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Factor-Specific Productivity

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Economists examine two types of variables when studying aggregate production and economic growth. Some of these variables are directly productive factors (physical capital, labor and human capital), while other variables aren't productive themselves, but affect production indirectly. I introduce an approach for studying indirect inputs by allowing them to affect output in three ways: by changing TFP, by changing the productivity of individual productive factors (Factor-Specific Productivity), and by changing the rates at which productive factors are accumulated. My model finds that indirect inputs have strong effects on the productivity of specific productive factors. My model outperforms a model which includes the same indirect inputs only as determinants of TFP. Increases in indirect inputs are found to lead to future growth in the supply of direct inputs. Additionally, my model has more empirically realistic implications for returns to scale and convergence than traditional neo-classical models.

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Under Review

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Keywords: TFP, production, returns to scale, convergence

JEL Codes: O4

Factor-Specific Productivity

1 Introduction

Broadly speaking, recent literature regarding the vast differences in output which exist among countries has sought to 1) argue for the relative importance of either productivity differences or differences in factor accumulations across countries as the underlying cause of output differences and, 2) for those arguing for the importance of productivity differences, put forth an explanation of which variables may underlie the existing productivity differences. One way to categorise inputs to production is to ask the question, “Could this input produce output by itself?” For physical capital, human capital, and labour, the answer to this question is yes. These variables will be collectively referred to as direct inputs to the productive process. Any variable which affects production but could not produce output by itself will be referred to as an indirect input to production.

Most researchers add indirect inputs to regressions, either explicitly modeling them as affecting TFP or implicitly adding them in a manner consistent with independent TFP effects. However, I outline three ways in which indirect inputs could affect production. Indirect inputs could change total factor productivity, they could change the productivity of individual direct inputs, or they could incentivise or disincentivise accumulation of direct inputs.

In this paper I construct a framework which allows indirect inputs to influence a production function through any of these three channels. Arguably, this extension allows for modeling an indirect input in a manner which is consistent with the microeconomic theories regarding its effects. In an empirical application, I allow indirect inputs to alter the productivity of individual direct inputs rather than just the total factor productivity of the model. The included indirect inputs, each of which has previously been found to be correlated with output differences across countries, reflect infrastructure, worker health, and childhood nutrition. Furthermore, I separately show that higher levels of indirect inputs are correlated with higher future stocks of direct inputs and that indirect input growth incentivises future growth in direct inputs.

The model which I introduce has three advantages over a standard model which includes the same inputs captured through a TFP term. First, my model reflects the channels through which microeconomic studies have found the indirect inputs operating. Including the indirect inputs in a TFP term captures neither the subtlety nor the specificity of indirect effects found at the individual level. Second, a Davidson and MacKinnon non-nested hypothesis test indicates that my FSP model is more appropriate than a model which allows only TFP effects in fitting the data. Evaluating the production function in levels, the FSP model is strictly preferred to the TFP model. In corresponding growth regressions, both FSP and TFP models have independent explanatory power. Third, from a policy perspective, the combination of better model performance and relevant connections to the microeconomic foundations may make an FSP model more useful for estimating aggregate impacts of micro policies focused on economic growth and development.

The rest of this paper is structured as follows. Section 2 provides a general overview of some of the existing literature on models which focus on differences in factor accumulation or differences in productivity in explaining cross-country outcomes. I also provide case studies using the microeconomic literature on how particular indirect inputs should affect production outcomes. Section 3 proposes a model for analyzing the effects of indirect inputs in production, both in levels and in growth rates. Section 4 applies this model to three indirect inputs and empirically tests the FSP model against a TFP model. The robustness of the test result is checked under a number of specifications. Section 5 discusses the implication on returns to scale and convergence in this new framework. Section 6 concludes.

2 Reviewing the Existing Literature

2.1 Stocks of direct inputs, productivity differences, and output differences

A few key works are responsible for advancing the debate on factor accumulation versus productivity differences. Strongly on the side that output differences are primarily the result of differing levels of direct inputs are works such as Mankiw, Romer, and Weil (1992), who estimate that 78% of the international variance in output can be explained by factor accumulation differences according to their famous augmented Solow model. Looking at a specific region, Alwyn Young (1994, 1995) further supports this theory in his finding that rapid factor accumulation seems to be the primary cause of the East Asian growth miracles. Nonneman and Vanhoudt (1996) find that the inclusion of "technological know-how" as a factor of production allows an augmented Solow model to explain three quarters of the variation in output among OECD countries.

Sturgill (2010) also argues that differences in factor accumulation, not productivity parameters, explain output differences across countries. His work is distinguished by the fact that factor shares (or specific factor productivity parameters) are not held to be constant through the development process. Instead, he shows that less developed countries observe higher returns to non-reproducible factors of production (labour and "natural capital"), while technological change in the development process actually shifts productivity away from the non-reproducible factors towards the reproducible factors (physical capital and human capital). I also allow for changes in the productivity of specific factors, and compare my results to those of Sturgill in Section 4. While Sturgill demonstrates how factor productivity differs across developed and developing countries, he does not go on to model how indirect inputs influence this difference.

The other side of the debate follows primarily from Hall and Jones (1999), who estimate the differences in productivity across countries as the residual from a Solow-type equation. They find that these differences, which are now commonly referred to as Total Factor Productivity (TFP), explain the largest portion of international output differences. Hall and Jones discuss "social infrastructure" factors which they feel are critical to explaining the cross-country differences in productivity. Similarly, Klenow and Rodriguez-Clare (1997) re-examine the approach of Mankiw, Romer, and Weil and, after small adjustments to data, argue that productivity differences, not factor accumulation, account for the majority of national income variations and call for additional focus on the causes of international productivity differences. In this line of research Robert Barro (1990, 1991, 1995, 1996, 1999, 2000, 2001, 2003, 2004; Barro & Sala-i-Martin, 1997) has written a series of empirical studies examining indirect inputs which are associated with growth differences across countries. If one takes the perspective that growth models are simply levels models of output viewed dynamically, these variables would be necessarily included in the productivity parameter in a production function approach. The list of variables Barro has examined include, but are not limited to, government consumption, political instability, market system, terms of trade, fertility rates, child mortality rates, inflation and its variability, life expectancy, educational spending, democracy, rule of law, intellectual property rights, research and development expenditures, income inequality, trade openness, and religion. Any or all of these variables could potentially help to explain the productivity differences across countries when appropriately included in a production function.

