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Dynamic Modeling of the Size of Technology Transfer

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Abstract

The size of technology imports and exports as well as the share of technology-based industries in the labor force are important means that can be utilized to assess the level of technology transfer in an economy. In this paper the annual size of imports, exports and trade balance of technology products is used to describe trend and make predictions and forecasts of the level of technology transfer with particular focus on the case of the United Arab Emirates (UAE). Using official trade data spanning the period from 1981 to 2010, the state-space methodology is utilized to handle the dynamic time series models and to study the developments of the state over time. Employing the Kalman filter, within the state-space framework, necessary estimation and forecasts are made. Evidence suggests increasing domestic demand for technology products, insufficient domestic production and increasing dependency on technology imports. Despite recent growth in UAE technology industries, the huge deficit in technology products trade balance indicates a negative trend in technology transfer. Policy implications are highlighted including the need for effective diffusion and internal transfer and generation of technology.

Keywords: State-space Model, Technology Transfer, Technology Products, Kalman Filter;

1. Introduction

Many countries have now embarked on changing from a resource-based economy to a knowledge-based one; several real examples can be cited in this respect including the examples of Malaysia, Thailand ([4]) in addition to other newly emerging transition economies. A well-educated population, skills-abundance and knowledge are the primary raw materials for knowledge-based economies. Evidence from international assessments of students suggests that some developing countries and transition economies lag significantly behind industrial countries in providing their population with the skills needed in the knowledge-economy ([12]). The dangers and problems of having large numbers of citizens who are neither sufficiently well-educated nor well enough trained to take part in the new economy are becoming increasingly apparent ([6]). Transferring people with requisite skills and knowledge to places where technology is needed represents an effective way to achieve *technology transfer*. However, to ensure that technology is successfully transferred and efficiently used, a broader aspect of *technology transfer* calls for the transfer of fundamental scientific and technological knowledge and skills to large number of people required in the work place ([6]). It is to note that the use of science and transferred technology involve improvement of living conditions and quality of life as well as protection of the environment without compromising economic goals.

One important aspect of the manufacturing sector in the United Arab Emirates (UAE) is its labor intensive nature, with relatively low labor productivity due to high dependency on unskilled and relatively inexpensive foreign labor supply ([1]). However, recognizing educational problems and the lack of technological knowledge and skills among the labor force, the UAE government future short and long term strategies (e.g. UAE Vision 2021 and Abu Dhabi Economic Vision 2030) are advocating a move towards a diversified competitive economy, focusing on knowledge-based industries and technology products. Realization of these strategies entails investments in acquisition of advanced technologies and development of technological skills and high competency in the workforce ([13]). According to Seyoum ([9]), a good measure of a country's competitiveness in high technology is the presence of substantial and sustained exports in high technology sector. Reich ([8]) regards high technology industries as the future primary source of wealth generation as opposed to resource and labor capital-intensive industries that dominated the twentieth century.

Several factors that affect the level and size of technology transfer in an economy are discussed in the literature; these include the country's technological infrastructure, level of available education and training to increase the capacities to assimilate, adapt, modify, and generate technology, attraction of foreign direct investment (FDI), and utility of foreign licensing. It is argued that countries' success in transferring and efficiently use technology rely largely on their ability to provide domestic production of technology and equipment sufficient to cater to domestic needs and to reduce demand and dependency on foreign technology accelerates, consequently lessening the negative impact of technology importation on the national balance of trade ([3]). Akubue ([2]) noted the massive but passive importation of technology by the Third World countries, referring to the tendency of these countries to adopt technological innovations without modification. He further argued that such arrangements could be the result of a strategy of the donor countries aimed at making Third World countries continuously rely on them for maintaining the new technology. Through this strategy of technology transfer, the donor country might also gain an additional advantage over purchasing raw material, such as oil and minerals or gaining political influence in the recipient country, in addition to profiting from technology maintenance.

