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The Effect of Technology on Development

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Standard aggregate production function models cite labor, capital and technology as the primary determinants of economic growth and development. In this paper, I extend standard models to distinguish between technology of ideas or "intellectual advancement" and that of "mechanical advancement." Further, following Mitra (2009) and Fisher-Vanen and Mun (2010), I include FDI and energy intensity, respectively, to create a growth model that more accurately represents development.

Based on his results, Mitra (2009) claims that FDI may stagnate growth in developing countries because labor in those countries lacks the human capital to effectively use the imported capital and technology. This, however, is not the case when countries develop their own technology. It is thus assumed that countries develop at such a rate that allows its labor force to adapt to technological changes – analogous to a built-in learning curve. Importing technology from countries with far superior technology disrupts his gradual transition (Mitra 2009). Fisher-Vanen and Mun claim that the effectiveness of technology depends on the amount of energy used in production. Although more advanced technology requires less energy, the quality and amount of resources available, according to their results, influences the amount of output generated. Therefore, energy intensity is concluded to sponsor economic growth. Finally, I estimate separate regressions for socioeconomic and economic growth to distinguish between the factors that contribute their respective growth.

In this analysis, regression models are estimated separately for developed and developing countries. Theoretically, because of differences in the quantity and quality of factors of production, excluded factors (e.g. political stability or gender inequality), and unobservable effects (e.g. national loyalty), additional increases in technology, capital, labor, energy intensity and human capital should have dissimilar effect on countries based on its level of current development.

The distinction between developing and developed countries is made using United Nation Development Program's (UNDP) Human Development Index. The HDI measures societal welfare through an index integrating education, life expectancy and GDP per capita outcomes. Countries with HDI greater than 0.800 are considered "developed" for the purposes of this paper.

Results suggest noteworthy differences in the determinants of HDI growth between developed and developing countries and, more importantly, the sources of socioeconomic and economic growth in developing countries. Capital formation associates with higher growth in both sets of countries, consistent with exogenous growth theories that stress capital accumulation. However, evidence indicates that in addition to capital formation, developed countries achieve growth through increases in technology and energy intensity, whereas developing countries rely more heavily on labor inputs. The models find no evidence to support the importance of human capital proposed by endogenous growth theory. Specifically, the growth of human capital is insignificant in the development regression for developing countries and is found to decrease HDI growth in developed countries.

Furthermore, developed countries are estimated to achieve socioeconomic and economic growth similarly through increases in technology and energy intensity. Interestingly, a similar result was not found with regards to developing countries. For these countries, economic growth is caused by increases in technology and capital, whereas socioeconomic growth is driven primarily by increases in labor force participation. This result not only highlights the difference between socioeconomic and economic growth, but it further suggest that policymakers should consider which type of development they seek to promote before implementing any new policy. The remainder of the paper is organized as follows. Section I outlines the economic theory associated with development and growth. Next, the empirical model and variables used in this analysis are explained, followed by the paper's results.

I. Economic Theory

In this analysis, I model economic development following a standard aggregate production function (Abel 2008):

$$Y = A * F(K, L)$$

(1)

,where *Y* is output, *A* is a measure of technology and ideas, *K* is capital stock and *L* is labor. To determine the effect of each variable on growth as opposed to the level of *Y*, I totally differentiate equation (1):

$$\Delta Y = \Delta A * F(K, L) + A * \frac{\Delta F(K,L)}{\Delta K} * \Delta K + A * \frac{\Delta F(K,L)}{\Delta L} * \Delta L$$

(2)

The expression is then divided through by *Y* to derive growth rates. Recall, *Y* can also be written as *A*F(K,L).*

$$\frac{\Delta Y}{Y} = \frac{\Delta A * F(K,L)}{A * F(K,L)} + \frac{A * \Delta F(K,L)}{\Delta K} * \frac{\Delta K}{Y} + \frac{A * \Delta F(K,L)}{\Delta L} * \frac{\Delta L}{Y}$$

(3)

The above simplifies to:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \frac{\Delta Y}{\Delta K} * \frac{\Delta K}{Y} + \frac{\Delta Y}{\Delta L} * \frac{\Delta L}{Y}$$
(4)

The last two terms are multiplied by K/K and L/L, respectively.

