\triangle l_{os}$ | 0.771 | 11.83 | 0.803 | 13.65 | 0.770 | 11.80 |
| $\triangle\triangle qo_{os}$ | -0.009 | -0.42 | 0.007 | 1.31 | - | - |
| $\triangle Si_{os}$ | - | - | - | - | -0.009 | -0.39 |

Diagnostics of model 2:
Adj-$R^2$ = 0.83 s = 0.005 F(6,55) = 89.51 BG = NA
ARCH-F(4,45) = 1.68 White-F(6,46) = 0.28 FF-F(9,45) = 0.23

**Table 11 The Magnitude and Direction of Sectoral Learning by Doing Induced Technological Progress**

| Sector | Learning By Doing Effect | |
|---|---|---|
| | Using Cumulative output | Using Cumulative Investment |
| Manufacturing | 1.161 | 9.584* |
| Electricity & Water | 0.600* | -1.779* |
| Construction | 0.048 | 0.052 |
| Wholesale & Retail Trade | 0.036 | 0.001 |
| Transport., Storage & Communication | -0.036 | -0.025 |
| Finance & Real Estate | 0.052[a] | -0.028 |
| Other Services | 0.003 | -0.280 |

* Statistically Significant.

[a] Weakly significant(15% level of significance).

## Appendix A

The following table list the critical values of various tests used in testing for unit roots and for cointegration:

| Significance Level | DF | ADF | PP* |
|---|---|---|---|
| 1% | -2.62 | -3.55 | -18.9 |
| 5% | -1.95 | -2.91 | -13.3 |
| 10% | -1.61 | -2.60 | -10.7 |

Source : Fuller (1976 : 371 and 373).
Notes : The critical values in the tables are for a sample of size 50.
* These values are for $Z_k$ test. For $Z_t$ the critical values of DF and ADF are the relevant ones.

The adopted DF test is of the form:

$$\triangle y_t = \theta y_{t-1} + u_t \tag{A.1}$$

The adopted ADF test is of the form:

$$\triangle y_t = \alpha + \theta y_{t-1} + \sum_{s=1}^{n} \beta_s \triangle y_{t-s} + u_t \tag{A.2}$$

To save space, the PP is used for the model:

$$y_t = \mu + \rho y_{t-1} + u_t \tag{A.3}$$

The forms of the $Z_k$ and $Z_t$ test are explained in Banerjee et. al. (1993, pp. 108-113).

## Appendix B

If we are trying to estimate the following equation

$$A(B)X_t = \varepsilon_t \tag{B.1}$$

where X is the matrix of the dependent and independent variables in the model and $\varepsilon$ is an i.i.d. error term. If the variable are I (1), then using the presentation of Engle and Yoo (1991), and error-correction model for this equation is:

$$A(B)\triangle X_t = -\gamma\alpha' X_{t-1} + \varepsilon_t \tag{B.2}$$

where $\alpha' X_{t-1}$ is the vector of lagged residuals obtained from the static (long-run) equation.

If the variable in the model are I (2), then the error- correction in (B.1) becomes:

$$\mathrm{A(B)}\triangle^2 \mathrm{X}_t = -\gamma(\mathrm{B})[\alpha'(1) + \alpha^*(1)\triangle]\mathrm{X}_{t-1} + \varepsilon_t \tag{B.3}$$

where the term $[\cdot]\mathrm{X}_{t-1}$ is the vector of lagged residuals obtained from the cointegrating regression equation where the variables appear in their first-difference and level forms.

The model in equation (B.3) does not suffer form the notorious effects of spurious regressions since all the terms are stationary. This, of course, is ascertained by applying DF test to the residual vector.

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