Using data gathered from different international sources, Seyoum ([10]) reviewed the change in international trade over the last two decades and highlighted the fast growth in exports of technology-intensive products (high technology goods such as aerospace and computers) compared to other products. He identified three factors that positively influence a country's level of high technology exports; namely, technological physical and dynamic human base infrastructure, home demand conditions or sophistication of buyer needs, and attraction of quality inward investment that allow for sophisticated activities and functions. He further noted that technology developments cannot always be realized just through domestic innovation activities, greater productivity gains are often the result of foreign technology acquired through foreign direct investment (FDI), licensing or acquisition of high technology firms.

Employing data collected from various international sources, Lee and Tan ([5]) investigated FDI and technology intensities in four of the ASEAN economies; namely, Singapore, Malaysia, Thailand and Indonesia. Their results ranked Singapore as a leader of the four counties in not just attracting FDI, but also in channeling the most modern technological knowledge and skills. The authors attributed this high competitiveness mainly to the Singaporean government speed, efficiency and flexibility. Malaysia ranked top of the other three counties in FDI and technology transfer intensities. Contrary to the other three countries, the analysis presented a clear evidence that the Malaysian experience in technology transfer has largely benefited from FDI, international trade, and the capacity of the economy; leading to significant impact on economic growth. The local capabilities, domestic activities together with heightening of competition among foreign and local investors have further contributed to greater and enhanced technology transfer into the country. The authors concluded that for countries to reap full benefits of FDI and technology transfer, they should understand its magnitude in terms of determinants and modes of transfer. This would provide for clear policies and strategies to upgrade technological capabilities, rather than just attracting FDI and technology per se, focusing mainly on effective transfer, diffusion and domestic generation of technology.

The objective of this study is, therefore, to empirically investigate the size of technology transfer and reliance of the UAE on technology importation based on studying the country's trade balance of technology products, products that employ technology aided manufacturing. The exposition is intended to describe, understand trend and make predictions and forecast of the gap (deficit) between the UAE exports and imports of technology products using time series data and methodology.

The rest of the paper is organized as follows. Section 2 details the research methodology outlining data sources and modeling techniques. Section 3 presents results of the fitted models. In section 4 the fitted models are used to forecast future trend. Section 5 concludes the paper and presents some policy implications.

2. Methodology

2.1. Data sources

The data used in this study represent the UAE annual imports and exports (including re-exports) of technology products covering the period from 1981 to 2010, totaling 30 observations retrieved from the UAE Bureau of Statistics National Accounts estimates and the country's foreign trade figures. Figure 1 reveals a time series plot that indicates a huge gap between imports and exports of technology products. Technology products utilized in this analysis are defined according to Revision 3 of the Standard International Trade Classification (SITC) retrieved from the World Trade Organization (WTO) Statistical Database (2011). For the UAE, the rest of the GCC countries and other selected countries these products mainly cover SITC sections 5, 6, 7, 8 minus division 68 and group 891; namely iron and steel, chemical products, machinery and transport equipment in addition to other products.

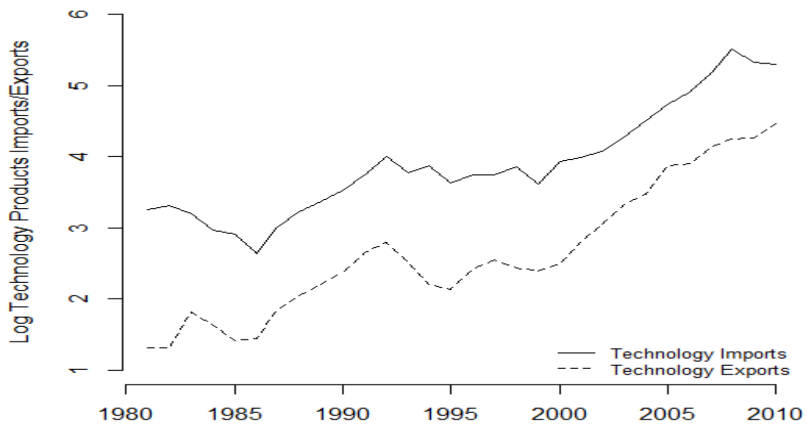

Figure 1: UAE Annual Technology Imports and Exports Data, 1981-2010

2.2. The dynamic linear model

The dynamic linear model (DLM), also known as the Gaussian linear model, is an important class of the state space models which offer a general framework for analyzing deterministic and stochastic dynamic systems measured or observed through a stochastic process ([7]). DLM is specified by a normal prior distribution for the p-dimensional state vector at time $t = 0$,

