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Middle East Miracle: Are Recent High Levels of Growth Sustainable?

Garret Issac Mann, Elon University

In the last twenty years, the world has experienced a surge in technological innovation which has contributed to economic growth around the globe. Surprisingly, the Middle East is one of the fastest growing regions in the world. Despite its long history of conflict, war, and government instability, this region has experienced an average GDP growth rate of 4.49%, compared with the average world GDP growth rate of 2.76% over the past twenty years.

How do we explain this unprecedented growth in the Middle East? One hypothesis is the dramatic rise in industrialization and technological innovation in these countries. One thing that most Middle Eastern countries have in common is their growing industrial sector (World Databank). Some have been successful manufacturers of technological supplies, some have simply fueled the industry with their abundance of natural gases, and some have contributed a great deal to research and development. Between 1991 and 2011, the total number of patents applied for per year in these countries increased by 100% (World Databank). The purpose of this paper is to (1) estimate a Cobb-Douglas production function to estimate the relationship between innovation, proxied by patent applications, and real GDP; (2) determine what combination of factors — capital stock, employment, and technological innovation — are most responsible for the recent economic growth throughout the Middle East; and (3) assess which countries' growth appears to be most sustainable.

The sample consists of seven countries from the Middle East — Egypt, Israel, Iran, Jordan, Syria, Saudi Arabia, and Yemen. The data came from the World Bank's Databank from this most recent era of technological evolution, 1991-2011. Unfortunately, due to data availability, the sample years for some of the countries in the final sample are smaller (Iran '91-'06, Jordan '01-'11, Syria '93-'06, and Yemen '99-'07). Total patent applications are used to proxy technological innovation. To account for cultural, religious and other such differences between countries, I estimate a fixed effects regression and a first difference regression. Finally, the model is used to examine the economic escalation in each country during the sample of years, to explain the source of the growth, and to determine whether or not that growth is sustainable.

I. Review of Theory & Literature

The seminal work on economic growth was pioneered by Robert Solow in his 1957 Nobel Prize winning paper on neutral technical progress. Solow estimated a production function where economic growth is the product of real capital stock, real labor, and a labor-augmenting exogenous variable. In contrast, the recent endogenous growth literature argues that economic growth is predominantly a result of endogenous factors within a country. Numerous theories have recently predicted Solow's technological innovation variable to be the result of changes in factors such as human capital (Boskin and Lau, 2000), social capital (Neira, Portela, and Veira, 2010), research and development (R&D) (Neira, Portela, and Veira, 2010), or a combination of all of these (Seater and Peretto, 2007); but no one factor has been accredited as Solow's neutral technical progress.

Zeira (2011) argues that as innovation and patents increase, so do research and development expenditure, but that a high research and development expenditure does not necessarily indicate more patents or successful innovation. There are some cases where countries spend large sums of money on research and development, but it is wasted because very few patents are produced. Even if they are produced, only a percentage of patents are effective and become widely produced. This partially explains why efforts to explain neutral technical innovation with research and development expenditures have proven largely unproductive.

Studies that include the effects of patents on economic growth and development come mainly from microeconomic literature. Chu and Pan (2013) look at specific qualities and characteristics of patents and their likelihood to stimulate economic growth. Chu and Pan find that patent laws that prohibit innovators from creating a similar product or process to the original create a negative effect on the arrival rate of patents, the so-called "blocking effect." The blocking effect does, however, stimulate economic growth by increasing the step size of innovation (i.e., the technological gap that the innovator will inevitably conquer to form his or her patent). This explains a basic way in which patents fuel economic growth.

When examining employment in technology and knowledge-intensive sectors, high-tech patent applications, and social capital, Neira, Portela, and Veira (2010) find that the number of high tech patent applications per million inhabitants is positively correlated with real GDP. Their findings also included that trust in the form of social capital is a significant determinant of neutral technical progress.

Van Reenen (1997) analyzes employment as a product of a specific measure of innovation, patents, and capital in a "Solowesque" model. Van Reenan uses a measure of innovation rather than patents. He hypothesizes that despite the decreased required labor per unit of output, technological progress reduces the effective cost of labor and heightens the quality and range of goods and will therefore cause a firm to increase output. Although Van Reenen argues patents are a poor proxy, he does find patents to be positively correlated and significant in his model for employment. His measures for innovation include: the number of innovations a firm commercialized in a given year, the number of innovations produced in a given year, and the number of innovations used in a given year. Intuitively, these seem like appropriate and accurate measures of innovation. However, raw patent application data—as used in my model—does not only measure a number, it measures effort and advanced thought.