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \frac{\Delta Y}{\Delta K} * \frac{\Delta K}{Y} * \frac{K}{K} + \frac{\Delta Y}{\Delta L} * \frac{\Delta L}{Y} * \frac{L}{L}$$
(5)

This transformation allows us to model output growth as a function of capital and labor input growth and the elasticity of output with respect to capital (α_K) and labor (α_L), where the latter are defined as:

$$\alpha_K = \frac{\Delta Y}{\Delta K} * \frac{K}{Y}$$
(6)

$$\alpha_L = \frac{\Delta Y}{\Delta L} * \frac{L}{Y}$$
(7)

The standard growth equation may now be expressed as:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha_K * \frac{\Delta K}{K} + \alpha_L * \frac{\Delta L}{L}$$
(8)

In growth theory, capital and labor are assumed to yield constant returns to scale, forcing $\alpha_K + \alpha_L = 1$. As a result, growth generated by either capital or labor eventually converges to a steady state. However, growth in technology changes this dynamic because ideas are non-rival. Unlike capital and labor that can only be present and used by one firm, ideas are usable by all workers simultaneously and thus lead to the possibility of increasing returns to scale at the economy level. Firms, however, still experience diminishing returns to scale with regards to *K* and *L*.

A variety of innovations to this basic model have manipulated the "*A*" parameter in order to more explicitly represent the determinants of technology growth. For example, the Romer model (1986) distinguished between technology and human capital by dividing labor into groups: people working to produce output (L_{Yt}) and people producing ideas (L_{At}).

$$L = L_{yt} + L_{At}$$

(9)

Similarly, in the Solow model (1956), *A* denotes a combination of technology and ideas.

$$\Delta A_t = Z * A_t * L_{at}$$

(10)

Models that control for both factors are generally regarded as better representation of the real world. However, the inclusion of both human capital and mechanical advancement as endogenous determinants of technology makes the model empirically intractable. As a compromise, I model technology as the sum of mechanical and intellectual advancement, but allow those parameters to be exogenously determined as described in more detail below.

Further, two additional inputs, energy intensity and foreign direct investment, are added to the standard model following the work of Fisher-Vanen and Mun (2010) and Mitra (2009), respectively. Incorporating these variables and the two technology parameters, the growth model becomes:

$$\frac{\Delta Y}{Y} = \frac{\Delta M}{M} + \frac{\Delta H}{H} + \alpha_{K_D} * \frac{\Delta K_D}{K_D} + \alpha_{K_F} * \frac{\Delta K_F}{K_F} + \alpha_L * \frac{\Delta L}{L} + \alpha_E * \frac{\Delta E}{E}$$

(11)

where *E* is a measure of energy intensity, K_D is the domestic capital stock and K_F is capital stock created by foreign direct investment (FDI). Fisher-Vanen and Mun argue that without energy the usefulness of labor, capital and technology dramatically decreases. Furthermore, the amount of energy needed to produce output in developing countries is greater, in comparison to developed countries, because of differences in capital and technology. With respect to the inclusion of FDI, Mitra suggests that because developed countries can invest in poorer nations, the latter should experience accelerated growth under high levels of FDI, depending on the level of human capital present.

Note that in equation (11), *A* has been replaced by *M* and *H*, where *M* is mechanical advancement and *H* is intellectual advancement or human capital. For estimation purposes, human capital is measured as education, typically by enrollment or literacy rate. Technology or mechanical advancement is the residual of the production function.

II. Empirical Model, Variable and Data Description

Following closely from the theoretical model, this paper examines the effect of technology on levels of socio-economic development using a dataset of developing and developed countries for the years 1980, 1985, 1990, 1995, 2000, 2005, and 2006. To estimate the impact of technological change on the development rate, the following specification is employed:

$$\frac{\Delta HDI}{HDI} = \beta_0 + \beta_1 \frac{\Delta M}{M} + \beta_2 \frac{\Delta K_D}{K_D} + \beta_3 \frac{\Delta H}{H} + \beta_4 \frac{\Delta L}{L} + \beta_5 \frac{\Delta K_F}{K_F} + \beta_6 \frac{\Delta E}{E} + \beta_7 \frac{\Delta M x \Delta E}{M x E} + \beta_8 \frac{\Delta T x \Delta K_F}{T x K_F} + \beta_9 YR + e \quad (12)$$

