Immigration, Wages, and the Solow Growth Model: An OECD Perspective

by

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Abstract

In this thesis, wage growth is regressed on the growth rates of both high and low-skilled immigrants in twenty-five OECD countries covering the years 1990 to 2000. A new approach in the international migration literature is used here, creating a hybrid methodology between the area and factor proportions approaches. In doing so, a nested CES neoclassical production function is used as the framework for the econometric model in this study. Along with this new approach a new technique is also employed to capture the potential endogeneity of the immigrant share. This technique is that of a Simultaneous Equations Model (SEM) and will be run in addition to both OLS and 2SLS regressions. The foundation for the dataset used in this study comes from the recently available database of Docquier, Ozden, and Peri (2010) which decomposes each country’s labor force into natives, immigrants, and emigrants of both high and low skill for the years 1990 and 2000. The remaining data was compiled of national level aggregate statistics in accordance with the national level approach as proposed by Borjas, Freeman, and Katz (1997). It is shown that evidence from this sample for the endogeneity of the immigrant share of both high and low skill is weak and therefore the procedure that best captures immigration’s effect on wages is that of OLS. It was found that by increasing the labor force immigrants exerted a downward force on prices; however, high-skilled immigrants also raised average wage growth by increasing the high-skilled labor percentage in each county while low-skilled immigrants had the opposite effect as they decreased the skilled worker percentage. Therefore, the neoclassical production function, adapted to incorporate the recent immigration literature, correctly modeled both the “size” and compositional” effects of immigration on wages. It is then shown how these results can be used in policy analysis by using the proposal of Pritchett (2006) as an example.
I. Introduction

Economic growth has been a hotly debated topic within the realm of macroeconomics. What are its determinants? Is growth unbounded or do all countries converge to a steady state? These are just some of the questions that growth theorists strive to answer. Much of the recent literature has been dedicated to endogenous growth models that feature technological progress as determined within the models (i.e. making it an endogenous variable), as well as non-diminishing returns to reproducible factors of production. In contrast, the neoclassical growth model saw a revival during the 1990’s with the work of Mankiw, Romer and Weil (1992). This controversy arises for three main reasons: there are no controlled experiments in economics (i.e. there is no ceteris paribus), the nature of the economy may be changing, and statistical evidence may be consistent with multiple explanations.

It is the purpose of this thesis to test the neoclassical production function along with the assumption derived from competitive economics, that factors of production are paid their marginal products, with an econometric approach. To do this, a production function from the current literature on immigration will be applied to a neoclassical growth model and an empirical test will be run to see if this new model accurately captures economic growth. In doing this, this thesis will test if the macroeconomic results are consistent with the microeconomic findings. Additionally I will apply the results of the regressions to Lant Pritchett’s (2006) proposal to increase the labor force of developed countries by three percent to include temporary workers from less developed nations. From the results of the regressions one can
show the effect of such a proposal on the growth of a country’s average annual wages. This will also be an illustration of how this study can help act as a tool for policy makers to utilize.

The Solow Model is arguably the most highly regarded economic growth model. Thus, an inquiry into its inner workings is necessary to fully understand the issue of economic growth and if this model represents the subject accurately. The Solow Growth Model, developed by Solow (1956), and the Augmented Solow Model, developed by Mankiw, Romer and Weil (1992), are two growth models that are used to reproduce the characteristics of development for countries on a macroeconomic level. These models have similar qualities, but the Augmented Solow Model includes human capital as a factor of production along with capital and labor, whereas the Solow Model only includes capital and labor. The following assumptions are built into the framework of the Solow Growth Model. First, the production function exhibits constant returns to scale in which all output is either consumed or saved. Second, equilibrium (also known as the steady state) can be found when break-even investment equals actual investment and the growth rate of output per effective worker is zero in the steady state. A further description of the models and these assumptions will come later in the text.

Both growth models state that when there is a large decrease in population size, usually due to emigration, there will be a subsequent increase in real wages and income per capita. The model also states that the capital stock will adjust over time so that a new equilibrium is reached. Olson (1996) looked into this aspect of the Solow and Augmented Solow Model and determined that it inaccurately portrayed
economic growth. He pointed to the fact that Ireland had seen “the largest proportion of outmigration in Europe, if not the world” but had not experienced a rapid growth in income per capita as these models predicted (Olson 1996, 10). Olson (1996) did not go on to test his hypothesis amongst other countries; he was merely satisfied to make the observation. Ortega and Peri (2009) found that immigration raised GDP of the receiving country but wages and income per capita remained unaffected, thus confirming Olson’s observation. This thesis will go on to empirically test this relationship and concludes that the data, which includes Ireland as an observation, verifies the assumptions of the neoclassical production function. This is in stark contrast to the arguments of Olson (1996).

The rest of this thesis is organized as follows: Section II briefly describes the Solow model and its implications, and justifies the use of the Solow model in this application; Section III reviews the literature on this topic and outlines several key approaches used in significant studies; Section IV expounds upon the empirical strategy used in this thesis, including a detailed description of the production function used and the econometric techniques employed; Section V examines the data used in the regression analysis as well as the reasoning behind the inclusion of each variable in the regressions model; Section VI documents the results of the regressions; Section VII extends the results from the regressions in order to analyze the policy proposal of Lant (2006) who argues in favor of the free mobility of labor; and finally, Section VIII discusses the implication of the results and concludes the findings of the paper.
II. Background Theory

II.1 The Solow and Augmented Solow Growth Model

In order to derive implications from the Solow and Augmented Solow model, it is first necessary to fully understand the models themselves. The Solow Model was developed by Robert Solow in his 1956 article titled “A Contribution to the Theory of Economic Growth” and supplemented by his 1957 article titled “Technical Change and the Aggregate Production Function.” Solow (1956) devised a growth model where economic growth derives from factor accumulation, i.e., as a nation accumulates more factors of production like capital and labor then economic growth will be generated. This definition is much too simple, but it captures the essence of the implications of the Solow Growth Model. A more revealing description can be found below.

Solow (1956) began with a production function with a general functional form, i.e.:

\[ Y = F(K, N) \]

Where Y denotes Output or Gross Domestic Product (GDP), K denotes the capital stock and N denotes the stock of labor in the aggregate economy. It is important to notice that Solow (1956) did not supply or restrict this model to a specific functional form. This has large implications for empirical studies that use the Solow Model as their base model as inconclusive results may be attributable to the functional form of the production function and not the model itself.

With this production function, Solow (1956) imposes the assumptions that the production function has constant returns to scale and that factors of production are
paid their marginal products. This latter assumption is one typical of neoclassical models. In his own words Solow writes “the real wage rate adjusts so that all available labor is employed, and the marginal productivity equation determines the wage rate which will actually rule” (1956, 68). This relationship is the area of interest to this thesis.