In most models, neutral technical progress is thought to provide a modification to labor. However, Boskin and Lau (2000) combine human capital and real capital to account for neutral technical progress. Seater and Peretto (2007) introduce an alternate production function that has no factor augmenting process. While there is no traditional form of neutral technical progress, investment into research and development becomes a factor exponent for capital. Their study was in-depth and created a basis for more work, but just as before, it is in no way a conclusive substitution for Solow's neutral technical progress.

While previous literature has tested a number of different determinants or proxies of technological innovation, there is no consensus. Furthermore, I do not think that the answer lies in a variable that is merely a measure of visible innovation. Patent applications are my proxy for technological innovation because it is the fact that society tries to make that giant step in the direction of innovation that causes patents to have a positive effect on the economy. Patent applications are also the most readily and widely available measure of innovation. In the following section I will estimate economic growth based on a Cobb-Douglas production function including capital, labor, and patent applications to determine what role society's effort to innovate has on economic growth.

II. Econometric Model & Data

The purpose of this section is to estimate an endogenous growth model with patent applications as the proxy for neutral technical progress in the standard growth model. In general, the production function can be written as:

Eqn. 1 $Q_{it} = K_{it}\, L_{it}\, A_{it}$

Output (Q) of the *i*th country in the *t*th year is a function of real capital (K_{it}), real labor (L_{it}), and neutral technical progress for a country in a specific year (A_{it}). This function is non-linear, but using logs **Eqn. 1** is easily converted to a linear form for econometric analysis:

Eqn. 2 $lQ_{it} = \beta_0 + \beta_1(lK_{it}) + \beta_2(lL_{it}) + \beta_3(lP_{it}) + u_{it}$

where $\beta_1>0$, $\beta_2>0$, and $\beta_3>0$.

My baseline model uses logged real Gross Domestic Product (GDP) in constant 2005 United States dollars (USD) for a country in a specific year (lQ_{it}) as the dependent variable. Logged gross capital formation in constant 2005 USD (lK_{it}) is the measure of real capital. Real labor is proxied by total employment (lL_{it}).

The preferred proxy for real labor is the product of total hours worked per employee and total employment creates total hours worked by the entire country in a given year. As opposed to total employment that just measures how many people in the labor force are employed, total hours worked tells us the labor input that contributes to output. Unfortunately, data for total hours worked per employee for this sample is not available. The use of this proxy for real labor introduces slight measurement error into the model.
The variable used to account for neutral technical progress is total yearly patent applications for a country in a specific year (lP_{it}). I use total yearly patent applications because it is the most readily and widely available measure of innovation.[1]

In estimating Eqn 2., I expect to encounter several econometric problems including unobserved heterogeneity across countries and auto-correlation of the error term. The unobserved heterogeneity exists as omitted variables that factor into the variations of individual observations both as the year and the country changes. If the omitted variables are not changing across time

[1] Total R&D in constant USD and R&D as a percentage of GDP were also tried. However these were dropped due to multicollinearity (see VIFs in A1 of the Appendix), scarcity of data, and simultaneity.

then a fixed effects model could potentially be applied. A feasible generalized least squares model, or a first difference model could be used to help solve auto-correlation.

III. Results

The sample consists of data from 7 countries between the years 1990 through 2012. All data come from the World Bank Databank, an extensive collection of data consisting of diverse development indicators across the world. Because of missing data in some years, the final sample consists of 104 observations.

The results are summarized in Table 1. The four models reported are: (1) an OLS model; (2) feasible generalized least squares model; (3) a fixed effects model; and (4) a first differences model. The full results for the OLS, feasible generalized least squares model, fixed effects model, and first difference model are reported in Table 2, Table 3, Table 4, and Table 5, respectively.