$$\frac{\Delta GDP}{GDP} = \beta_0 + \beta_1 \frac{\Delta M}{M} + \beta_2 \frac{\Delta K_D}{K_D} + \beta_3 \frac{\Delta H}{H} + \beta_4 \frac{\Delta L}{L} + \beta_5 \frac{\Delta K_F}{K_F} + \beta_6 \frac{\Delta E}{E} + \beta_7 \frac{\Delta M x \Delta E}{M x E} + \beta_8 \frac{\Delta T x \Delta K_F}{T x K_F} + \beta_9 YR + e \quad (13)$$

where *HDI* represents the United Nations Human Development Index, *GDP* represents GDP per capita, *M* represents total factor productivity (as the calculated residual of per capita GDP growth models[i]), K_D represents gross capital formation as a percent of GDP, *H* represents total public spending on education as a percent of GDP, *L* represents labor force participation, K_F represents net inflows of foreign direct investment as a percent of GDP, *E* represents total primary energy consumption in quadrillions of BTUs (British terminal units), and *Yr* represents year dummies. Again, all variables represent growth rates.

Under the assumption that energy and foreign direct investment (FDI) represent additional inputs, measures of energy intensity per quadrillion BTUs and foreign direct investment as a proportion of GDP are included following the work of Fisher-Vanen and Mun (2010) and Mitra (2009). According to these papers, energy resources are influential to growth because of their relationship to technology. Creation of new technologies requires natural resource inputs. Thus, increases in a nation's energy intensity are predicted to increase future levels of development through current development. Moreover, the authors conclude that without gradual increases in this input, technological progress will be ineffective as all technology demands raw materials to continue to function. Failure to include energy intensity would positively bias estimates of the TFP because the direct effect of natural inputs on development will be included in TFP's coefficient.

With respect to foreign direct investment, the standard growth model assumes that all development efforts are concentrated in domestic actions. However, a more realistic assumption is that foreign direct investment can enable countries to gain access to advanced technology without the need to produce them. Because of the low –skilled labor force present in many developing countries, significant development may not occur even in the presence of adequate labor and capital inputs because workers are unable to maximize the new technology's potential. Thus, inclusion of the FDI variable is predicted to both increase development directly and indirectly through more efficient TFP use. For the latter reason, FDI enters the model individually and through an interaction with total factor productivity. Energy intensity is interacted with TFP for a parallel reason.

One innovation of this paper is the use of a broad development measure, the Human Development Index, in addition to GDP in the analysis. The HDI measures growth as a composite of life expectancy, adult literacy rate, combined enrollment and GDP per capita. Much of the existing literature linking productivity to economic growth uses per capita GDP growth rates as the dependent variable (Henry 2010, Krishanasmy 2009). While useful in their own right, these analyses fail to consider the role of technology in the non-economic aspects of development. To highlight the distinction of socioeconomic from economic growth, separate regressions are estimated using GDP per capita and HDI. I use the HDI as the outcome measure in this analysis to provide a parameter for development not completely driven by economic indicators, but I acknowledge common criticisms of that measure.

Specifically, critics of the HDI cite its failure to acknowledge gender inequality (Chatterjee 2005) or political stability (Costanza 2009) as key deficiencies in the HDI measure. Further, Segura and Moya (2007) argue that the HDI's even three-fold composition allows countries with a low-score in one area to compensate with higher scores in the others, thus artificially generating high HDI. To evaluate this concern, the authors construct a "non-compensatory HDI" and find that their development rankings with the new index closely resemble the HDI's. Similarly, in Bérenger (2007), the author creates two indices measuring standard of living and quality of life and then compares it to HDI-based rankings of development. Again, differences between the two are minimal. Bérenger's contention that "it [HDI] does in fact take the essential indicators into account, since it establishes country rankings very close to those of our two indices" (Bérenger 2007))represent some external validation of my use of the measure.

My estimation strategy addresses a number of potential empirical problems. Because all variables are measured as growth rates, the model eliminates potential bias from unobserved country heterogeneity. Year dummies, represented by the vector "YR" in the specification, control for year fixed effects. Estimation of this model separately for "developed" and "developing" countries, as defined by the UNDP, allows for structural differences in the determinants of development, resulting from the underlying macroeconomic differences between the two groups. Estimation of variance inflation factors indicates that none of the regressions have multicollinearity. Durbin-Watson statistics were also estimated by country and indicate that none have serial autocorrelation (see Appendix B).