Two previous works have worked with similar models in order to look at indirect inputs and production or productivity. Dearmon and Grier (2009) estimate a reduced form model which allows for social capital to affect worker productivity, without attempting to generate a structural model which would correspond to their reduced form. Piper (2011) employs one special application of the general framework introduced here to examine the benefits of improved nutrition on aggregate productivity. In so doing, he uses a model which includes nutrition as an indirect input which affects the productivity of labour and of human capital, demonstrating how factor-specific models can be used evaluate microeconomic policies.

2.2 Infrastructure, Health and Nutrition in Development Accounting

Estache and Fay (2007) provide an excellent summary on the history of infrastructure's inclusion in growth and development debates as well as the current views on the topic. The literature suggests that the primary effects of improved infrastructure (especially measured by something like electrical capacity) should be on the productivity of firms through the types and effectiveness of available capital, although it can also affect investment adjustment costs, capital durability, and the supply and demand for health and education services, as well as the effectiveness of investments in education (Agenor & Moreno-Dodson, 2006; Brenneman, 2002). Infrastructure is a very inclusive term, and it is certain that no single measure can adequately capture the total infrastructure of a country. Some measures which are common in the literature include miles of roads or numbers of vehicle per capita, which measure some aspects of transportation infrastructure, coverage of telegraphs, telephones, or cellular phones, which capture communication infrastructure, and the availability of clean water or electricity, which are more general infrastructure measures. Because it is such a general measure, and because it has good data availability, I employ a measure of a country's electricity generating capacity for the empirical analysis. This data comes from David Canning's data set, updated from Canning (1998). As suggested by the microeconomic literature, the primary role of infrastructure relates to the effectiveness of physical capital, so the empirical analysis includes infrastructure in the factor-specific term for capital.

The net effects of infrastructure on growth or development have been much examined, although findings on the net returns have varied from negative or zero to positive and significant (Romp & de Haan, 2005; Straub & Vellutini, 2006; Biceno, Estache, & Shafik, 2004; Gramlich, 1994). There does, however, exist a growing consensus in the literature that, whatever the returns to infrastructure may be, they are likely not linear and may be dependent upon the levels of other inputs to production (Roller & Waverman, 2001; Fernald, 1999; Albala-Bertrand & Mamatzadakis, 2004).

Several papers have previously examined the relationship between aggregate health and aggregate production (Ashraf, Lester, & Weil, 2008; Bloom & Canning, 2005; Bloom, Canning, & Sevilla, 2004; Weil, 2007). Findings have ranged from no effect to small but significant positive returns to increased health. Unlike this paper, most of the previous literature has treated health as a direct input into production or as an indirect input affecting overall productivity.

For the purposes of this paper, health will refer to the overall health of current workers, specifically in ways which would affect their ability to engage in their normal tasks. To reflect overall worker health, I employ an estimate of average life expectancy, which is commonly used in macroeconomic analyses to reflect overall health conditions (for example, Bloom and Canning (2005) and Ashraf, Lester, and Weil (2008)). Some of the commonly reported estimated effects of improved health are decreases in Years Lost to Disability (YLD), increased labour market participation, increases in worker performance while at work, increased savings, increased investments in human capital, and decreased fertility rates.

Because the greatest effects of improved health fall directly on workers, the health measure is included in the factor-specific productivity term on the labour supply, although I will also look at the effects of increased health on the accumulation of all three direct inputs.

Nutrition is one variable which has been somewhat absent from the literature on aggregate production despite a rich microeconomic literature focusing on the individual benefits to improved nutrition. While some authors group nutrition in with other health measures, the microeconomic literature suggests unique and important roles for nutrition distinct from other health measures, specifically in cognitive development in utero and in early childhood. This micro-founded literature has found significant effects of improved nutrition, especially early in life, on cognitive development, labour market outcomes, test scores, and grades completed (Alderman, Hoddinott, & Kinsey, 2006; Behrman, 2007; Behrman & Rosenzweig, 2004; Glewwe & King, 2001; Grantham-McGregor, Fernald, & Sethuraman, 1999; Grantham-McGregor et al. 2007; Johnston, Low, de Baessa, & MacVean, 1987; Maluccio et al. 2009; Strauss & Thomas, 1998; Victora, et al., 2008). Results seem especially strong for women (Malluccioet al., 2009). Taken together, the micro results suggest that the primary effects of nutrition are related to education and that increased nutrition affects both the returns to education for individuals and the accumulation of human capital. Nutrition will thus be included in the FSP term for human capital in the empirical analysis.

Piper (2011) looks at the aggregate effects of nutrition on country output, and finds that proper nutrition is key to making investments in human capital productive in the future, and that improved nutrition has strong effects on current worker productivity. This paper, like Piper (2011), allows the overall nutrition level to be captured by the average caloric intake of the population of a country.

3 A model for looking at indirect inputs

In developing a general model of production, I begin with an augmented Solow model of the form:

$$Y_{it} = A(K_{it})^{\alpha}(L_{it})^{\beta}(H_{it})^{\gamma} \quad (1)$$

Here, production in country i at time t is a function of direct inputs (labour (L), capital (K), and human capital (H)), along with some overall productivity scaling factor (A).

It is possible to extend this framework to allow for indirect inputs to affect production through three distinct channels. First, indirect inputs should be able to systematically influence the TFP term across countries. Therefore, instead of having a constant TFP term, A, total productivity will be a function of indirect inputs denoted A(•). This channel would be appropriate for modeling an indirect input which altered the overall productivity in a country. Consider, for example, an input which facilitated general technology transfer across countries.

Second, indirect inputs should be able to have heterogeneous effects on the productivity of each of the direct inputs to production. To achieve this, I replace the standard exponents α, β, and γ, with Factor-Specific Productivity (FSP) functions, α(•), β(•), and γ(•). Just as the standard exponents in Solow-type models have dual interpretations as both relative productivity parameters and factor income shares, the FSP functions have two interpretations: one interpretation reflecting heterogeneous relative factor productivities across countries and time and another interpretation as reflecting differing factor shares of income. This leaves my production function of interest as:

$$Y_{it} = A(\bullet)(K_{it})^{\alpha(\bullet)}(L_{it})^{\beta(\bullet)}(H_{it})^{\gamma(\bullet)} \tag{2}$$

The third way indirect inputs could potentially influence production is through the accumulation of the direct inputs, K, L and H. To account for this, I allow the growth of the direct inputs as to depend upon the levels and growth rates of indirect inputs in separate regressions.