Table 1: Total Results Summary

Variable	Ordinary Least Squares	Fixed Effects	Feasible Generalized Least Squares	First Difference
lnCapital	0.886*	0.217*	0.288*	0.148*
	[0.03]	[0.05]	[0.04]	[0.034]
lnEmployment	0.020	0.932*	0.789*	0.299*
	[0.024]	[0.109]	[0.064]	[0.069]
lnPatents	0.048*	0.052	0.077*	0.043*
	[0.018]	[0.038]	[0.021]	[0.014]
Constant	3.526*	5.021*	5.68*	
	[0.601]	[1.806]	[0.042]	
Observations	116	116	109	104
Adjusted R-sq.	0.955	0.916	0.853	0.385

Standard errors are in brackets. All standard errors—except for FGLS's—are robust.
Robust standard errors for Fixed Effects are clustered by country.
*Significant at 1%

Table 2: Ordinary Least Squares Regression

Variable	Coefficient	Robust Std. Er.	t	P>t
lnCapital	0.886*	0.030	29.260	0.000
lnEmployment	0.020	0.024	0.870	0.387
lnPatents	0.048*	0.018	2.690	0.008
Constant	3.526*	0.601	5.870	0.000

Number of Observations = 116
R-squared = 0.957
F-test = 820.84
*Significant at 1%

Table 2 shows the full results of the baseline OLS model. As predicted, all of the coefficients are positive. I used robust standard errors because the model was ever so slightly heteroscedastic as you can see in the residual plot (Figure 1 in the Appendix). In addition, the Breusch-Pagan test (A2 in Appendix) rejected the null of homoscedasticity. As seen by the VIF scores (A3 in Appendix), there is no multicollinearity in the baseline model, because there is no correlation between total capital and total employment, total capital and total patent applications, or total employment and total patent applications. The insignificance of employment is likely the result of the measurement error as previously mentioned.

The insignificance may also be due to omitted variables caused by unobserved heterogeneity at the country level and by auto-correlation of the error term across time. Unobserved heterogeneity at the country level is expected the sample includes some fairly diverse countries. In fact there are many factors that could be different across country such as climate, geography, topography and infrastructure; differences in resources and endowments. While Israel operates out of a parliamentary system in the form of their Knesset, dictators, kings, sheikhs, and even terrorists operate other countries in the area. The variation in governing bodies could grossly affect many development indicators. This and many other factors due to cultures in this part of the world create much unobserved heterogeneity. Politics are also an excellent example for a cause of auto-correlation of the error term across time in the Middle East. Conflicts between and within countries in the Middle East have happened fairly often in the past 50 years. Certain years when conflict is occurring and subsequent years after a regime change come with vast changes in the economy as well. Unobserved heterogeneity due to these kinds of factors will be controlled for using a fixed effects model.

In Table 3, I present the feasible generalized least squares model regression. The FGLS estimates an auto-regression. While the coefficients in the FGLS are now all significant, we have yet to account for unobserved heterogeneity. As you can see in Table 3, a negative correlation exists between the error term and the predicted values of GDP and that the share of the estimated variance of the overall error accounted by the individual effect (ρ) is just under 1. This is a telling sign to try a first difference model that turns all of my variables into growth rates and eliminates the need for a constant. Present results from the fixed effects model in Table 4.

Table 3: Feasible Generalized Least Squares Regression

Variable	Coefficient	Standard Errors	t
lnCapital	0.288*	0.040	7.160
lnEmployment	0.789*	0.064	12.350
lnPatents	0.077*	0.021	3.730
Constant	5.680*	0.042	134.670

Number of Observations = 109
$\rho = 0.993$
*Significant at 1%
F-test(3,99)=211.55

Table 4: Fixed Effects Regression

Variable	Coefficient	Robust Standard Error	t
lnCapital	0.217*	0.050	4.390
lnEmployment	0.932*	0.109	8.560
lnPatents	0.052	0.038	1.370
Constant	5.021*	1.806	2.780