Solow (1956) used this production function to show that in the long run each country will converge upon an equilibrium growth rate, more commonly referred to as a steady state. The steady state, which is defined to be the equilibrium growth rate of the country, occurs when:

\[
\text{Actual Investment} = \text{Break-even Investment}
\]

\[
sf(k) = (n + g + \delta) \times k
\]

Where \( n \) is the growth rate of the labor supply, \( g \) is the labor augmented technological growth, \( \delta \) is the depreciation rate, \( y \) is output per effective laborer, and \( k \) is capital per effective laborer. Three of these variables, namely \( n \), \( g \) and \( \delta \), are determined exogenously. Here, one can see why this is a steady state. If actual investment is greater than break-even investment, then the aggregate economy is maintaining a higher than necessary capital to labor ratio and, therefore, \( k \) will decrease toward the equilibrium \( k \), or \( k^* \). If actual investment is below break-even investment then the aggregate economy is clearly investing too little and needs to increase \( k \) to reach \( k^* \). Thus, it can be seen that countries converge upon their steady states and this phenomenon is aptly named convergence. A more detailed discussion on convergence can be found later in this thesis.
Due to the lack of convergence found in the Solow Model, many believed that there must be an important variable missing from this economic growth theory. Barro (1991) was believed to have found this variable and deemed it human capital. Since human capital is an unobserved variable, Barro chose to proxy the variable with various levels of academic enrollment to capture its flavor and found it to be statistically significant and positively related to economic growth. This finding led Mankiw, Romer and Weil (1992) to improve upon the Solow Model by including human capital as a factor of production. They named this new model the Augmented Solow Model.

The Augmented Solow model of Mankiw, Romer and Weil (1992) is similar to that of the Solow model but utilizes a new production function:

\[ Y = F(K, H, A \cdot N) \]

Where H is the stock of human capital. A production function such as this results in a steady state with these two conditions:

\[ s_k \cdot y = (n + g + \delta) \cdot k \]
\[ s_h \cdot y = (n + g + \delta) \cdot h \]

Here, \( s_k \) is the savings rate of physical capital, \( s_h \) is the savings rate of human capital, and \( h \) is level of human capital per effective laborer. These conditions of the steady state make it clear that there is room for larger variations in steady state levels across countries as there are more variables to consider, as well as the fact that educational policies vary widely between countries and continents.

With the inclusion of human capital, the Augmented Solow model is able to explain the lack of convergence. In the Solow model, when capital per effective
worker is low, its marginal product is really high. This means that by increasing
capital per effective worker by a little, this results in a large movement toward the
steady state. However, in the Augmented Solow model this is not the case. Here, if
capital per effective laborer is low then its marginal product can still be low as well.
This occurs when the country’s human capital is low as well. This means that
increasing physical capital will not lead to much of an increase in output per effective
worker, and therefore convergence will occur at a much slower pace.

II.2 Convergence and a Brief History on the Theory of Economic Growth

In order to further understand the question at hand, it is necessary to look into
the history of the field of economic growth in terms of the Solow Growth Model. In
the 1980’s, economists began to empirically test the conclusions of the neoclassical
growth model. Baumol (1986) tested one of the main hypotheses of the Solow
model: that all countries converge to their steady state. According to this hypothesis,
countries will adjust capital per effective worker in order to equate actual investment
with break-even investment. As mentioned earlier, due to the presence of
diminishing marginal product of capital, countries with low levels of capital per
effective worker should grow faster, in terms of output per effective worker, as they
increase their capital per effective worker. Baumol (1986), along with and Nguyen
(1989) and Barro and Sala-i-Martin (1991), found there to be strong evidence for this
convergence in homogenous regions.

However, De Long (1988) argued that there was a sample selection bias in
Baumol’s (1986) regression based on the fact that Baumol used “an ex post sample of
countries that are now rich and have successfully developed” (1138). Accounting for
this bias, De Long (1988) found little evidence for the theory of convergence. This argument was supported by Pritchett (1997) and Romer (1987) who also used a diverse sample of countries in their studies yet found no evidence of convergence.

Although it may seem that the studies of De Long (1988), Pritchett (1997), and Romer (1987) have undermined the validity of the Solow model, with a further examination into Solow’s (1956) article it becomes clear that his theory remains grounded in a strong foundation. As Mankiw (1995) writes “[the neoclassical growth model] does not necessarily predict convergence” (284). How can this be so? The Solow model predicts that countries will converge to their steady state, which is determined by their population and savings growth rates. What this means is that each country will converge to their own individual steady state, which is unique. Mankiw (1995) denotes this type of convergence to be called “conditional convergence” (284). Thus, trying to test whether all countries converge upon the same steady state, as was done in Baumol (1986), Barro and Sala-i-Martin (1991), De Long (1988), Dowrick and Nguyen (1989), Pritchett (1997), and Romer (1987), is based on a misunderstanding of the Solow model.

Even though the evidence against convergence is not concrete, it was enough to cause some scholars to turn to a new theory, known as endogenous growth theory, which was able to explain a lack of convergence between countries. Economic growth, defined as an increase in a nation’s income per capita, is derived from factor accumulation (i.e., an increase in one or both of the factors of production) in the neoclassical growth models. However, according to endogenous growth models, this growth is a result of an increase in productivity (i.e., an increase in total factor
productivity, also referred to as the Solow residual). Endogenous Growth models were first proposed by Romer (1986) and Lucas (1988). They allow for the growth rate of technological progress to be determined endogenously (i.e., technological progress is determined within the model rather than be taken as exogenous as it is in the Neoclassical framework), and that factors of production exhibit increasing returns to scale (Romer 1986, 1003). These new assumptions create a situation where “per capita output can grow without bound, possibly at a rate that is monotonically increasing over time” (Romer 1986, 1003). This result is in stark contrast with that of the Solow Model which predicts each economy to converge upon a steady state.

Endogenous growth models became popular soon after the publications of Romer (1986) and Lucas (1988); however, as mentioned earlier, there was a neoclassical revival that was sparked by the research of Mankiw, Romer and Weil (1992). Amidst heavy criticism the Solow model was showing some resiliency. Mankiw, Romer and Weil (1992) used data compiled by the same scholars, Summers and Heston, as Romer (1987) and was able to show that the Solow model, augmented to include human capital, was able to explain eighty percent of economic growth.¹ A couple of years later two articles written by Alwyn Young were published and again provided evidence in support of the Solow model. Young (1994, 1995) looked into the economic growth of newly industrialized countries (NIC’s) in East Asia and concluded that their growth could not be attributed to an increase in productivity (total factor productivity), as in the endogenous growth model, but rather to an increase in their factors of production as stated by the Solow model. This result was a

major step forward for the Solow model because it produced seemingly irrefutable evidence that neoclassical growth models accounted for growth while endogenous growth models did not. However, the validity of these studies would soon be called into question.

In 1997, Klenow and Rodriguez-Clare responded with their article titled “The Neoclassical Revival in Growth Economics: Has it Gone too Far?” Klenow and Rodriguez-Clare (1997) show that in actuality the results of Mankiw, Romer and Weil (1992) along with Young (1994, 1995) indicate that the majority of economic growth is attributable to an increase in productivity and not factor accumulation. Klenow and Rodriguez-Clare (1997) conclude this by correcting for a major criticism they have for both Young (1994, 1995) and Mankiw, Romer and Weil (1992). This major criticism is that an increase in physical capital due to an increase in technological productivity should not be considered a physical capital addition; rather, it should be viewed as an increase in productivity. Recently, this argument surfaced again as Madsen (2010) stressed Klenow and Rodriguez-Clare’s (1997) point that “TFP-induced capital deepening” needs to be accounted for (Madsen 2010, 753). This criticism is debatable, as an individual’s answer is likely to be biased depending on whether they feel the neoclassical or endogenous growth model is more applicable. Due to the fact that the results may be a function of a subjective answer to this question, this is yet another crux that must be overcome to understand the truth behind economic growth.