Within the framework of equation (2), the researcher's discretion is still involved in the selection of which indirect inputs to examine, which of the four productivity functions each input should be included in, and the functional forms of the TFP and FSP functions. I endeavor to be guided in these choices by the existing literature and by microeconomic foundations.

I select three indirect inputs for inclusion in FSP terms. I include electricity generating capacity per capita as a measure of infrastructure. As the literatures suggests that infrastructure most strongly influences the returns to physical capital, electrical consumption is included in the FSP function $\alpha(\bullet)$. For simplicity, $\alpha(\bullet)$ is modeled as a linear function of infrastructure and a constant:

$$\alpha\left(INF_{i,t}\right) = \alpha_0 + \alpha_1 INF_{i,t} \tag{3}$$

To proxy for worker health, I include average life expectancy of a country's population as an indirect input modifying the FSP function for labour, $\beta(\bullet)$. While the life expectancy data in each year is intended as the projected life expectancy of babies born in that year, because it is calculated based on the existing health of the current population, it should be a good proxy for the health of current workers. β(•) is a linear function of this measure of worker health and a constant1:

$$\beta\left(HEALTH_{i,t}\right) = \beta_0 + \beta_1 HEALTH_{i,t} \quad (4)$$

As a measure of childhood nutrition I include the average caloric intake within a country, lagged 15 years. I scale the caloric value relative to a recommended intake of 2500 calories daily. To account for the decreasing returns to average nutrition, the square root is then taken of this scaled value, and I label the result RDA. Childhood nutrition, as indicated by the microeconomic literature, affects the returns to educational investments by individuals and is thus included in the FSP term for human capital, γ(•), along with a constant.

$$\gamma\left(RDA_{i,t-15}\right) = \gamma_0 + \gamma_1 RDA_{\ i,t-15} \quad (5)$$

$$RDA_{i,t-15} = \left(\frac{NUTR_{i,t-15}}{2500}\right)^{1/2} \quad (6)$$

For the purposes of my model, TFP will be represented by a constant, e^{A}. TFP will be considered constant both across countries and through time. I will compare this very restrictive specification to others where TFP varies according to the levels of indirect inputs. For robustness, I will also check my model against alternative models where TFP is additionally allowed to have country or year fixed effects.

Traditionally, production functions are rewritten so that direct inputs and resulting GDP can be expressed in per-capita or per-worker terms. However, by allowing FSP functions to vary across countries and across time, it becomes impossible to cleanly divide through by population or by the labour force. It is important to keep in mind that results should be interpreted in terms of overall production, not output per capita. So, replacing the FSP functions in the production function in (2) we can write:

$$Y_{it} = e^{A}(K_{it})^{\alpha_0+\alpha_1 \mathrm{INF}_{i,t}}(L_{it})^{\beta_0+\beta_1 \mathrm{HEALTH}_{i,t}}(H_{it})^{\gamma_0+\gamma_1 \mathrm{RDA}_{\,i,t-15}} \quad (7)$$

For estimation purposes, natural logs are taken of both sides of equation (7) yielding:

$$y_{it} = A + \alpha_0 k_{i,t} + \alpha_1 \mathrm{INF}_{i,t} k_{i,t} + \beta_0 l_{i,t} + \beta_1 \mathrm{HEALTH}_{i,t} l_{i,t} + \gamma_0 h_{i,t} + \gamma_1 \mathrm{RDA}_{\,i,t-15} h_{i,t} \quad (8)$$

where lowercase variables represent the natural logs of their uppercase counterparts. Equation (8) represents my primary FSP model in levels. Additionally, I will examine the FSP model in growth rates after rewriting the interaction terms as single variables. $\mathrm{INF}_{i,t}k_{i,t}$ is rewritten simply as $\mathrm{Effective\ Capital}_{i,t}$ and is abbreviated $\mathrm{EK}_{i,t}$. Similarly, the HEALTH/labour and RDA/human capital interactions are renamed $\text{Effective Labour}_{i,t}$ and $\text{Effective Human Capital}_{i,t}$ and are abbreviated as $EL_{i,t}$ and $EH_{i,t}$ respectively. The corresponding FSP growth equation can then be written as:

$$\%\Delta y_{i,t} = \alpha_0 \%\Delta k_{i,t} + \alpha_1 \%\Delta EK_{i,t} + \beta_0 \%\Delta l_{i,t} + \beta_1 \%\Delta EL_{i,t} + \gamma_0 \%\Delta h_{i,t} + \gamma_1 \%\Delta EH_{i,t} \quad (9)$$

I now move to an empirical investigation of the benefits of my model.

4 The Effects of Infrastructure, Worker Health, and Childhood Nutrition on Production

4.1 Primary Regression Results

I estimate equation (8) on an unbalanced panel of countries at five year intervals over the time period 1980-2000, for a maximum of five observations per country. Eighty-eight countries are included.[2] Data on the stocks of physical and human capital are included along with estimates of the labour force, following Benhabib and Spiegel (1994). While this approach differs from most existing work, which instead includes estimates of factor income shares, it allows for an explicit estimation of the elasticities of outputs with respect to inputs (Temple, 1999). The stock of physical capital is constructed by a perpetual inventory method using a 5% depreciation rate. The reader is referred to the data appendix for full information on the construction and sources for all variables and a list of which countries are included in the sample.

In considering specifications (8) and (9), it seems apparent that the dependent variables and many of the right hand side variables may be simultaneously determined, leading to endogeneity concerns. This potential endogeneity could be coming from two sources. First, un-modeled factors could systematically influence both the dependent and RHS variables. This concern would apply to the model in levels but not to the growth model if the un-modeled factors were time invariant. Endogeneity could also occur if RHS variables were, in part, determined by contemporaneous levels of income. This concern applies equally to both the level and growth models, and needs to be addressed through instrumentation. I consider instrumentation potentially necessary for the stock of physical capital (k), electricity generating capacity (INF), the labour supply (l), life expectancy (HEALTH), and the stock of human capital (h). RDA is already constructed with a 15 year lag and so it seems unreasonable that current income could be influencing it.