Number of Observations = 116
$\rho = 0.994$
*Significant at 1%
F-test(3,6)=47.07

The fixed effects model accounted for unobserved heterogeneity across countries. It fixes these effects by assuming that the unobserved heterogeneous variable remains constant over time. Each of the variables in my regression is then interpreted as deviations from the average measure of that variable in a specific country across the entirety of years observed in the sample. Because the unobserved heterogeneous variable remains constant over time, it remains the same and is only to be observed once for each country. The fact that the robust standard errors reported for the fixed effects equation are actually higher than the non-robust standard errors was initially troubling. Not only that but the t-stats and the significance of the regression decreased after robust standard errors were reported. However, Bertrand, Duflo, and Mullainathan (2004) note that the usual standard errors of the fixed effects model are radically understated in the presence of auto-correlation. Given the drastic changes that occurred, I would not only argue that robust standard errors are necessary for this specific fixed effects regression, but that the variation reflects the significance of fixed effects for my baseline model. It is well known that serially uncorrelated errors in the baseline model lead econometricians in the direction of fixed effects because using a first difference model would then present auto-correlation where there was none to begin with. But in this case, we do have auto-correlation in the baseline model, and we would still have it after using a fixed effects regression.

Similarly to a fixed effects model, a first difference model changes the measure of the variables. The first-difference model solves both problems of unobserved heterogeneity and autocorrelation. Again, we are no longer observing the levels in each country for every year in the sample. In the first difference model, we look at the differences of our variables from one year to another. The β_0 from the baseline model is eliminated because it is a constant. We assume that the unobserved heterogeneous variable is not dependent on time and therefore remains constant with time. Without the unobserved heterogeneity or auto-correlation in the error term, the covariance between the first differences in our explanatory variables and the first differences in our error term is equal to zero.

Table 5: First Difference Regression

Variable	Coefficient	Robust Standard Error	t
ΔlnCapital	0.148*	0.034	4.350
ΔlnEmployment	0.299*	0.069	4.330
ΔlnPatents	0.043*	0.014	3.170

Number of Observations = 104
*Significant at 1%
R-squared = 0.40
F-test(3,101)=30.13

As seen in Table 5 the t-statistics are all significant at a 1% level. Using an F-test the model was determined to be significant at all levels. Due to the nature of coefficients in a first difference model and the fact that our variables are logged, the coefficients are now measured in growth rate. Thus, my regression equation becomes:

Eqn. 3 $$\Delta lG_{it} = 0.299(\Delta lK_{it}) + 0.148(\Delta lL_{it}) + 0.043(\Delta lP_{it})$$

It can first be seen that as the growth rate of real capital increases by 1 percentage point the growth rate of real GDP increases by 0.15 percentage points, all else constant. Second, as the growth rate of total employment increases by 1 percentage point, all else held constant, the growth rate of real GDP increases by 0.3 percentage points. Lastly, as the growth rate of total patent applications increases by 1 percentage point, all else held constant, the growth rate of real GDP increases just over 0.04 percentage points.

IV. Growth Accounting

In this section, I will decompose each country's growth into that which can be explained by change in capital, labor, and technology. To proxy technology, I will use two estimates. First, I will use estimates from my model (Eqn. 3), where technology is proxied by innovation in the form of patent applications. Second, I will estimate a Solow residual. In Douglas and Cobb (1928), as well as Solow (1957), neutral technical progress is simply the residual term, or the output that could not be explained by capital and labor (e). To create the Solow residual I run the first difference regression Eqn. 4, which only has capital and labor as the explanatory variables. Then I predict the residuals, which gives me the Solow value for neutral technical progress. The average first differences for real GDP, real capital, employment, and patent applications are taken from the final sample for each country. These, along with each economy's mean Solow residual for the same respective time periods is reported in Table 9.

Eqn. 4 $\Delta lG_{it} = \beta_1(\Delta lK_{it}) + \beta_2(\Delta lL_{it}) + \Delta e_{it}$

Table 6: Average First Difference Percentage Growth

Country	Years	Real Gross Domestic Product	Real Capital	Employment	Patent Applications	Solow Residual
Egypt	1991-2011	4.02%	-0.92%	2.56%	3.72%	4.03%
Iran	1991-2006	4.34%	3.51%	3.63%	21.82%	2.80%
Israel	1991-2011	4.38%	3.34%	3.38%	1.22%	2.93%
Jordan	2001-2011	5.79%	6.97%	1.69%	-5.22%	4.23%
Saudi	1991-2011	3.90%	6.26%	2.91%	12.59%	1.75%
Syria	1993-2006	4.93%	5.26%	2.27%	-5.59%	3.49%
Yemen	1999-2007	4.08%	0.54%	2.32%	5.02%	3.37%
Sample		4.49%	3.57%	2.68%	4.79%	3.23%

Whether growth in a country is sustainable lies in the balance of capital, labor, and GDP. According to Solow's theory a perfectly sustainable economy has growth rate of real GDP that is equal to its growth rate of real capital, and the sum of the growth rates of real labor and the Solow residual equal the growth rate of real capital.