There have been other responses to the neoclassical revival that, like Klenow and Rodriguez-Clare (1997), are not so favorable to the Solow model. One such
study is that of Bernanke and Gurkaynak (2001), who took an entirely different approach then Klenow and Rodriguez-Clare (1997). Bernanke and Gurkaynak (2001) showed that the framework of Mankiw, Romer and Weil (1992) “applies broadly to almost any economic growth model that admits a balanced growth path” (53). From this statement one could argue that the reason behind Mankiw, Romer and Weil’s (1992) success was not because of their foundation in the Solow model but rather their generalization to include aspects of other economic growth models, and that it was from the aspects of the other economic growth models that created their success. This logic seems reasonable after acknowledging that Bernanke and Gurkaynak (2001) also went on to show that the “restrictions specifically imposed by the Solow model tend to be rejected” (53).

II.3 A Choice Between the Neoclassical or Endogenous Growth model

After the preceding subsection it has become apparent that the debate over which growth model is the most applicable is still fiercely contested. Thus, it is the purpose of this section to justify the use of the Solow model for the basis of this thesis. Firstly, the objective of this thesis is to study how changes in the labor supply affect wages in relation to economic growth, and the main explanatory variable is a factor of production. Thus, the Solow growth model was the clear choice, as it is the model which includes factor accumulation as a main focal point. According to some endogenous growth models, changes in the labor supply have no affect on economic growth, and thus it will be seemingly impossible to find interesting results from the use of such a model. In addition, the labor supply is typically normalized away in endogenous growth models and therefore it does not show up in the production
function. This characteristic makes the endogenous growth model hard to use if the labor supply is the main variable of interest. As immigration policy remains a topic of concern for many countries, it can be agreed upon that changes in their labor supply are important and by using the Solow model as the base model for economic growth, this thesis will be able to capture at least some of that importance.

Gregory Mankiw writes, “instructors of macroeconomics who teach their students about economic growth often use Solow’s version of the neoclassical growth model as the starting point for discussion” (Klenow and Rodriguez-Clare 1997, 103). Thus, the second reason for choosing the Solow model as the base model for economic growth is that it creates the opportunity to test whether the Solow model’s prominence in the classroom is justified. The main way of examination is by applying a microeconomic foundation to macroeconomic theory. In this case, the microeconomic theory is derived from the literature on immigration, which studies how changes in the labor supply affect the wages of natives in one solitary country. By doing this, one can see if the macroeconomic results are consistent with the findings of microeconomic studies.

The purpose of this section up until this point has been to validate the decision of choosing a neoclassical growth model, such as the Solow model, as the base model for economic growth in this thesis. Major issues with the Solow model have been explained and also shown to be vulnerable to debate as well. This thesis utilizes a neoclassical production function and tests the application of the neoclassical growth model in the growth empirics literature. This choice is supported by Friedberg and Hunt (1995) who also extend the Solow growth model in their study of immigration
and economic growth. While the Solow model, may not be the best measure of economic growth, but it is a viable model that is the most adept to answer the problem at hand.

II.4 Implications of the Solow Growth Model for Wages

Now, one is able to see the application of the question at hand and its similarities to the problem of finding support for the theory of convergence in economic growth. An assumption within the Solow Model is that of diminishing marginal product of labor. Under the assumption that factors of production are paid their marginal products, one can equate the marginal product of labor with the cost of labor, i.e., real wage. By rearranging this equation, then nominal wages are equal to price multiplied by the marginal product of labor. Formally, we get,

\[ \frac{w}{p} = MP_N \quad \text{or} \quad w = p \cdot MP_N \]

Now, one can observe how changes in the marginal product of labor are predicted to affect nominal and real wages. If the marginal product of labor were to increase (while keeping the capital stock constant), wages should increase, and then both nominal and real wages should increase as well. If the marginal product of labor were to decrease and the capital stock were to remain constant, then nominal and real wages will decrease in a similar fashion. Due to the assumption of diminishing marginal product of labor, we know that for higher levels of labor, \( N \), the marginal product of labor will be smaller than a country with lower levels of labor. Another way to describe this phenomenon is that in adding to the labor supply, future additions will be less productive and, conversely, when the labor supply shrinks, those workers still in the labor supply will become more productive. Thus, one can
see that if the amount of labor were to decrease, then the marginal product of labor will increase, and therefore this should cause nominal and real wages to follow suit. The same is true if labor were to increase; this would cause the marginal product of labor and, similarly, nominal and real wages to decrease,

\[
\text{If } N \downarrow \quad \implies \quad \text{MP}_N \uparrow \quad \implies \quad w \uparrow \quad \text{or} \quad \text{If } N \uparrow \quad \implies \quad \text{MP}_N \downarrow \quad \implies \quad w \downarrow
\]

There have been many instances throughout history where this relationship has been upheld. A famous instance of this was in 1348 when the bubonic plague ran rampant through Europe, with devastating effects. By the end of the 14th century, over forty percent of the European population had died because of the plague, resulting in “a drastic decline in rents and increase in wages” (Friedman 1977, 63). In this situation, the Solow model production function accurately predicts that wages would increase. This is firm evidence that supports the usage of such a production function as well as the assumption of diminishing marginal product of labor.

How would the amount of labor change other than from the destructive forces of a plague? Changes in labor could be a result of individuals migrating between countries to achieve higher wages. Thus, migration should, in theory, alter the labor supply and result in similar alteration in wages. In this case, we can see there is an issue of endogeneity here as both variables affect one another. The methodology section expands upon this problem. There have been other explanations for what motivates immigrants to leave their country and travel to a different nation. Hatton (2010) writes that there are “push” factors and “pull” factors that motivate an immigrant to leave the country and settle in a new one (942). Push factors, such as business cycle variables like the unemployment rate, are generated in the immigrants’
native country and drive them to leave. Pull factors, such as the promise of higher wages elsewhere, are generated in the immigrants’ receiving country and encourage the immigrants to settle in the new country.

Thus, it is evident that the Solow Model has strong implications for what should happen to wages when there are contemporaneous changes in the labor supply. It is the purpose of this thesis to explore and empirically examine this relationship to test if the results are consistent with both the literature and the Solow model.

III. Literature Review

III.1 A Review of the Literature

As mentioned in the introduction, the main questioned to be analyzed is whether the data supports the claims of the Solow model when it comes to wages and migration. Consider a closed economy with two locations, A and B, each with a different stock of labor. If the assumptions of the Solow model are assumed, then we know that constant returns to scales imply diminishing marginal products of labor. We also know that factors of production are paid their marginal product, so real wage can be equated to the marginal product of labor. Now, examining the relationship between location A and location B in terms of the labor supply, it is evident that they may not have the same value for the labor supply. If location A has more workers than location B, then from diminishing marginal products one knows that the marginal product of labor is higher in location B than location A. Thus real wages in location B are higher than in location A. This wage differential is a signal to the workers in location A to immigrate to location B in order to capture a higher wage.
The marginal product of labor in location B begins to decrease as laborers settle there and the marginal product of labor in location A begins to increase as its labor supply shrinks. Immigration will continue until real wages in location A and B are the same. This relationship has similar implications if location B begins with more laborers as well. A graph of this relationship can be found in table C.1 in the appendix.