For instruments, I utilise variables on population age distributions. These variables reflect the fraction of a country's population in each 5 year bin from ages 0-80. Cook (2002) points out that life cycle theories tie savings and investment to the population age structure. Empirical evidence of this relationship is found in Higgins (1998). This relationship makes the age distribution appropriate as instruments for both the stock of physical capital and the infrastructure level. Because the fraction of young people in schools has increased over time, the age distribution should also be related to the human stock of capital. Age structure has previously been used as an instrument for human capital stocks in Ciccone and Peri (2006). Life expectancy estimates take into account the existing population's age structure, and models of labour force participation establish a relationship between age structure and participation as well (Toossi, 2011). Wilson (2000) provides additional motivation for the relationship between demographic variables and factor inputs. Considering all of this evidence, the age structure data has an established relationship with all of the potentially endogenous variables. Moreover, changes in age structure are primarily the result of outcomes, shocks, and decisions sufficiently in the past that the data should pass the exclusion restriction for an appropriate instrument as well.

The age distribution instruments are constructed using the United Nations' World Population Prospects: The 2010 Revision. This data set provides the distribution of each country's population into 5 year age categories from ages 0-80 and a single category for those age 80+. Because this age distribution data is encompassed by 17 different variables, it can be used to instrument for all of the potentially endogenous variables. For technical details on the formation of the IVs, the reader is referred to Appendix 2. Table 1 provides summary statistics on the levels and growth rates of the variables of interest for the full sample period.

Table 2 presents the results of my instrumented regression from (8). Standard errors are included in parentheses below the point estimates. First stage estimates of model fit for both the FSP levels and FSP growth regressions are included in Table 3. A Hausman test, conditioned upon having appropriate instruments, strongly rejects the null hypothesis of no endogeneity in the levels regression.

The results of the FSP levels regression indicate that, by itself, the capital stock is significant in determining output, with a coefficient of 0.430. The supply of labour has a coefficient of 0.520, also statistically significant. The stock of human capital, by itself, has a negative and significant effect on output with a coefficient of -0.188. The significance of physical capital and negative coefficient on human capital are common in much of the literature regarding development and are not unexpected. The discussion of the negative coefficient on human capital goes back to

Islam (1995) and is further discussed in Pritchett (2001). Pritchett suggests that this result may be due to perverse institutional environments, the supply of educated labour expanding while demand remained constant, or educational quality having been so low that years of schooling create no human capital, an explanation consistent with this work. The approximate magnitudes of these coefficients on direct inputs are not out of line with other estimates.

The more interesting variables within the model are the three indirect inputs. Better infrastructure is associated with higher productivity of physical capital, but the interaction term is not statistically significant. I will show in the next section that this result is due, in part, to heterogeneous effects of improved infrastructure in developed and developing countries.

As would be predicted, improved worker health is positively associated with labour productivity. This relationship is not only statistically significant, but also economically meaningful. The estimated coefficient implies that a one standard deviation increase in life expectancy (about 11 years) would increase the productivity of labour by about .015. From an alternate perspective, you could interpret this as indicating that a one standard deviation improvement in health increases the labour share of income by 1.5%.

Nutrition, also as predicted, has a positive and significant effect on the FSP of human capital. With caloric intake at or above recommended levels, the effect of nutrition largely offsets the negative estimated coefficient on human capital independent of nutrition. The exact magnitude of the effects of improved nutrition is sensitive to several factors, including how caloric intake is scaled to reflect diminishing returns and the ratio of developed to developing countries in the sample. However, the positive and significant coefficient on nutrition is not sensitive to changes in sample or specification.

The combined results on indirect inputs would support the conclusion that the model is capturing the predicted effects these inputs should have on productivity.

The three indirect inputs which I examine serve as first step for studying the aggregate productivity effects of indirect inputs in general, but many other variables can be included within the framework of my model. However, in addition to estimating the effects of these three indirect inputs, this paper proposes an alternative model which hopefully can add to the explanatory power of existing production functions. An improved model of production allows for a better understanding of the development process and, importantly, allows for better estimates of the effects of development policies targeting indirect inputs. While I have already shown how this new model is able to theoretically reflect microeconomic effects of indirect inputs in a broader and potentially more appropriate manner than a baseline model using TFP, it remains to be demonstrated that these additions provide a more appropriate empirical description of the growth process than a model which includes the same indirect inputs as independent determinants of TFP as opposed to determinants of FSP.

Because the model specification in equation (2) could encompass my FSP model of output, a more traditional TFP model, or a combination of the two, a natural test would be to nest the two and see where the data indicates statistical significance. However, the multicollinear nature of the data makes it impossible to interpret findings when the indirect inputs are included in several different forms. Instead, I turn to the non-nested models test of Davidson and MacKinnon (1981). They propose a test of two models each seeking to explain the same outcome whereby the dependent variable is regressed on all variables which are included in model A but not model B. The fitted values of this regression, called $\hat{y}_A$, are then included in a regression of the outcome on all the variables of model B and $\hat{y}_A$. If the fitted values have a statistically insignificant coefficient, then model A adds nothing to model B. If the coefficient is significant, then model A does add to B. The test is then repeated with A and B switching places in the process. The dependent variable is regressed on those explanatory variables unique to model B, and the fitted values $\hat{y}_B$, are formed. These fitted values are added to model A, and their significance is tested. Once completed, there are four possible results of the test: First, A could add to B, but not vice versa, indicating that A is the preferred model. Second, B could add to A, but not vice versa, indicating that B is the preferred model. Third, both models could significantly add to the other, indicating that neither is preferred by itself but rather each has independent explanatory power, or fourth, neither model could add to the other, also indicating that neither is strictly preferred.

While these last two cases are not informative in picking one model over another, they are still useful in my specific case because they would justify the simultaneous inclusion of TFP and FSP effects in a production function. I apply the Davidson and MacKinnon test to two models, my preferred model resulting from equation (8), and a second model where all the indirect inputs are instead included in the TFP term, A(•), as in equation (10).

$$y_{it} = A_0 + A_1 INF_{i,t} + A_2 HEALTH_{i,t} + A_3 RDA_{\,i,t-15} + \alpha_0 k_{i,t} + \beta_0 l_{i,t} + \gamma_0 h_{i,t} \tag{10}$$

The results of the Davidson and MacKinnon test can be seen in Table 4, and indicate that my model of FSP is strictly preferred to a model where the inputs are solely modeled as a part of TFP. In practice, while it might be extreme to claim that these three indirect inputs have no effect on TFP, the test does indicate that the primary effects of these indirect inputs are better reflected in factor-specific productivity, and thus if they can only be included in one portion of the production function, FSP terms are the appropriate forms.