Finally, as with any macroeconomic time series, accurate representation of the direction of causality in this model is difficult. Theoretically, it is believed that as the factors included on the right hand side of the specification increase, growth occurs. However, it may be the case that because a country is developing, it is able to acquire more labor, capital, etc. and thus development increases as those factors increases. Tests for granger causality are performed to provide statistical evidence of the direction of causality of the independent variables in relation to the dependent variable. If the former scenario prevails, then we would find evidence that independent factors granger cause HDI growth while if the latter scenario prevails, we would find evidence that the growth rate in HDI granger causes each factor. Granger causality uses a series of f-tests to derive this outcome.

III. Results

Table 1 presents model descriptive statistics separately for developed and developing countries. Note that a second version of each set of summary statistics represents the subsample averages with outliers removed.

Table 1: Sample Descriptive Statistics

Variable	Developing	Developing*	Developed	Developed**
HDI Growth	0.981	0.960	0.432	0.430
	(1.102)	(1.182)	(0.263)	(0.253)
GDP Per Capita Growth	2.216	2.599	2.668	2.584
	(4.663)	(5.070)	(2.648)	(2.471)
TFP Growth	1.243	1.572	1.482	1.302
	(6.254)	(7.143)	(2.897)	(2.459)
Capital Growth	21.309	21.826	21.760	21.446
	(6.602)	(7.223)	(4.623)	(4.187)
LFP Growth	2.928	2.739	1.763	1.755
	(1.599)	(1.776)	(1.317)	(1.308)
EdExp Growth	1.869	0.569	0.338	0.459
	(10.541)	(6.115)	(4.613)	(4.156)
Energy Growth	5.737	5.392	2.601	2.256
	(9.578)	(9.342)	(3.696)	(3.151)
FDI Growth	-62.025	69.241	64.715	31.941
	(931.655)	(290.007)	(392.863)	(103.611)
Observations	144	102	198	180

Variable standard derivations are found in parentheses
All variables measured as percentage points
* The following "developing" countries are omitted because of the presence of outliers in FDI and EdExp growth: Dominican Republic, Paraguay, Guatemala, Benin, Nicaragua, Burkina Faso and Syrian Arab Republic
**The following "developed" countries are omitted because of the presence of outliers in FDI and EdExp growth: Japan, Malaysia, Venezuela and Trinidad and Tobago.

Table 2: The effect of technology on growth, developing countries

	GDP Per Capita Growth		HDI Growth	
Variable	***Developing (1)***	***Developing (2)***	***Developing (1)***	***Developing (2)***
TFP Growth	0.551 (0.409)***	0.529 (0.466)***	0.002 (0.016)	-0.002 (0.017)
Capital Growth	0.079 (0.041)*	0.089 (0.050)*	0.026 (0.016)*	0.026 (0.018)
LFP Growth	-0.199 (0.164)	-0.233 (0.191)	0.126 (0.062)**	0.146 (0.069)**
EdExp Growth	0.026 (0.023)	0.027 (0.051)	0.002 (0.009)	0.013 (0.018)
Energy Growth	-0.015 (0.026)	-0.024 (0.035)	0.010 (0.010)	0.017 (0.013)
FDI Growth*	0.006 (0.003)	0.001 (0.001)	0.008 (0.009)	0.001 (0.004)**
TFP Growth x FDI Growth*	0.004 (0.002)	0.004 (0.003)	-0.002 (0.009)	-0.001 (0.009)
TFP Growth x Energy Growth*	0.005 (0.003)	(0.004) (0.004)	0.003 (0.001)	-0.005 (0.001)
Observations	144	102	144	102
Adj. R-Squared	0.6278	0.6295	0.0323	0.1046

*For actual coefficient estimates, multiply FDI by 0.010 (in GDP equations) and by 0.100 (in HDI equations), TFPxFDI by 0.100 and TFPxEnergy by 0.100

Year dummy variables (not present here) control for year fixed effects.

Standard errors are in parentheses *p<.10, **p<.05 ***p<.01

All variables measured as percentage points

Joint Significance of TFPxFDI is (0.7104) in GDP Eq (1), (0.0630) in GDP Eq (2), (0.0000) in HDI Eq (3), and (0.0000) in HDI Eq (4)

Joint significance of TFPxEnergy is (0.5616) in GDP Eq (1), (0.4049) in GDP Eq (2), (0.0171) in HDI Eq (3), and (0.0000) in HDI Eq (4).