Given Egypt and Yemen's rate of growth of the Solow residual and GDP, it appears the growth rate of capital stock is too low. If they were to take action to increase capital stock, then the growth rate of capital stock will increase in a linear manner while the growth rate of GDP increases with diminishing returns. The two rates will eventually converge. Allowing their capital stock to catch up, by increasing their savings rate for example, will result in more investment that will then increase their GDP and result in a higher level of economic growth.

Israel and Iran are in a similar situation to Egypt and Yemen, just at a different level. Their growth rates of capital stock are larger than Egypt and Yemen's, though their Solow residual is slightly smaller. While their rate of GDP is initially higher than Egypt and Yemen's, it will only grow marginally until capital stock and GDP meet and level out. Therefore, even while Israel and Iran have more sustainable growth now, Egypt and Yemen may have more growth in the long run when they too reach a sustainable growth.

In contrast to these, Saudi Arabia is plagued with too high a growth rate in capital stock relative to its GDP growth. This is known as capital deepening, and it is unsustainable. Growth by capital deepening eventually leads to the plummeting of capital stocks growth rate, while GDP's growth rate will steadily decrease. As the two rates begin to approach one another, they will slow to a point where the growth rate of capital stock is slightly larger than that of GDP.

The most balanced economies appear to be Jordan and Syria. Jordan's Solow residual is higher than Syria's, and their respective rates of GDP growth reflect this difference. Both economies employment growth rates are low, which indicates sustainable growth. And both could manage to reduce their rate of capital stock growth, which would be by a miniscule amount and would result in a very insignificant decrease in the growth rates of GDP.

V. Summary & Conclusion

The purpose of this paper has been to provide evidence that the growth of the economies in the Middle East has been driven by innovation, and to determine whether the current rapid rates of growth in the region is sustainable. The empirical research shows that patent applications have a small but significantly positive impact on the economic growth of the Middle East. Moreover, the evidence from the growth accounting appears to suggest that these high growth rates are in fact relatively sustainable for most countries. Two countries are in balance, and four countries should experience even higher future economic growth rates because their capital is lower than their GDP and will catch up. Only Saudi Arabia appears to be headed for economic slowdown.

However, some caution must be taken as these predictions do not take factors like political stability into account. Egypt's future looks strong if they take action to increase their capital formation, but two government overthrows in the last five years threaten to undermine any such efforts. Syria's recent numbers look stable, but the continued threat of civil war will negatively affect the growth rates. These countries have shown considerable growth and sustainability in the recent past. Exactly what these economies do going forward that will alter their sustainability is unknown.

VI. References

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VII. Appendix

A1	VIF: lnR&D=11.29; lnPatents=7.61
A2	BP test Chi_2(1)=2.82
A3	VIF: lncap.=2.38; lnpat.=1.89; lnemp.=1.43
A5	SE: f-test(3,106)=394.99. RSE: f-test(3,6)=47.07