Recall that in my model, TFP is treated as a constant, while FSP varies across countries and time. The Davidson and MacKinnon test above compares my model to one in which FSPs are constant while TFP varies along with the indirect inputs. For robustness, I retest my model against specifications in which the TFP function includes not only the indirect inputs, but also time and/or country fixed effects. When either time or country fixed effects are included, the result of the test is unchanged. My model continues to be strictly preferred to the model where TFP varies.3 When both time and country fixed effects are included, neither model is preferred with a traditional 10% cutoff for statistical significance. However, the added term from my model has a p-value of 0.17 while the added term from the alternative model has a p-value of 0.5, still indicating support, albeit weaker, for my model over the alternative.

I additionally test the robustness of the Davidson and MacKinnon test to different specifications of the forms of indirect inputs by allowing for the indirect inputs to enter as natural logs instead. Changing both my model and the alternative to instead include ln(INF), ln(HEALTH), or ln(RDA) in any combination, the test in every case indicates that my model is preferred.

4.2 Model fit for OECD and NON OECD countries

Different production functions will provide a much better fit for the outcomes in some countries than the outcomes in others. Often, the groups of countries for which fit is particularly good or poor may have observable characteristics in common such as level of development or geographic region. In fact, it is still under much debate whether a single function can describe the production of different nations, specifically developed and developing nations simultaneously. Sturgill (2010) investigates this question specifically, and finds that the productivity of direct inputs changes over the course of the development process. In particular, he finds that, after separating the factors of production (direct inputs) into reproducible factors (physical capital and human capital) and non-reproducible factors ("natural capital" and labour), that non-reproducible factor shares (and productivity) decrease with development while reproducible factor shares increase with development. I examine these results within the context of my model by re-estimating equation (8) on subsamples of OECD and NON-OECD countries separately. Results are found in Table 5.

By separating the subsamples, differences become apparent when examining both the coefficients of the direct inputs and of the indirect inputs as well. Consistent with the findings of Sturgill (2010), physical capital and human capital (as reproducible factors) have much higher estimated shares in the OECD subset, while labour, a non-reproducible factor, has a much higher share in the NON-OECD subset. This finding indicates that FSP terms should include more variables reflecting those factors which distinguish OECD and NON-OECD countries if the samples are going to remain grouped. At the very least, an OECD dummy could be included in the FSP functions. As for the indirect inputs, the estimated effects of improved health and nutrition are stronger in NON-OECD countries, while the effects of improved infrastructure are stronger in OECD countries. From a policy perspective, these results would support a claim that efforts in developing countries aimed at increasing production would do well to focus on investing in indirect inputs which improve the productivity of individuals instead of investing in physical capital or increased infrastructure. From a modeling perspective, the differing results for OECD and non-OECD countries indicate that additional non-linearities should be investigated in the FSP functions for the model to apply optimally to all countries.

4.3 Growth Regression results

Table 6 contains FSP regression results using the growth specification in equation (9). Were the production function perfectly specified, these results would be exactly the same as the corresponding estimates from the level regression. However, with weaker first stage results and a production function of only three indirect inputs, coefficients will likely not be identical. Still, results should be largely similar. In fact, with the exception of the coefficient on capital growth being small and insignificant, the results in Table 6 are relatively close to those in Table 2. Combined growth in capital and infrastructure leads to economic growth as well. Labour growth has positive and significant productivity and labour productivity increases with better worker health. Human capital investments have negative and significant returns by themselves but this is offset in part by investments combined with appropriate nutrition.

Again, it is important to determine whether a model of factor specific productivity is any improvement over a model using the same variables as part of a more traditional TFP term. Table 7 contains the results from repeating a Davidson and MacKinnon test, this time with my model in growth rates.

In this case, the test indicates that both the FSP model and the TFP model have unique explanatory power. Therefore, the evidence on growth rates would indicate that a general model as in equation (2) which allows for both types of effects would be ideal in circumstances where it can be practically applied.

4.4 Factor accumulation results

So far, I have allowed for two of the three potential effects of indirect inputs on production: TFP effects and FSP effects. I now turn to the third potential effect, that indirect inputs may incentivise the future accumulation of direct inputs. To investigate this potential, I introduce new equations relating the levels and growth rates of the direct inputs to the prior levels and growth rates of the three indirect inputs, INF, HEALTH, and RDA. Equations (11), (12), and (13) provide evidence relating the levels of direct inputs and the prior levels of indirect inputs. Equations (14), (15), and (16) are the corresponding growth equations relating direct input growth rates to the past growth of indirect inputs.

$$\mathrm{k}_{\mathrm{i,t}} = \delta_0 + \delta_1 \mathrm{INF}_{\mathrm{i,t-5}} + \delta_2 \mathrm{HEALTH}_{\mathrm{i,t-5}} + \delta_3 \mathrm{RDA}_{\mathrm{i,t-15}} \quad (11)$$

$$\mathrm{h}_{\mathrm{i,t}} = \theta_0 + \theta_1 \mathrm{INF}_{\mathrm{i,t-5}} + \theta_2 \mathrm{HEALTH}_{\mathrm{i,t-5}} + \theta_3 \mathrm{RDA}_{\mathrm{i,t-15}} \quad (12)$$

$$\mathrm{l}_{\mathrm{i,t}} = \varphi_0 + \varphi_1 \mathrm{INF}_{\mathrm{i,t-5}} + \varphi_2 \mathrm{HEALTH}_{\mathrm{i,t-5}} + \varphi_3 \mathrm{RDA}_{\mathrm{i,t-15}} \quad (13)$$

$$\%\Delta \mathrm{k}_{\mathrm{i,t}} = \delta_1 \%\Delta \mathrm{INF}_{\mathrm{i,t-5}} + \delta_2 \%\Delta \mathrm{HEALTH}_{\mathrm{i,t-5}} + \delta_3 \%\Delta \mathrm{RDA}_{\mathrm{i,t-15}} \quad (14)$$

$$\%\Delta \mathrm{h}_{\mathrm{i,t}} = \theta_1 \%\Delta \mathrm{INF}_{\mathrm{i,t-5}} + \theta_2 \%\Delta \mathrm{HEALTH}_{\mathrm{i,t-5}} + \theta_3 \%\Delta \mathrm{RDA}_{\mathrm{i,t-15}} \quad (15)$$

$$\%\Delta \mathrm{l}_{\mathrm{i,t}} = \varphi_1 \%\Delta \mathrm{INF}_{\mathrm{i,t-5}} + \varphi_2 \%\Delta \mathrm{HEALTH}_{\mathrm{i,t-5}} + \varphi_3 \%\Delta \mathrm{RDA}_{\mathrm{i,t-15}} \quad (16)$$

Results from these six regressions are found in Table 8. The regressions in levels are suggestive of a relationship between indirect inputs and factor stocks. Higher levels of infrastructure show no significant relationship with any of the factor supply measures. Improved health is correlated with higher stocks of both physical and human capital, consistent with the idea that longer-lived individuals will invest more in both types of capital. Higher levels of past nutrition are correlated with increased stocks of physical capital.