Outliers represent countries with values, particularly in *FDI* and *EdExp Growth*, that were drastically different than the bulk of countries within their cohort. As seen with regards with *FDI Growth* above, the mean and standard errors are much different when the outliers are omitted.

Table 3: The effect of technology on growth, developed countries

	GDP Per Capita Growth		HDI Growth	
Variable	***Developed (3)***	***Developed (4)***	***Developed (3)***	***Developed (4)***
TFP Growth	0.725 (0.040)***	0.885 (0.394)***	0.015 (0.006)**	0.024 (0.007)***
Capital Growth	0.095 (0.025)***	0.090 (0.023)***	0.005 (0.004)	0.001 (0.004)
LFP Growth	-0.047 (0.093)	0.028 (0.078)	0.017 (0.015)	0.008 (0.015)
EdExp Growth	-0.025 (0.025)	0.003 (0.022)	-0.004 (0.004)	0.004 (0.004)
Energy Growth	0.058 (0.034)*	0.060 (0.033)*	0.020 (0.005)***	0.028 (0.006)***
FDI Growth*	-0.002 (0.003)	0.001 (0.001)	-0.001 (0.004)	0.004 (0.002)**
TFP Growth x FDI Growth *	-0.001 (0.002)	-0.001 (0.001)	-0.004 (0.003)	-0.007 (0.003)***
TFP Growth x Energy Growth*	-0.002 (0.007)	(0.001) (0.006)	-0.002 (0.001)**	-0.002 (0.001)**
Observations	198	180	198	180
Adj. R-Squared	0.6605	0.7565	0.1611	0.1985

*For actual coefficient estimates, multiply FDI by 0.100 (in GDP equations) and by 0.010 (in HDI equations), TFPxFDI by .0100 and TFPxEnergy by 0.0001
Year dummy variables (not present here) control for year fixed effects.
Standard errors are in parentheses *p<.10, **p<.05 ***p<.01
All variables measured as percentage points
Joint Significance of TFPxFDI is (0.0.0000) in GDP Eq (3), (0.0005) in GDP Eq (4), (0.0000) in HDI Eq (3), and (0.0000) in HDI Eq (4)
Joint significance of TFPxEnergy is (0.0.0000) in GDP Eq (3), (0.0000) in GDP Eq (4), (0.0171) in HDI Eq (3), and (0.0000) in HDI Eq (4).
Outliers represent countries with values, particularly in *FDI* and *EdExp Growth*, that were drastically different than the bulk of countries within their cohort. As seen with regards with *FDI Growth* above, the mean and standard errors are much different when the outliers are omitted.

Table 2 and Table 3 presents coefficient estimates from the regression analysis by country development status. Due to the presence of outliers in *EDEXP* and *FDI* within both sets of countries, the analysis is run on the full sample and a subsample excluding the outliers. A full list of countries included in each specification is provided in the appendix.

According to the analysis results for the developing model, labor force participation is a significant driver of socioeconomic development. Specifically, a one-percentage point increase in labor force participation growth is estimated to increase HDI growth by 0.126 percentage points in the full sample and by 0.146 percentage points in the subsample excluding outliers. Interestingly, labor force is insignificant in the GDP per capita. Instead, technology and capital growth are estimated to stimulate economic growth, both in the full and subsample model. A one-percentage point increase in technology growth is estimated to increase GDP per capita by

0.551 percentage points in the full model and by 0.529 in the restricted model. Similarly, a one-percentage point increase in capital growth is estimated to increase GDP per capita by 0.079 percentage point the full model and by 0.089 percentage points if the outliers are excluded. The latter provides evidence to the claim that socioeconomic and economic growth do not necessarily derive from the same factors.

Capital growth (either domestic or foreign) has a much less significant impact on HDI growth, and the effect varies based on the inclusion of the seven outliers. With the outliers, *CAPITAL* is significant, but has a small effect on development. A one-percentage point increase in capital stock formation causes HDI to increase by 0.026 percentage points. Alternatively, without the outliers, *FDI* is significant and has a positive effect on HDI growth. Results indicate that a one-percentage point increase in FDI is associated with an estimated 0.001 percentage points in HDI. Note that the FDI interaction terms are insignificant, both individually and jointly with the corresponding level effects, in the developing model.