Olson (1996) looked directly into this prediction implied by the Solow model and found it to be inaccurate. He concluded this because he had presumably observed a counter example: Ireland. Olson (1996) states that Ireland has experienced “the largest proportion of outmigration in Europe, if not the world” and as a result they should have also “enjoyed an exceptionally rapid growth of per capita income…and the outmigration should eventually have ceased” (Olson 1996, 10). Unfortunately this was not the case and Olson (1996) writes that Ireland still sees large outmigration without the contemporaneous increase in income per capita. Olson (1996) merely stated that this relationship was false due to the existence of a counter-example. The rest of this section reviews the literature that went on to empirically test this hypothesis.

Many studies work to consider how immigration affects wages but, as George Borjas writes, “the measured impact of immigration on the wage of native workers fluctuates widely from study to study (and sometimes even within the same study)” (Borjas 2003, 1335). Ortega and Peri (2009) found that immigration raised the GDP of the receiving country, but wages and income per capita remained unaffected, thus confirming Olson’s observation. Along with Ortega and Peri (2009), there have been other studies that have found immigration to have little to no effect on wages and
income per capita. These studies include Borjas, Freeman and Katz (1997); Butcher and Card (1991); Card (1990, 2001, 2009); D’Amuri, Ottaviano and Peri (2008); Friedberg and Hunt (1995); and Zorlu and Hartog (2005). Others like Ottaviano and Peri (2006); Ottaviano and Peri (2008); Peri (2009); and Boeri and Brucker (2005) have found there to be a positive relation between immigration and wages, thus meaning that immigration raises wages and income per capita in the long run. In contrast, Borjas (1994, 1999, 2003); Borjas, Freeman and Katz (1997); and Borjas and Katz (2007) show that immigration has an adverse affect on wages in the receiving country. As Ottaviano and Peri (2008) note, many studies that find this large adverse effect of immigration on wages utilize what is called the national approach, which will be described later in this section. It is clear that this selection of studies confirms Borjas’ statement that no relationship between the affect of immigration on wages and income per capita is the clear leader in the eyes of empirical economists.

It is possible that the reason for this dispersion of results lies within the other controversy of what is the right question to ask. Most empirical studies in this field look to answer two questions, according to Ottaviano and Peri (2008). The first is: how does an inflow of foreign-born workers affect the wages of native-born laborers? The second concerns how these effects are distributed across native-born workers with various levels of education. Along with these questions, Hatton (2010) goes on to add that the “bulk” of the literature on this topic focuses on “migration from Europe to the New World” (2). The notion that most of the empirical studies are conducted on immigrants entering the United States workforce is also supported by
Longhi, Nijkamp and Poot (2005). It is clear that, regardless of the question, most of the studies in this field focus only on one country and that one country is usually always the United States. Thus, any research on this topic that involves multiple countries will add a great amount to the literature. The question asked in this thesis is a combination of the two set forth by Ottaviano and Peri (2008): how will an inflow of foreign-born workers with various levels of education affect the wages of native-born workers of various levels of education? Furthermore, there is also controversy over what is the best approach to take to answer the question. Several possible approaches to analyzing this question are examined below.

III.2 The Local Approach Versus The National Approach

This subsection covers the debate over what geographic region best captures the effects of immigration on the receiving economy. As the title of this subsection implies, there are two general approaches that are commonly accepted in the literature. The first approach is the local approach, which looks at how immigrants affect the wages of native workers in small regions, typically cities, within a country. The second approach is the national approach, which looks at how immigration affects the aggregate wages of native workers in the entire country. This approach is relatively new and has only been in practice for the past couple of decades, whereas the local approach has been the main method of assessment for studies since research on this topic began. The latter statement is fully supported by the work of Friedberg and Hunt (1995). Ultimately, the debate is over which geographical region best captures the essence of the closed economy for which the theory predicts that an increase in the labor supply should decrease wages?
Many studies assert that immigration has the biggest impact on native-workers on the local level. Thus, in order to capture these local affects, these studies, include Card (2001), Card (2009), Card and Lewis (2007), Friedberg and Hunt (1995), and Peri (2009), use models that pull data from states or smaller regions. The emphasis on using small regions within a country to capture immigration is also stressed by Hatton (2010). What is the benefit of using the local approach? As Friedberg and Hunt (1995) point out, immigrants not only pick their destination countries but they also pick which city in the receiving county they wish to settle in as well. Thus, by using the local approach empirical studies can capture the city level determinants that attract immigrants. Additionally, each city can offer different wages to their inhabitants and these wage differentials may attract immigrants to settle in specific cities. Behind this idea is the fact that wages can differ within a country and thus this characteristic can only be empirically studied and taken into account if smaller regions, like cities are the main area of observation. Friedberg and Hunt (1995) also include that the local approach will also provide evidence of natives being displaced, which is important to research as it is of primary importance to the country’s citizens who do not want to be forced to move from their homes. David Card also provides evidence in support of the local approach. Mobility of the natives is a major criticism of the local approach and will be discussed in more length in the description of the national approach. Card (2001) was able to show that large increases in the immigrant population did not create “offsetting mobility flows by natives” in the United States during the period 1985 to 1990 (56). In a later study Card (2009) was
able to show that results from studies using the local approach were consistent with those of the national approach and, thus, it is still a viable method.

The national approach first began to build support with the work of Borjas (1994) and Borjas, Freeman and Katz (1996, 1997). This national level approach has recently been adopted by a large portion of the current studies including Aydemir and Borjas (2010), Borjas and Katz (2007), Ottaviano and Peri (2006), Ottaviano and Peri (2008), and D’Amuri, Ottaviano and Peri (2008). Borjas (2003) argues that local labor markets may adjust to immigrant inflows and, therefore, the best way to capture the effect of immigration on wages is on the national level. Local labor markets can adjust to immigrant inflows if natives leave and move to another city within the same country. The rate at which natives move within the same country due to an increase in immigrants is referred to as the mobility rate by Borjas, Freeman and Katz (1997) and Card (2009). Card (2001) also adds that, “in the long run, an immigration induced increase in the supply of labor to a particular city can be diffused across the economy by intercity trade” (23). Thus, the effects of immigration are felt on the aggregate economy wide level and not on the local level. Another issue with the local approach is again discussed in Card (2001), and is resolved with the national approach. This issue lies in the fact that local demand shocks may greatly bias the wages in a given city and, thus, the amount of immigrants attracted to settle there. For these reasons, the national approach has gained large support in the recent decades and has become one of the main methods used in current research. With this approach, aggregate time series data is used to measure the effect of immigration on the entire economy of a given country.
With these two approaches in mind, it has been determined that the best approach for the purposes of studying the question of interest to this thesis is the national approach. There are three main issues with the local approach that have been seemingly solved by the national approach, making it a very desirable method to use. As for the results of Card (2001), he shows that mobility rates in the United States from 1985 to 1990 were negligible, but it seems that the time span of this study is too narrow and that the results are not widely applicable. Thus, these results do not undermine the validity of the national approach. In addition to its apparent strength relative to the local approach, it also provides an advantage to the additional application of economic growth. In order to study economic growth, aggregate economic data is often used. Therefore, using the national approach compliments this aspect of the economic growth research. This is extremely helpful for the purposes of this thesis.