The factor models in growth rates are expected to be preferable to the models in levels because they difference out any time-invariant omitted variables. The differencing process also alleviates any concerns that the right hand side variables are endogenous because levels of direct inputs and indirect inputs are both being determined by some third factor. The factor growth regressions show that past growth rates of indirect inputs are strongly related to future growth of direct input stocks. All three indirect inputs have a statistically significant relationship with all three future direct input growth rates. The strongest effects of improved infrastructure are on the growth rate of capital, and the strongest effects of improved past nutrition are on the accumulation of human capital. Both of these results are consistent with what the microeconomic literature would suggest. The largest magnitude effects overall though, come from improvements in health. A one percent increase in life expectancy is associated with greater than one percent growth of all three direct inputs in the future. This suggests that models which fail to account for the factor accumulation effects of increases in indirect inputs like health might significantly underestimate the net macroeconomic benefits of these inputs.

5 Factor-Specific Productivity, Returns to Scale, and Convergence in Output

Many models of aggregate output imply that returns to scale are constant across all countries. In the case of the Solow models, the implication is that all countries have constant returns to scale. Other models have been developed specifically to have increasing returns to scale for all countries. One result of having the same returns to scale across nations is that these models imply convergence of output across countries, at least conditional upon the convergence of the direct inputs. Feyrer (2007) and Grier and Grier (2007) test these implications to critique Solow based models, finding that despite the convergence of direct inputs (and many indirect inputs as well), output simply is not converging. This, of course, leads to the question of why output does not converge. The FSP model would suggest that output should not be converging across countries because the returns to scale in production are not the same for all countries, or even within a single country through time. By construction, returns to scale should vary in the same way that FSPs vary, namely through differing levels of indirect inputs. If two countries have different infrastructure levels, for example, then their returns to capital should differ and, if they differ enough, convergence in output should not be expected even if capital stocks converge.

Using the significant coefficients from the FSP model in Table 5, I calculate a returns to scale parameter as the sum of the net exponents from the original production function for the OECD and non-OECD subsets. For non-OECD countries, this estimated parameter ranges from 0.922 to 1.028, indicating that non-OECD countries may experience constant or slightly diminishing returns to scale. For OECD countries, the parameter ranges from 1.087 to 1.114, indicating that more developed countries all experience increasing returns to scale. This would be a possible explanation for the divergence of income noted by Grier and Grier (2007) and Feyrer (2007). If OECD countries have slightly increasing returns to scale while non-OECD countries have decreasing or constant returns to scale because of indirect inputs to production, even though non-OECD countries are closing the gap in terms of stocks of productive inputs, OECD countries could be pulling away in terms of income levels as a result of stronger returns to scale.

6 Conclusions

The development literature has debated whether cross-country output differences are driven by the accumulation of direct inputs or by productivity effects of indirect inputs almost continuously over the past twenty years. I propose a framework where indirect inputs have three effects. They can alter the Total Factor Productivity of all the direct inputs simultaneously, they can change the Factor-Specific Productivity of one or more direct inputs in different magnitudes, or they can incentivise the accumulation of direct inputs. The introduction of FSP allows for a more nuanced inclusion of indirect inputs which reflect the microeconomic channels through which they work.

Using three indirect inputs as examples, I employ the non-nested hypothesis test proposed by Davidson and MacKinnon to compare an FSP model against a more traditional TFP model including the same indirect inputs. The test finds that the FSP model outperforms the TFP model in levels, while both models have unique explanatory power in growth rates. This suggests that, data permitting, both forms of productivity effects should be included simultaneously. These results are robust across a variety of specifications. I also document how the indirect inputs appear to have significant effects, in both levels and growth rates, on the future accumulation of direct inputs.

Finally, this analysis highlights how a model with FSP terms can be used to explain the observation that, while the per capita stocks of direct inputs have been converging across countries, output has diverged. This prediction arises from eliminating the common restriction that returns to scale should be the same across countries. Instead, an FSP model suggests that returns to scale should differ systematically across countries and time because of differences in indirect inputs of production, and that convergence will not occur if returns to scale differ enough.

Future research should expand upon the indirect inputs included in the production function within the framework introduced here. Initial investigations in this direction could be guided by both the microeconomic literature about the indirect inputs and by the existing aggregate literature on which indirect inputs are most robustly related to output.

Appendix A: Data Appendix

Data sources

Variable	Description	Source	Notes
$Y_{i,t}$	Real GDP in country i at time t	Penn World Tables v. 6.3	
$K_{i,t}$	Stock of Physical Capital in country i at time t	Penn World Tables v. 6.3	Constructed from investment series using perpetual inventory method
$L_{i,t}$	Labour force in country i at time t	Penn World Tables v. 6.3	Constructed using GDP/Capita and GDP/Worker
$H_{i,t}$	Average educational attainment age 15+ in country i at time t	Barro and Lee (2010)	
$INF_{i,t}$	Electrical Consumption in country i at time t /1,000,000	World Development Indicators	Scaled for the easy presentation of coefficients
$HEALTH_{i,t}$	1-fraction of population with tuberculosis in country i at time t	World Development Indicators	
$NUTR_{i,t}$	Average daily caloric intake in country i at time t	UN Food and Agricutural Organization	
$RDA_{i,t}$	Sqaure root of the ratio: NUTR/2500		Scaled by the recommended daily allowance of calories for an adult male
$GDP_{i,init}$	GDP in country i in 1970	Penn World Tables v. 6.3	
$OECD_i$	Dummy variable indicating if country was a member of the OECD in 2010	OECD	