$$\theta_0 \sim N_p(m_0, c_0), \tag{1}$$

in addition to linear observation and state equations for each time $t \geq 1$, expressed respectively, using Gentleman et al. ([7]) formulation as

$$Y_t = F_t\theta_t + \nu_t, \qquad \nu_t \sim N_m(0, V_t), \tag{2}$$

$$\theta_t = G_t\theta_{t-1} + w_t, \qquad w_t \sim N_p(0, W_t), \tag{3}$$

where Y_t is the vector of measured variables of dimension $m \times 1$, θ_t is the state vector of unobserved variables of dimension $p \times 1$, F_t and G_t are known matrices of parameters of order $m \times p$ and $p \times p$, respectively, $(\nu_t)_{t \geq 1}$ and $(w_t)_{t \geq 1}$ are two independent sequences of independent Gaussian random vectors with mean zero and unknown variance matrices $(V_t)_{t \geq 1}$ and $(W_t)_{t \geq 1}$, respectively. It is assumed that θ_0 is independent of (ν_t) and (w_t).

The Kalman filter is used to provide estimates of the state vector θ_t based on an iterative procedure in which state values are successively predicted given the past observations, and then updated upon the reception of the next observation. Other parameters, including the hyper-parameters V_t and W_t, are usually obtained using the maximum likelihood principle.

The linear growth or local linear trend model for a univariate time series $(Y_t : t = 1, 2, \ldots)$ is a special case DLM derived from (2) and (3) by defining

$$\theta_t = \begin{bmatrix} \mu_t \\ \beta_t \end{bmatrix}, \qquad G = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}, \qquad w_t = \begin{bmatrix} \zeta_t \\ \xi_t \end{bmatrix}, \qquad W = \begin{bmatrix} \sigma_\zeta^2 & 0 \\ 0 & \sigma_\xi^2 \end{bmatrix}, \qquad F = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

Using scalar notation leads to

$$\begin{aligned} Y_t &= \mu_t + \nu_t, & \nu_t &\sim N(0, V) \\ \mu_t &= \mu_{t-1} + \beta_{t-1} + \zeta_t, & \zeta_t &\sim N(0, \sigma_\zeta^2) \\ \beta_t &= \beta_{t-1} + \xi_t, & \xi_t &\sim N(0, \sigma_\xi^2) \end{aligned} \tag{4}$$

with uncorrelated errors ν_t, ζ_t and ξ_t.

3. Fitting DLM to UAE Technology Products Deficit

The UAE demand for and dependency on foreign technology generated a negative upward trend of technology transfer. Figure 2 provides evidence of a steady increase in the size of trade deficit (exports minus imports) in technology products over the period from 1981 to 2010. The declining trend in technology deficit that is clearly evident during the mid-1980s can be related to the collapse in oil prices and subsequent drop in the country's oil and mining trade surplus. After the 1990 Gulf War the deficit stayed constant up to 2000 followed by a steady increase afterwards. It is noteworthy to mention that the big increase in technology deficit during the 2008 crisis came to settle down to pre-2008 figures as depicted in Figure 2. Excluding UAE fuel and mining trade surplus (71.0 billion US$) from the national trade balance (60.0 billion US $) for 2010, the country would have run into a deficit of 11.0 billion US $ ([1]). This demonstrates the importance of trade in technology products in determining the country's balance of trade and underscores the lack of innovative activities and inability of the UAE economy to assimilate and create new knowledge and technologies that cater for domestic needs ([1]).