III.3 The Area Approach Versus The Factor Proportions Approach

In addition to the debate over which geographical region best captures the effects that immigration has on the receiving society, there is another controversy that has arisen and is founded in the question of which method is the most appropriate for modeling the effects of immigration on wages. Just as with the geographical debate, there are two rival approaches that both have the respect of scholars and prominence in the literature: the area approach and the factor proportions approach. The area approach builds its regression model around the fact that “immigration is spatially highly concentrated, so that a negative spatial correlation may be expected between the proportions of the labour force in local labour markets that are immigrants and the
wages of natives who they can substitute for” (Longhi, Nijkamp and Poot 2005, 454). The factor proportions approach takes a different angle and considers immigrant and native workers to be separate factors of production that are not perfect substitutes. Both of these approaches are aimed at finding the effect of an increase in immigration on wages, but their methods are entirely different. As a result, some studies use both methods, including Borjas (2003), Borjas, Freeman and Katz (1997), and Borjas and Katz (2007), to check the robustness of their results. The remainder of this subsection describes the two approaches and outlines the reasons for which method is used in this thesis.

As mentioned above, the area approach is built around the idea that as the immigrant stock rises in an area, the wages of the native workers should decrease. In order to capture this effect, a simple regression can be devised where the wages of the native workers is regressed on the immigrant stock, which is the main explanatory variable of interest, along with other control variables. The result of interest is the coefficient of the immigrant stock as it illustrates the measured effect of immigration on wages. This method is used in many studies including Aydemir and Borjas (2010), Boeri and Brucker (2005), Oretega and Peri (2009), Grogger and Hanson (2008), and Zorlu and Hartog (2005). As Longhi, Nijkamp and Poot (2005) note, “the area approach is rarely built up from theoretical microfoundations,” and is subject to three potential hazards that could bias the results of the study. These three potential hazards are model misspecifications, endogeneity of the explanatory variables, and the understanding that immigration may have unique effects on wage for any given situation. As with all regressions, the “true” model can never be known
for certain. Thus, many scholars differ in their view of the “true” model, which creates model misspecification. If an important variable that belongs in the “true” model is left out of the regression, then the results of the regression are subject to omitted variable bias which may harm the conclusions of the study. It is also possible for some of the explanatory variables in the model to be endogenous. A method for dealing with the endogeneity of such variables is to find an instrumental variable (IV) for it and substitute the IV into the regression. Unfortunately, if a poor instrument is used this will also bias the results and may in fact turn out to be more harmful. The argument that immigration has a unique effect on wages for every given situation is not supported in economic theory and therefore is still viable to generalize the effects of immigration.

To combat the potential downfalls of the area approach, the factor proportions approach has been devised to have a stronger foundation in microeconomic theory. This is done by assuming that native and foreign-born workers are not perfect substitutes and thus constitute different factors of production. This is done in several ways, one of which is discussed in further length in the next subsection as well as in the methodology section of this thesis. The elasticity of substitution between native and foreign-born workers is calculated through regression analysis and then is converted to estimate the coefficient of immigration on wages as if it were run in a regression. This approach has been utilized in many studies including Card (2009), D’Amuri, Ottaviano and Peri (2008), Docquier, Ozden, and Peri (2010), Ottaviano and Peri (2006), and Ottaviano and Peri (2008). Unfortunately, there are also several areas for concern with this approach as well. As Longhi, Nijkamp, and Poot (2005)
explain that due to the construction of the production function, the factor proportions approach needs a larger amount of assumptions that may or may not be applicable. Another area for concern described by Longhi, Nijkamp, and Poot (2005) is that the factor proportions approach does not account for other variables that may affect wages, and thus may suffer from omitted variable bias. Borjas (2003) offers another critique of this approach, writing, “the factor proportions approach is ultimately unsatisfactory. It departs from the valuable tradition of empirical research in labor economics that attempts to estimate the impact of labor market shocks by directly observing how those shocks affect some workers and not others. For a given elasticity of substitution, the approach mechanically predicts the relative wage consequences of supply shifts” (6).

A combination of these two approaches will be utilized here. This hybrid approach lets the data predict the effect of immigration on wages while still maintaining a foundation in microeconomics as well as macroeconomics. In order to do this, this thesis will adopt a production function as defined by the factor proportions approach. In doing so, both native and foreign-born workers will be viewed as separate factors of production. This solidifies the microeconomic theory into the model. This production function will then be applied to the Solow growth model and the marginal product of each type labor will be found. This can be equated to real wages and will constitute the main regression model. This will be discussed in further detail in the methodology section. At this point, this thesis departs from the factor proportions model and does not calculate the elasticities of substitution between foreign and native-born workers. Instead, a regression will be
run with real wages as the main dependent variable in accordance with the area
approach. Control variables other than the factors of production will be included in
the regression so that the omitted variable bias is nullified. Endogeneity must also be
considered in this regression. Thus, this hybrid approach attempts to incorporate the
benefits of each method while mitigating their potential errors.

III.4 Contribution to the Literature

It is clear after reviewing the literature on immigration and wages, that there is
little agreement amongst labor economists on this particular question. It is the
purpose of this thesis to help shed some light on the underlying truths of this problem
by offering a new approach. Many studies only look at one or a few countries within
a particular region, i.e., either just the United States as in Ottaviano and Peri (2008),
Card (2009) and Borjas (2003), or a subset of the European countries as in Boeri and
Brucker (2005), Ortega and Peri (2009) and Hartog and Zorlu (2005). It is the
purpose of this thesis to apply these econometric models to a wider range of countries
that are located on different continents. In doing so, this thesis applies the
aforementioned methods to a whole new sample of countries. This new method has
created a new question that has rarely been asked in the literature: how do changes in
the labor supply affect a large number of countries? Although this is a new question,
the answer will be extremely interesting and important for nations’ immigration
policies.

In addition to asking a new question, this thesis also proposes a new approach
as well as a new technique for studying the effects of migration on wages. This new
approach is a combination of the area and factor proportions approaches and has been
devised so that the benefits of both methods can be obtained while mitigating the biases associated with them. This method maintains a strong foundation in microeconomic theory as in the factor approach and allows the data to determine the effect of migration on wages as in the area approach. The new technique that will be used in this thesis is that of the Simultaneous Equations Method (SEM) which is new to this literature. This method will be used in order to account for the potential simultaneity between wages and the immigrant share. No consensus has been reached among academics on the best method to use to account for the potential endogeneity of the immigrant share. This thesis considers a new approach that should also be considered.