Countries Included

Algeria	Gambia	Nicaragua
Argentina	Ghana	Niger
Australia	Greece	Norway
Austria	Guatemala	Panama
Barbados	Haiti	Paraguay
Belgium	Honduras	Peru
Benin	Hungary	Philippines
Bolivia	Iceland	Portugal
Botswana	India	Rwanda
Brazil	Indonesia	Senegal
Burundi	Iran	Sierra Leone
Cameroon	Ireland	South Africa
Canada	Israel	Spain
Central African Republic	Italy	Sri Lanka
Chile	Jamaica	Sweden
Colombia	Japan	Switzerland
Congo	Jordan	Syria
Costa Rica	Kenya	Thailand
Cote d'Ivoire	Luxembourg	Togo
Cyprus	Malawi	Trinidad and Tobago
Democratic Republic of the Congo	Malaysia	Tunisia
Denmark	Mali	Turkey
Dominican Rep.	Mauritania	Uganda
Ecuador	Mauritius	United Kingdom
Egypt	Mexico	United Republic of Tanzania
El Salvador	Morocco	USA
Fiji	Mozambique	Venezuela
Finland	Nepal	Zambia
France	Netherlands	Zimbabwe
Gabon	New Zealand	

Appendix B: The formation of Instrumental Variables

The primary models to be estimated are represented by equations (9) and (10) in the text. In equation (9), capital stocks, infrastructure, labour supply, health, and human capital stocks are all treated as potentially endogenous. In equation (10), all RHS variables are considered endogenous. To correct for potential endogeneity in the levels regression in (9), instruments are formed using population age breakdown variables representing the fraction of a country's population in each five year category from 0-5 up to 75-80 and a single category for population age 80+. I denote these variables a05-a80 and a80plus. To allow for differential effects of population age on my endogenous variables in OECD and non-OECD countries, the population breakdown variables are interacted with O, a dummy variable for OECD countries, and N, a dummy variable for non-OECD countries. This generates 34 potential instruments, half of which are non-zero for any given country. To instrument for the endogeneity in the growth regression (10), I use the percentage change of the population fraction in each category, %Δa05-%Δa80plus. Once again, this vector is interacted with the OECD and non-OECD dummy variables.

According to the theories which establish these instruments as valid (as discussed in the main text), a relationship exists between the population age breakdowns and the total stocks of capital, labour, and human capital, not with the natural logs of these stocks. Therefore, I instrument first, and then take the natural logs of the predicted values from the first stage.

Because different countries have such vastly different stocks of direct inputs, and because I have data on so many potential instruments, one consequence of the instrumentation process is that predicted values in the first stage can actually wind up being negative for some country-years. To eliminate this issue, the direct inputs in the first stage are scaled down to be a fraction of their respective values in 1970, then regressed on the vector of instruments, and lastly scaled back up.

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[1] Alternative specifications where α(•) and β(•) included the indirect inputs squared were tested as well. Results are highly similar to those presented here, and are available upon request.

[2] The countries which are included are all of those which have enough observations in each of the variety of sources from which I am drawing in order for each country to have more than one complete observation.

[3] Results not presented here, but are available upon request.

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Table 1: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max
Y	313 billion	972 billion	917 million	11.1 trillion
Capital	945 billion	299 billion	661 million	325 trillion
Labor	13.5 million	38.2 million	106 thousand	387 million
Human Capital	83.4 million	220 million	288 thousand	1.83 billion
INF	0.00069 megawatts	0.0010 megawatts	0.0000023 megawatts	0.0062 megawatts
HEALTH	64.72 years	10.93 years	29.10 years	81.08 years
RDA	0.998	0.098	0.793	1.120
%Δy	0.142	0.138	-0.551	0.546
%Δk	0.144	0.117	-0.136	0.551
%Δl	0.120	0.073	-0.255	0.463
%Δh	0.215	0.121	-0.234	0.735
%ΔINF	0.090	0.239	-0.844	1.783
%ΔHEALTH	0.017	0.042	-0.357	0.391
%ΔRDA	0.011	0.034	-0.121	0.119

Table 1 shows the summary statistics for the variables of interest for the full sample from 1980 to 2000.

Table 2: FSP Model in Levels

Two Stage Least Squares Results		
$Capital_{i,t}$	0.430	***
	(0.025)	
$INF_{i,t}$*$Capital_{i,t}$	1.627	
	(1.509)	
$Labor_{i,t}$	0.520	***
	(0.037)	
$HEALTH_{i,t}$*$Labor_{i,t}$	0.001	***
	(0.0003)	
Human $Capital_{i,t}$	-0.188	***
	(0.045)	
$RDA_{i,t-15}$*Human $Cap_{i,t}$	0.134	***
	(0.021)	
A	5.394	***
	(0.352)	
Obs:	435	
Adjusted R^2	0.9505	

*** p<0.01, ** p<0.05, * p<0.1
Hausmann p-value < 0.0001

Table 2 shows the results of a 2SLS IV estimation of the FSP model in equation (8). First stage summaries are found in Table 3. A Hausmann test was performed to determine whether instrumentation was necessary.

This test, which is built upon the assumption that the instruments used were valid, was rejected with a p-value < 0.0001, indicating that instrumentation was, in fact, necessary.

Table 3: First Stage Results for Levels and Growth Models

First Stage Results in Levels					
	Dependent Variables				
	Capital	INF	Labor	HEALTH	Human Capital
R^2	0.2069	0.6230	0.5281	0.8030	0.3738

First Stage Results in Growth Rates						
	Dependent Variables					
	%Δk	%ΔEK	%Δl	%ΔEL	%Δh	%ΔEH
R^2	0.1045	0.1986	0.3595	0.1831	0.4644	0.2111

Table 3 shows the fit of the first stage results for estimating equations (8) and (9).

Table 4: Davidson and MacKinnon Test of TFP and FSP Models in Levels

Test of Hypothesis that Model B adds to Model A				Test of Hypothesis that Model A adds to Model B			
First Regression		Second Regression		First Regression		Second Regression	
$INF_{i,t}$	175.988 (150.285)	**$\hat{y}_A$**	**-0.269 (0.221)**	$INF_{i,t}$*$Capital_{i,t}$	-17.206 *** (2.062)	**$\hat{y}_B$**	**0.628 *** (0.184)**
$RDA_{i,t-15}$	3.027 ** (1.279)	A	12.071 *** (5.500)	$RDA_{i,t-15}$*Hum. $Cap_{i,t}$	0.357 *** (0.029)	A	0.855 * (0.465)
$HEALTH_{i,t}$	0.072 *** (0.013)	$Capital_{i,t}$	0.430 *** (0.025)	$HEALTH_{i,t}$*$Labor_{i,t}$	4.284 *** (0.006)	$Capital_{i,t}$	0.431 *** (0.025)
Const.	16.910 *** (1.098)	$INF_{i,t}$*$Capital_{i,t}$	3.106 (1.936)	Const.	13.263 *** (0.275)	$Labor_{i,t}$	0.357 *** (0.086)
		$Labor_{i,t}$	0.423 *** (0.088)			Hum. $Capital_{i,t}$	-0.267 *** (0.073)
		$HEALTH_{i,t}$*$Labor_{i,t}$	0.003 ** (0.001)			$INF_{i,t}$	338.425 *** (88.966)
		Human $Capital_{i,t}$	-0.228 *** (0.056)			$HEALTH_{i,t}$	-0.035 * (0.016)
		$RDA_{i,t-15}$*Hum. $Cap_{i,t}$	0.181 *** (0.043)			$RDA_{i,t-15}$	-1.576 (1.179)
Obs:	435		435		435		435
Adjusted R^2	0.3330		0.9505		0.8541		0.9508

*** p<0.01, ** p<0.05, * p<0.1

Table 4 shows the results of the Davidson and MacKinnon J-test. All equations are estimated via 2SLS. The significant coefficient on $\hat{y}_B$ but not on $\hat{y}_A$ indicates that model B is preferred to model A in terms of explanatory power.