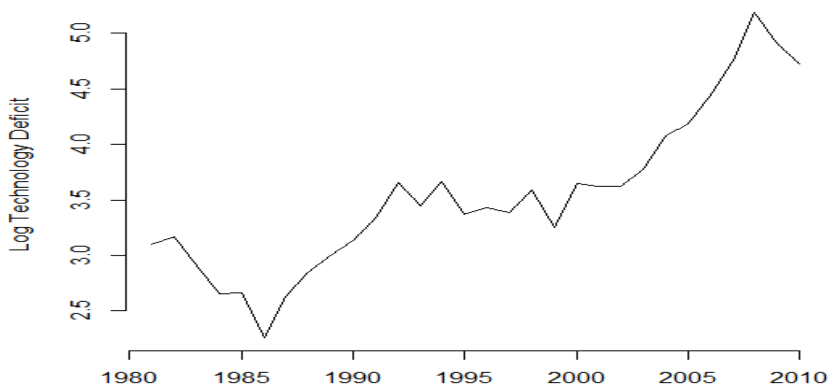

Figure 2: UAE Annual Technology Deficit Data, UAE

Utilizing the state space framework and the linear growth dynamic model outlined in equation (4) above, it was possible to obtain an explicit description of the trend in the UAE technological deficit (measured in log scale) for the period between 1981 and 2010. Figure 3 presents Kalman filtered estimates together with the smoothed estimates of the state vector θ_t . Diagnostic tests of model residuals, Table 1, satisfy the three following properties. The most important assumption of residuals independence is verified, ruling out any serial correlation, using the Box-Ljung statistic, $Q(k)$, which represents accumulation of residuals autocorrelation, measured at different lags, $k = 1,2,3,\ldots,15$. Testing for residuals homoscedasticity is based on a test statistic (H) following F-distribution (Commandeur and Koopman, 2007; p92). Normality of the residuals is confirmed using Shapiro-Wilk statistic, W , Table 1. All test statistics in Table 1 are associated with large p-values, supporting independence, homoscedasticity and normality of residuals.

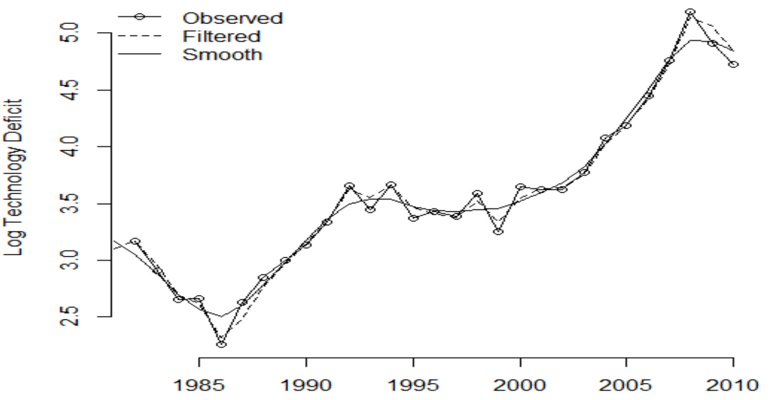

Figure 3: UAE Annual Technology Deficit (Billion AED), 1981-2010

Table 1. Diagnostic tests for linear growth model of UAE Technology Deficit, 1981 - 2010

	Statistic	Value	P-value
Independence	$Q(k)$	6.695	0.9565
	$r(1)$	0.052	0.8409
	$r(12)$	-0.010	0.9557
Homoscedasticity	H	1.108	0.4407
Normality	W	0.972	0.5984

4. Forecasting Future Trend in UAE Technology Deficit

The smoothed linear growth model adopted in this study (see model fit in Figure 3) is further used to forecast future size and trend of the growth in UAE technology deficit using a lead time of five years. To depict possible uncertainty in the produced forecast, a less conservative prediction interval of 85% is provided, Figure 4. The model is applied to log of UAE technology deficit, implying forecasted values of 4.7538, 4.6668, 4.5798, 4.4927 and 4.4057 for 2011 to 2015, respectively. In terms of absolute numbers, this means a declining trend in UAE technology deficit with predicted numbers of 116, 106, 97, 89 and 82 billion AED, respectively. Indeed, it is noteworthy that the current diversification trend and the move towards technology products in the UAE are picking up and are dictating different pace across the different emirates forming the union. The Emirate of Dubai, for example, has succeeded in diversifying 90 percent of its economy away from hydrocarbons, while Abu Dhabi Emirate's economy is still 66 percent hydrocarbon-based, [11].