IV. Empirical Strategy

As mentioned in the introduction, this study tests the neoclassical production function, adjusted to incorporate current immigration literature, and the assumption that comes out of competitive economics, which is that factors of production are paid their marginal products. In doing so, this thesis follows the work of Docquier, Ozden and Peri (2010), among others, in its construction of the production function. The Solow model production function predicts that an increase in the labor supply, or immigration to a country, would cause real wages to decrease. Thus, one would expect to see a negative relationship between labor supply and real wages. This relationship becomes more complicated when the skill level of the labor force is included as with a production function used in Docquier, Ozden and Peri (2010). The
reason for this will become clearer after the production function, which disaggregates the labor supply into native and immigrant workers by skill level, has been explained.

This paper heavily relies on the economic theory of the Solow Model and the production function utilized Docquier, Ozden and Peri (2010) in determining the appropriate econometric model to use. The use of a production function framework in measuring the effect of immigration on wages is confirmed by Ottaviano and Peri (2008) who write, “a production function framework is needed to combine workers of different skills in order to evaluate the competition as well as cross-skill complementary effect of immigrants on wages” (1). This thesis uses a nested CES production function that is widely used in the immigration literature. As mentioned above, it has been used most recently by Docquier, Ozden and Peri (2010), along with Borjas (2003); Borjas, Freeman, and Katz (1997); Borjas and Katz (2007); Card (2009); D’Amuri, Ottaviano, and Peri (2008); Ottaviano and Peri (2006); and Ottaviano and Peri (2008). The production function that will be used in this paper is a nested CES production function, namely:

\[
Y_t = A_t K_t^\alpha N_t^{1-\alpha}
\]

Where:

\[
N_t = \left[ \theta_{Ht} N_{Ht} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} + \theta_{Lt} N_{Lt} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right] \frac{\sigma_{HL}}{\sigma_{HL}^{-1}}
\]

And:

\[
N_b = \left[ \theta_{Dbt} N_{Dbt} \frac{\sigma_{IMMI}^{-1}}{\sigma_{IMMI}} + \theta_{Fbt} N_{Fbt} \frac{\sigma_{IMMI}^{-1}}{\sigma_{IMMI}} \right] \frac{\sigma_{IMMI}}{\sigma_{IMMI}^{-1}}
\]

Where:

\( t \) stands for time
\( b \in B = \{H, L\} \)

Here, the baseline production function is a Cobb-Douglas production function with constant returns to scale just as in the production function used by Solow (1956). The labor supply has then been disaggregated using a CES production function that
allows for imperfect substitutability between the different types of labor supplied to the market. The labor supply is broken into two labor aggregates: workers with a high degree of education (H) and those with a low degree of education (L). The variable \( \sigma_{HL} \) is the elasticity of substitution between high and low skilled workers. \( \theta_{Ht} \) and \( \theta_{Lt} \) are the productivity levels of high and low skilled workers respectively that when added together equal one. Each labor aggregate is then disaggregated again using a CES production function between native (denoted D, for domestic, in the model) and foreign-born (denoted F in the model) workers. The variable \( \sigma_{IMMI} \) is the elasticity of substitution between native and foreign-born workers. While \( \theta_{Dt} \) and \( \theta_{Ft} \) are the productivity levels of native and foreign-born workers respectively, in their specific skill aggregate, that when added together equal one. There is also much evidence that calls for further disaggregation of each labor aggregate by each worker’s experience level. Unfortunately, the data does not widely exist and so will not be incorporated into this paper.

As mentioned above, using a CES production function to disaggregate the labor supply allows the model to account for imperfect substitutability between all of the labor aggregates. This concept was first generated by studies that found it necessary to partition the labor force into high and low skill components. These studies include Acemoglu (2002), Angrist (1995), Autor, Katz and Krueger (1998), Johnson (1997), Katz and Murphy (1992), Krusell et al. (2000), and Murphy and Welch (1992). Ottaviano and Peri (2008) write that beginning with these studies “economists have argued that in order to understand the impact of changes in the supply and demand for labor on the wages of workers of different education levels it
is very helpful to consider highly educated and less educated workers as imperfectly substitutable (with constant elasticity)” (7). This thesis draws from the dataset of Docquier, Ozden, and Peri (2010) and thus defines high-skilled workers as individuals who have a college degree, or the equivalent thereof, or higher and defines low-skilled workers as individuals who have a high school degree, or the equivalent thereof, or lower. This disaggregation is typical of the literature as it is generally assumed that the elasticity of substitution between workers with no degree and a high school degree is infinite, while workers with a college degree and those with higher education are almost perfect substitutes. However, there have been studies that have looked to further disaggregate the labor force into four skill levels, mainly no degree, high school degree, some college experience and a college degree and higher. These studies include Borjas (2003), Borjas and Katz (2007) and Ottaviano and Peri (2006). This method was tested by Ottaviano and Peri (2008), who found that the data strongly favored the two-skill level disaggregation over the four.

Recently, there have also been studies that have shown that immigrants and native workers are imperfect substitutes as well. The majority of these studies have been focused mainly on the United States, including Ottaviano and Peri (2006, 2008) and Raphael and Smolensky (2009) who all found estimations for $1/\sigma_{IMMI}$. However, recently there have been studies that have estimated the same parameter in other countries as well. These studies include Manacorda, Manning, and Wadsworth (2006) who used data from the United Kingdom and D’Amuri, Ottaviano, and Peri (2008) who estimated $1/\sigma_{IMMI}$ using German data. It is important to show that
immigrants and native workers in multiple countries are imperfect substitutes as it
strengthens the argument that this production function is a suitable measure for a
cross-country comparison. This is necessary because using such a production
function in a cross-country comparison is relatively new to literature as it has only
studied by Docquier, Ozden, and Peri (2010) as the appropriate data has only just
been made available.

It is important to note the implications of using such a production function. In
using a production function of this form strong assumptions are being made. The first
assumption has plagued economic growth literature since the time of Solow (1956).
Applying such a production function to every country is assuming that every country
has the same production function. Ottaviano and Peri (2009) utilize this production
function under the basis that “there is abundant evidence for the U.S.” for the use of a
Cobb-Douglas production function framework (3). Having said this, there is not an
abundance of evidence that says the Cobb-Douglas production function captures the
production process of every country. This issue is noted by Durlauf, Kourtellos, and
Minkin (2001) and Eberhardt and Teal (2010). Unfortunately, the current data does
not allow researchers to test different production functions for each country for this
specific case (the reason for such a small dataset is discussed in section V). However,
many studies that have used a Cobb-Douglas production function across multiple
countries, like Bosworth and Collins (2003), Docquier, Ozden, and Peri (2010), and
Mankiw, Romer, and Weil (1992) among others, have been successful in their results
which supports such a method. The assumption that all countries have a Cobb-
Douglas production function may not be valid for all countries of the world.
However, this study includes a very homogenous subset of countries, all of which are similar to the United States. Thus it is much more probable to make the assumptions that all OECD countries follow the Cobb-Douglas production function and therefore should not drastically bias the results.