Table 5: FSP Model Estimated over OECD and NON-OECD Subsamples

	OECD		NON-OECD	
Capital	0.573	***	0.419	***
	(0.056)		(0.029)	
INF*Capital	2.872	**	-13.576	
	(1.312)		(16.917)	
Labor	0.456	***	0.527	***
	(0.069)		(0.052)	
HEALTH*Labor	0.00005		0.0018	***
	(0.00007)		(0.0006)	
Human Capital	-0.120		-0.233	***
	(0.073)		(0.059)	
RDA*Human Cap.	0.058	**	0.163	***
	(0.027)		(0.028)	
A	3.635	***	5.492	***
	(0.752)		(0.436)	
Obs:	130		305	
Adjusted R^2	0.9808		0.9100	

*** p<0.01, ** p<0.05, * p<0.1

Hausmann p-value: < 0.0001 < 0.0001

Table 5 shows the results of a 2SLS IV estimation of equation (8) over two samples, OECD countries and NON OECD countries. A pair of Hausmann tests were performed to determine whether instrumentation was necessary.

These tests, which are built upon the assumption that the instruments used were valid, were each rejected with a p-value < 0.0001, indicating that instrumentation was, in fact, necessary.

Table 6: FSP Model in Growth Rates

Two Stage Least Squares Results		
%Δk	0.011	
	(0.049)	
%ΔEK	2.930	*
	(1.696)	
%Δl	0.355	**
	(0.177)	
%ΔEL	0.001	***
	(0.0003)	
%Δh	-0.179	***
	(0.060)	
%ΔEH	0.061	***
	(0.018)	
Obs:	347	
Adjusted R^2	0.2032	

*** p<0.01, ** p<0.05, * p<0.1
Hausmann p-value < 0.0001

Table 6 shows the results of a 2SLS IV estimation of equation (9). A Hausmann test was performed to determine whether instrumentation was necessary.
This test, which is built upon the assumption that the instruments used were valid, was rejected with a p-value < 0.0001, indicating that instrumentation was, in fact, necessary.

Table 7: Davidson and MacKinnon Test of TFP and FSP Models in Growth Rates

Test of Hypothesis that Model B adds to Model A						Test of Hypothesis that Model A adds to Model B					
First Regression			Second Regression			First Regression			Second Regression		
$\%\Delta INF_{i,t}$	0.141		**$\hat{y}_A$**	**1.016**	***	$\%\Delta EK$	-0.605		**$\hat{y}_B$**	**0.908**	***
	(0.107)			**(0.069)**			(1.270)			**(0.101)**	
$\%\Delta RDA_{i,t-15}$	0.261		$\%\Delta k$	0.012		$\%\Delta EH$	0.005		$\%\Delta k$	0.008	
	(0.219)			(0.039)			(0.012)			(0.037)	
$\%\Delta HEALTH_{i,t}$	0.201		$\%\Delta EK$	-0.366		$\%\Delta EL$	0.0001		$\%\Delta l$	-0.002	
	(0.197)			(1.343)			(0.0002)			(0.127)	
Const.	0.122	***	$\%\Delta l$	0.003		Const.	0.140	***	$\%\Delta h$	-0.046	
	(0.014)			(0.140)			(0.009)			(0.045)	
			$\%\Delta EL$	-0.00001					$\%\Delta INF$	0.116	
				(0.0002)						(0.109)	
			$\%\Delta h$	-0.041					$\%\Delta HEALTH$	0.121	
				(0.048)						(0.224)	
			$\%\Delta EH$	0.0006					$\%\Delta RDA$	0.212	
				(0.014)						(0.223)	
Obs:	347			347			347			347	
R^2	0.0116			0.5139			0.0023			0.5236	

*** p<0.01, ** p<0.05, * p<0.1

Table 7 shows the results of the Davidson and MacKinnon J test for the growth model. All equations are estimated via 2SLS. The significant coefficients on $\hat{y}_B$ and on $\hat{y}_A$ indicate that both models have unique contributions in terms of explanatory power.

Table 8: Factor Accumulation Regressions in Levels and Growth Rates

	Levels Regressions				Growth Regressions		
	Dependent Variable:				Dependent Variable:		
	$k_{i,t}$	$h_{i,t}$	$l_{i,t}$		$\%\Delta k_{i,t}$	$\%\Delta h_{i,t}$	$\%\Delta l_{i,t}$
$INF_{i,t-5}$	38.608	-66.816	-94.488	$\%\Delta INF_{i,t-5}$	0.169 ***	0.128 ***	0.083 ***
	(101.385)	(100.194)	(98.953)		(0.038)	(0.049)	(0.030)
$HEALTH_{i,t-5}$	0.108 ***	0.042 ***	-0.002	$\%\Delta HEALTH_{i,t-5}$	1.415 ***	2.459 ***	1.530 ***
	(0.012)	(0.012)	(0.012)		(0.265)	(0.341)	(0.204)
$RDA_{i,t-15}$	4.126 ***	1.940	1.909	$\%\Delta RDA_{i,t-15}$	0.725 ***	1.012 ***	0.632 ***
	(1.326)	(1.310)	(1.294)		(0.274)	(0.352)	(0.211)
Constant	14.466 ***	12.353 ***	13.508 ***				
	(1.008)	(0.996)	(0.983)				
Obs:	347	347	347		259	259	259
Adjusted R^2	0.4940	0.1182	0.0004		0.2679	0.2951	0.3151

*** p<0.01, ** p<0.05, * p<0.1

Table 8 shows the results of estimating equations (11)-(16).