The drivers of HDI growth among developed nations differ from those for developing nations. Again, the significance of *FDI* variables differs based upon the presence of the six outliers. In the full sample, foreign rather than domestic capital growth is significant, with the effect of a one-percentage point increase in FDI on growth is estimated to vary depending on the rate at which the country's technology grows. A one-percentage point increase in FDI in countries with an average TFP growth of 1.371 percentage points is associated with a 0.024 percentage point increase in HDI. Similarly, with a minimum TFP growth of -7.761, FDI is predicted to increase HDI by 0.025 percentages point and by 0.023 in countries with a maximum TFP growth rate of 7.761. This indicates that growth can be sponsored by foreign sources – even if no technological progression is occurring.

In contrast to the developing country results and consistent with Fisher-Vanen and Mun (2010), *ENERGY* influences growth among developed countries. A one-percentage point increase in energy intensity is estimated to increase HDI by 0.028 percentage points. Interestingly, regardless of the rate at which developed countries experience technological growth, increases in energy intensity yield roughly the same increase in development. A percentage point increase in energy intensity in countries with an average TFP growth of 1.371 is estimated to increase HDI by 0.028 percentage points. If the country has a minimum TFP growth of -9.944, then the same increase in energy intensity causes a 0.0282 percentage point increase in HDI. In countries with maximum TFP growth of 7.761, then the increase is 0.02784 percentage points. This suggests that natural inputs can generate growth, holding constant levels of technology growth. A test of joint significance indicates the statistical significance of the interaction in both developed models.

Interestingly, with regards to developed countries, socioeconomic and economic growth is achievable by appealing to the same factors, namely technology and energy growth. This result, coupled with findings from the developing regressions, suggest that the determinants of socioeconomic and economic growth differ only in developing countries. Once a country has developed beyond a certain threshold, socioeconomic growth and economic growth are essentially interchangeable. A few differences, however, do persist. For example, increases in *CAPITAL* cause economic growth, whereas socioeconomic growth is possible with increases in *FDI.* A one-percentage increase in capital growth is estimated to increase GDP per capita by 0.095 in the full model and 0.090 in the restricted model. Similarly, a one-percentage point increase in FDI growth is estimated to increase HDI by 0.0004 percentage points.

Turning to a discussion of the technology covariate, note that TFP influences HDI growth in developed but not developing nations, although its impact is small considering its prominence in the growth literature. Further, the effect varies depending on the growth of energy intensity. In countries with an average energy intensity growth of 2.256, a one-percentage point increase in technology is associated with a 0.02395 percentage point increase in HDI. More interestingly, however, one-percentage point in technology in countries with minimum energy intensity growth of -14.650 is predicted to increase HDI growth by 0.0243, whereas in countries with a maximum energy intensity growth of 15.646 technology growth is associated with a 0.0237 increase in HDI. These results suggest that energy intensity and technology may be substitutes, which entails that socioeconomic growth is achievable through resource growth alone. Further, development may be possible given growing resource constrains. This refutes the results of Fisher-Vanen and Mun (2010).

Overall, the developed country results differ significantly from those among developing countries, as evidenced by the Chow test statistics of 2.908 on the full model with outliers and 3.799 on the model without outliers. Difference in adjusted r-squared for the *Developing* and *Developed* regression reveal that the factors of production explain a smaller amount of the variance in development in the former.

Table 4. Results of Granger Causality Test

	TFP Growth	***Capital Growth***	***LFP Growth***	***EdExp Growth***	***Energy Growth***	***FDI Growth***
HDI Growth-	0.368	0.576	0.546	0.958	0.623	0.217
HDI Growth-	0.535	0.812	0.546	0.330	0.284	0.233
HDI Growth-	0.619	0.474	0.924	0.875	0.282	0.089*
HDI Growth-	0.801	0.801	0.427	0.163	0.651	0.032**

Granger causality test statistics *p<.10, **p<.05 ***p<.01

*Regressions exclude respective outliers

A series of Granger causality tests examine whether HDI growth causes or is caused by growth in the included independent variables.[1] Standard errors and p-values for the relevant coefficients from the Granger test are presented in Table 4. In the developed country regressions, tests indicate that HDI is Granger caused by the model covariates. In the developing country models, there is evidence of reverse causality with respect to foreign domestic investment only. These results increase the validity of the output displayed in Table 2 and 3.