The second strong assumption being made is that applying such a production function to multiple countries also implies that each country has the same elasticity of substitution both between high and low skilled laborers as well as between native and immigrant workers. A way around this assumption is to run separate regressions for each country, which will allow (even though each country is still assumed to have the same production function) the study to relax these assumptions. Not only would these regressions relax the assumption but they would also act as robustness checks as well, to see if they reinforce the results from the collective regressions. Unfortunately, as mentioned above, the existing data (which is currently one observation per country) does not supply one with sufficient observations to carry out these regressions. Although these strong assumptions are being made, Docquier, Ozden, and Peri (2010) still show that utilizing this production function is still very useful in describing wage growth across a cross-section of countries.

From the assumption that factors of production are paid their marginal products, we know that real wage is equated to the marginal product of labor, as was shown in section II. Therefore, taking the derivative of this production function with respect to each type of labor and applying methods used in growth accounting creates the basic framework for the regression model used in this paper. Note that there is a marginal product of labor for each labor aggregate. This means that each labor
aggregate will receive different real wages. Data on such wages is not currently available and is discussed in greater detail in section V. One can begin by finding the marginal product of each type of labor by taking the derivative of the production function with respect to each labor aggregate. This returns the following four equations:

\[
\frac{w_{D_{bt}}}{p} = M_{P_{N_{D_{bt}}}} = A_t K_t^\alpha N_t^{-\alpha + \frac{1}{\sigma_{HL}}} \theta_{bt} N_{bt}^{-\frac{1}{\sigma_{HL}}} \theta_{bIMMI} N_{bIMMI}^{-\frac{1}{\sigma_{IMMI}}}
\]

And:

\[
\frac{w_{F_{bt}}}{p} = M_{P_{N_{F_{bt}}}} = A_t K_t^\alpha N_t^{-\alpha + \frac{1}{\sigma_{HL}}} \theta_{bt} N_{bt}^{-\frac{1}{\sigma_{HL}}} \theta_{F_{bt}} N_{F_{bt}}^{-\frac{1}{\sigma_{IMMI}}}
\]

Note that each equation actually stands for two equations as b can stand for either high or low-skilled labor. The derivation of these equations can be found in section B of the appendix.

The question of interest of this thesis is the relationship between the growth rates of all of these variables. Thus, it is necessary to use growth accounting to find the relationship between these variables’ growth rates. The technique of using growth accounting to “improve…our understanding of growth experiences across countries” is a technique used and recommended by Bosworth and Collins (2003) (113). Setting the definition of \( \bar{H} \) to mean the growth rate of some variable H, one can now use a technique used in growth accounting, mainly log-linearization, to solve for the growth rate of the marginal product of each type of labor. In doing so this returns:
\[ \frac{\bar{W}_{D_{bt}}}{p} = \frac{MP_{ND_{bt}}}{p} = \bar{A}_t + \alpha \bar{R}_t + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \bar{N}_t + \bar{\theta}_{bt} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) \bar{N}_{bt} + \bar{\theta}_{D_{bt}} + \left( \frac{-1}{\sigma_{IMMI}} \right) \bar{N}_{D_{bt}} \]

And:

\[ \frac{\bar{W}_{F_{bt}}}{p} = \frac{MP_{NF_{bt}}}{p} = \bar{A}_t + \alpha \bar{R}_t + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \bar{N}_t + \bar{\theta}_{bt} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) \bar{N}_{bt} + \bar{\theta}_{F_{bt}} + \left( \frac{-1}{\sigma_{IMMI}} \right) \bar{N}_{F_{bt}} \]

It is important to note here that the growth rate of the labor supply, \( N \), depends on the growth rate of the four labor aggregates. Similarly, the growth rate of each skill-level, \( N_H \) and \( N_L \), depends on the growth rates of the native and immigrant workers in those skill levels. Accounting for this allows one to write the real wage growth equations in terms of the smallest aggregates available. This process returns:

\[ \frac{\bar{W}_{D_{bt}}}{p} = \frac{MP_{ND_{bt}}}{p} = \bar{A}_t + \alpha \bar{R}_t + \bar{\theta}_{bt} + \bar{\theta}_{D_{bt}} + \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{bt} C_{D_{bt}} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{D_{bt}} + \left( \frac{-1}{\sigma_{IMMI}} \right) \right] \bar{N}_{D_{bt}} \]

\[ + \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{bt} C_{F_{bt}} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{F_{bt}} \right] \bar{N}_{F_{bt}} \]

\[ + \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{(-b)t} C_{D_{(-b)t}} \right] \bar{N}_{D_{(-b)t}} \]

\[ + \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{(-b)t} C_{F_{(-b)t}} \right] \bar{N}_{F_{(-b)t}} \]
And:

\[
\frac{\tilde{w}_{F,b,t}}{p} = \tilde{M}_{F,b,t} \tilde{P}_{N_{F,b,t}} \\
= \tilde{A}_t + \alpha \tilde{K}_t + \tilde{\theta}_{bt} + \tilde{\theta}_{F,t} \\
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{bt} \tilde{C}_{Db,t} + \left( \frac{1}{\sigma_{IMM}} - \frac{1}{\sigma_{HL}} \right) C_{Db,t} \right] \tilde{N}_{Db,t} \\
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha \right) C_{bt} \tilde{C}_{F,b,t} + \left( \frac{1}{\sigma_{IMM}} - \frac{1}{\sigma_{HL}} \right) C_{F,b,t} + \left( \frac{-1}{\sigma_{IMM}} \right) \right] \tilde{N}_{F,b,t} \\
\]

With:

\[
C_{bt} = \frac{\theta_{b(t-1)} N_{b(t-1)} \sigma_{HL}^{-1}}{\theta_{b(t-1)} N_{b(t-1)} \sigma_{HL}^{-1} + \theta_{(-b)(t-1)} N_{(-b)(t-1)} \sigma_{HL}^{-1}} \\
C_{(-b)t} = \frac{\theta_{(-b)(t-1)} N_{(-b)(t-1)} \sigma_{HL}^{-1}}{\theta_{b(t-1)} N_{b(t-1)} \sigma_{HL}^{-1} + \theta_{(-b)(t-1)} N_{(-b)(t-1)} \sigma_{HL}^{-1}} \\
C_{Db,t} = \frac{\theta_{D_{b(t-1)} N_{D_{b(t-1)}} \sigma_{HL}^{-1}}}{\theta_{D_{b(t-1)} N_{D_{b(t-1)}} \sigma_{HL}^{-1}} + \theta_{F_{b(t-1)} N_{F_{b(t-1)}} \sigma_{HL}^{-1}}} \\
C_{F,b,t} = \frac{\theta_{F_{b(t-1)} N_{F_{b(t-1)}} \sigma_{HL}^{-1}}}{\theta_{D_{b(t-1)} N_{D_{b(t-1)}} \sigma_{HL}^{-1}} + \theta_{F_{b(t-1)} N_{F_{b(t-1)}} \sigma_{HL}^{-1}}} \\
C_{D_{(-b)t}} = \frac{\theta_{D_{(-b)(t-1)} N_{D_{(-b)(t-1)}} \sigma_{HL}^{-1}}}{\theta_{D_{(-b)(t-1)} N_{D_{(-b)(t-1)}} \sigma_{HL}^{-1}} + \theta_{F_{(-b)(t-1)} N_{F_{(-b)(t-1)}} \sigma_{HL}^{-1}}} \\
C_{F_{(-b)t}} = \frac{\theta_{F_{(-b)(t-1)} N_{F_{(-b)(t-1)}} \sigma_{HL}^{-1}}}{\theta_{D_{(-b)(t-1)} N_{D_{(-b)(t-1)}} \sigma_{HL}^{-1}} + \theta_{F_{(-b)(t-1)} N_{F_{(-b)(t-1)}} \sigma_{HL}^{-1}}} \\
\]

For a full derivation of these equations, see section B of the appendix. Writing the marginal product of each labor aggregate as a function of the growth rates of the smallest input factors minimizes the correlation between the independent variables,
thus mitigating the presence of multicollinearity in the model. The last two growth rate equations will form the basic framework of the regression models used in this thesis.