Figure 1: Residual Scatter Plot for OLS

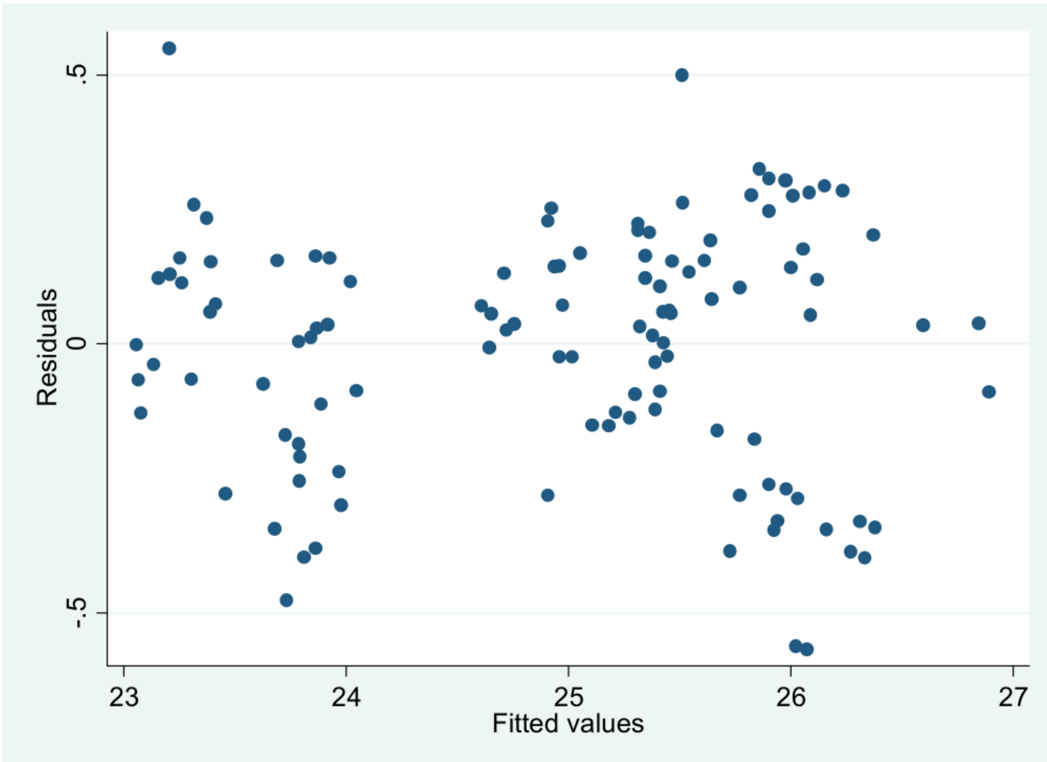

Table 8: Summary Statistics for Yemen

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	9	35	8	24	48
Gross Capital Formation (Million Constant USD)	9	2,870	283	2,400	3,220
GDP (Million Constant USD)	9	15,400	1,710	12,800	17,900
Total Employment	9	4,351,923	370,236	3,559,846	4,761,589

Table 9: Summary Statistics for Syria

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	12	181	63	63	257
Gross Capital Formation (Million Constant USD)	12	5,190	453	4,540	5,910
GDP (Million Constant USD)	12	23,600	3,900	17,800	30,300
Total Employment	12	4,375,927	543,071	3,516,068	5,173,646

Table 10: Summary Statistics for Saudi Arabia

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	18	768	248	476	1,331
Gross Capital Formation (Million Constant USD)	18	59,200	21,700	42,000	127,000
GDP (Million Constant USD)	18	277,000	66,300	216,000	473,000
Total Employment	18	6,528,700	1,325,776	5,223,062	9,673,211

Table 11: Summary Statistics for Jordan

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	11	359	175	138	585
Gross Capital Formation (Million Constant USD)	11	3,620	1,050	2,050	4,720
GDP (Million Constant USD)	11	13,700	2,850	9,730	17,500
Total Employment	11	1,269,979	154,996	1,047,728	1,461,412

Table 12: Summary Statistics for Israel

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	21	5,792	1,833	2,886	9,875
Gross Capital Formation (Million Constant USD)	21	24,600	3,920	18,900	34,900
GDP (Million Constant USD)	21	120,000	29,000	74,300	173,000
Total Employment	21	2,300,519	426,355	1,589,375	3,052,157

Table 13: Summary Statistics for Iran

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	16	1,392	1,767	397	6,527
Gross Capital Formation (Million Constant USD)	16	50,100	11,400	26,600	66,200
GDP (Million Constant USD)	16	146,000	29,000	114,000	203,000
Total Employment	16	17,600,000	3,486,276	12,600,000	24,600,000

Table 14: Summary Statistics for Egypt

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Patent Applications	17	1,379	521	694	2,230
Gross Capital Formation (Million Constant USD)	17	15,400	4,700	10,200	24,600
GDP (Million Constant USD)	17	80,300	24,500	50,100	123,000
Total Employment	17	18,900,000	3,462,968	15,000,000	26,600,000