Abu Dhabi Emirate's desire to build a diversified economy, however, has prompted "The Abu Dhabi Economic Vision 2030", a long term strategy, launched 2009, seeking to reduce reliance on the hydrocarbon-based sector as a source of economic activity, increasing the contribution of non-hydrocarbon-based sectors to the Emirate's Gross Domestic Product (GDP) and focus on knowledge-based industries in the future. The responsibility to realize Abu Dhabi Emirate diversification strategy is mainly entrusted on "Mubadala", Abu Dhabi Government-owned Development Company. Mubadala has recently embarked on a number of strategic overseas investments and partnerships with global leading technology companies, resulting so far in, for instance, the emergence of an aerospace components industry in the emirate and in the initiation of global cooperation platforms in renewable energy projects through its subsidiary company Masdar.

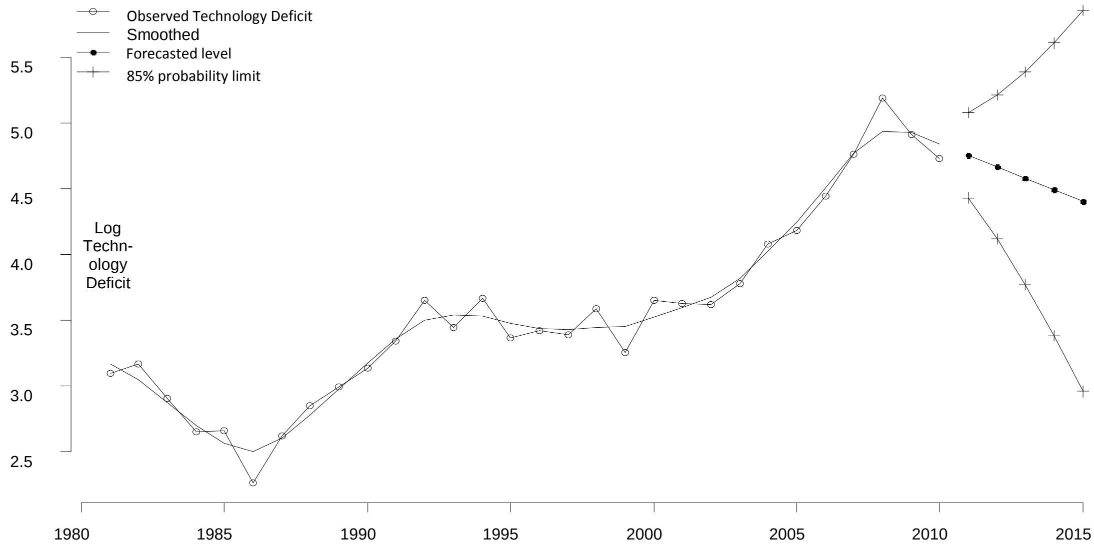

Figure 4: UAE Technology Deficit - Smoothed Trend and Five-year Forecasts with 85% Confidence Limits

5. Conclusion

The study utilized time series data retrieved from the UAE Bureau of Statistics National Accounts estimates and the country's foreign trade figures together with the DLM approach within the state space framework to empirically investigate the size of UAE imports-exports of technology products and to describe and predict the trend and gap in trade balance.

The analysis results reveal a huge gap between UAE imports and exports of technology products, indicating increased dependence on foreign technology imports and a negative trend in balance of payments and technology transfer.

To reduce over-reliance on foreign technology, the UAE needs to formulate and vigorously implement policies that increase investment in domestic knowledge innovations and promote R&D through university-industry partnership and capacity building of the workforce in science and technology. The success of the UAE in maximizing benefits from FDI for the production and export of technology products depends on the country's ability to diffuse knowledge and technology.

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