IV. Conclusions

The goal of this paper was to quantify the effect of changes in technology, labor, physical and human capital, FDI, and energy intensity on HDI growth. Results indicate that the determinants of growth differ between developed and developing countries. Specifically, increases in labor force participation contribute greatly to HDI growth in developing countries, whereas technology and energy intensity fosters HDI growth in developed countries. The latter result is inconsistent with Fisher-Vanen and Mun (2010). Surprisingly, domestic capital plays a limited role in growth in both nations, although FDI, or foreign sponsored capital, plays a role in promoting growth in some of the models estimated. Results seem to suggest that separate growth models are needed to determine growth based on the level of development in the country of interest. Results further suggest that "development" which encompasses social as well as economic outcomes may need to be considered differently than purely economic growth when developing policy initiatives. Developed countries tend to have more advanced capital integration. Therefore, increases in labor force participation may only marginally contribute to growth. The same increase in labor in developing countries, with less advanced capital, may motivate significant growth. This paper's results provide evidence of the latter.

V. Acknowledgments

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[1] Given concerns that reverse causality is compromising the validity of the results, additional regressions were estimated using lagged independent variables. Results found no further evidence of reverse causality.

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VII. Appendix

Appendix A: Countries

The following countries are included in my dataset:

Very High Development	**High Development**	**Medium Development**	**Low Development**
Norway	Bahrain	Thailand	Benin*
Australia	Turkey	Dominican Republic *	Rwanda
Iceland	Chile	Jordan	Mozambique
Canada	Uruguay	Paraguay*	Burkina Faso*
Ireland	Mexico	Sri Lanka	Mali
Netherlands	Costa Rica	Philippines	Central African Republic
Sweden	Peru	El Salvador	
France	Panama	Syrian Arab Republic*	
Japan*	Trinidad and Tobago*	Honduras	
Finland	Malaysia*	Bolivia	
United States	Brazil	Guatemala*	
Austria	Colombia	Nicaragua*	
Spain		Botswana	
Denmark		Morocco	
Belgium		India	
Italy		Swaziland	
New Zealand		Bangladesh	
United Kingdom		Cameroon	
Greece			
Israel			

Distinction is based of United Nations Development Program rankings.
*Represents outliers omitted from *Developing(2)* and *Developed(4)*

Appendix B: Durbin Watson Statistics, by country

Countries	HDI	GDP	Countries	HDI	GDP
Australia	1.931	1.910	Japan*	1.932	1.960
Austria	1.817	1.881	Jordan	1.958	1.934
Bahrain	1.921	1.982	Malaysia*	1.922	1.971
Bangladesh	1.990	1.899	Mali	2.111	1.959
Belgium	2.091	1.999	Mexico	1.981	2.011
Benin*	2.110	1.899	Morocco	1.921	1.851
Bolivia	2.021	1.913	Mozambique	1.946	1.956
Botswana	1.916	1.910	Netherlands	1.925	1.966
Brazil	2.000	1.981	New Zealand	1.952	1.943
Burkina Faso*	1.995	1.889	Nicaragua*	1.958	1.962
Cameroon	2.000	2.119	Norway	1.918	1.999
Canada	1.943	1.973	Panama	1.912	1.952
Central African Republic	1.998	1.941	Paraguay*	1.976	1.965
Chile	2.011	1.953	Peru	1.946	1.969
Colombia	1.871	1.964	Philippines	1.873	2.222
Costa Rica	1.901	1.941	Portugal	2.116	1.952
Denmark	2.111	1.963	Rwanda	1.853	1.942
Dominican Republic *	2.010	1.953	Spain	1.985	1.926
El Salvador	1.899	1.934	Sri Lanka	1.900	1.915
Finland	1.901	1.958	Swaziland	1.943	1.964
France	2.005	1.955	Sweden	1.953	1.986
Greece	1.945	1.964	Syrian Arab Republic*	1.937	1.965
Guatemala*	1.953	1.946	Thailand	1.954	1.925
Honduras	1.916	1.961	Trinidad and Tobago*	1.985	1.934
Iceland	1.963	1.942	Turkey	1.965	1.905
India	1.976	1.901	United Kingdom	1.933	1.929
Ireland	1.980	1.924	United States	2.134	1.909
Israel	1.911	1.954	Uruguay	2.111	2.017
Italy	1.981	1.924			

[i] TFP parameter was generously provided and estimated by Dr. Anders Isaksson. See Isaksson, Anders (2007), "World Productivity Database: A Technical Description," RST Staff Working Paper 10/2007, Vienna: UNIDO for more details.