Before laying out the model that forms the groundwork for the econometric research in this paper, there are several important issues that need to be discussed. First, it is necessary to address the terms that account for the productivity of high and low skilled labor along with native and immigrant workers as well. $\theta_{ht}, \theta_{lt}, \theta_{dht}, \theta_{fht}, \theta_{dlt}$ and $\theta_{ft}$ are set to constant numbers by Docquier, Ozden, and Peri (2010), mainly $\theta_{ht} = \theta_{dht} = \theta_{dlt} = 0.6$ and $\theta_{lt} = \theta_{fht} = \theta_{ft} = 0.4$. This is a strong assumption and not necessarily true, however Docquier, Ozden and Peri (2010) show that their results are not sensitive to values of these productivities so it is assumed that setting these productivities to be constants will not harm the regression results in this study either. Due to the fact that the productivity levels of each type of labor are believed to remain constant for all countries and any period of time, it is clear that their growth rate will be zero and will thus drop out of the growth accounting equation. Not only are the growth rates of these variables zero, they also do not vary across countries and, therefore, including them in the regressions would violate the assumption of no perfect collinearity. Thus, these productivities will not appear in the regression model.

Another more pressing issue to address is one that has been an area of concern for many studies in labor economics and immigration literature specifically. There are legitimate concerns that measures of the immigrant stock may be endogenous. The potential endogeneity of the immigrant share of the labor supply arises from the
notion that high wages provide an incentive for immigrants to migrate to those regions that offer those high earnings. There are several consequences to running an Ordinary Least Squares (OLS) regression with an endogenous explanatory variable. The main consequences are that it leads to bias and inconsistency in OLS. Friedberg and Hunt (1995) write that if the endogeneity of the immigrant share is not controlled for then it will result in a positive bias on the estimators as well as “as bias toward zero due to factor price equalization across the country” (34). Longhi, Nijkamp, and Poot (2005) add that this positive bias causes studies to find a less negative effect of immigration on wages and that the endogenous variable leads to inconsistent estimators. Due to the potential endogeneity of the immigrant share, many economists have strived to find the best solution that will provide the most unbiased results. Unfortunately, a consensus has not been reached and therefore several methods will currently be explained in greater detail.

The first technique is one that is utilized in the study of Ottaviano and Peri (2008). Hulten (2009) states that the best way to measure the labor supply in a growth accounting regression is through the flow of labor services, which is best captured by a variable that measures hours worked. With this in mind, Ottaviano and Peri (2008) used the foreign to native employment ratio as an instrument for hours worked. Unfortunately, this method is not applicable to this thesis. As has been mentioned earlier, a dataset that records natives and immigrant workers by their skill level has only just been made available in December of 2010 which builds upon the earlier study of Docquier and Marfouk (2005). Thus data on hours worked for immigrants and native workers based on their skill level is currently unavailable at
this time. In order to use an instrumental variable, the endogenous variable (in this the hours worked of one of the labor aggregates) must be regressed on an exogenous variable (in this case the corresponding labor aggregate stock), which is uncorrelated with the error term and correlated with the endogenous variable. Fitted values from this regression are then used in place of the endogenous variable. As mentioned above, data on hours worked for each labor input is not currently available and so a 2SLS regression of this type cannot be run.

The technique in Ottaviano and Peri (2009) sought to find an instrumental variable for the entire labor supply. However, it is typically assumed that only the immigrant share of labor is potentially endogenous as it is only immigrants who “are particularly attracted to regions where wage growth is the highest” (Longhi, Nijkamp and Poot 2005, 455). In this light, it is only necessary to find instrumental variables for the immigrant share of the labor force. As Aydemir and Borjas (2010) note, the most widely used and accepted instrument for the immigrant density of a country is a measure of the lagged immigrant stock. For example, Altonji and Card (1991) use the immigrant stock in 1970 as an instrumental variable for the change in the immigrant share from 1970 to 1980. Many other studies have used this approach including, Aydemir and Borjas (2010), Card (2001), Friedberg and Hunt (1995), Longhi, Nijkamp, and Poot (2005), Schoeni (1997) and Zorlu and Hartog (2005). The reasoning behind the use of this instrument is summarized nicely by Aydemir and Borjas (2010) who write “the continuing influx of immigrants into particular markets is based mostly on the magnetic attraction of network effects rather than on any income-maximizing behavior. In theory, these IV regressions provide an
alternative method for correcting for sampling error bias because the sampling error in the current and lagged values of the immigrant share is uncorrelated in independent samples‖ (38). Longhi, Nijkamp, and Poot (2005) also note that the lagged immigrant share is usually highly correlated with immigrant inflows, causing it to be a strong instrumental variable. It is also important to note that although this method is used primarily in studies that measure the effect of immigration on wages at the city level, Aydemir and Borjas (2010) argue that it can also apply to national-level studies as well.

Although this technique of using an instrumental variable for the immigrant stock is widely used, it still has many critiques. Even though Aydemir and Borjas (2010) use an IV in their regressions, they also show that “it is far from clear that the lagged immigrant share is a legitimate instrument” (38). First, if earlier immigrants migrated to these areas because of the benefits in job opportunities and wages, then if there is any serial correlation present, the conditions of an instrumental variable are not met. Second, if there is any sampling error in the measurement of the lagged immigrant share, then this will cause it to be a weak instrument. The consequences of this may be severe. As Wooldridge (2009) notes, the presence of a weak instrumental variable can cause the IV estimates to have large standard errors as well as having large asymptotic bias, or inconsistency.

In addition to the criticism of the use of this particular instrumental variable, there are other economists who argue that the use of any instrument is unnecessary. Although Schoeni (1997) uses the lagged immigrant share instrument in his regressions, he also states that evidence supporting the hypothesis that immigrants are
attracted to high wage regions is weak. This argument is supported by Borjas, Freeman, and Katz (1997), who state that recent changes in the labor supply have not been due to “contemporary labor market conditions,” and therefore the variables are not endogenous (3). This idea is further supported by Longhi, Nijkamp, and Poot (2005) who argue that the endogeneity of the immigrant supply may only be a minor problem as immigrants migrate to areas where previous immigrants have migrated to for historical rather than economic reasons.

These three studies promote the idea that the argument that immigration is endogenous relative to wages is founded upon a false pretense and that the data does not correspond to the reasoning for implementing the instrumental variable. Mankiw (1995) also attacks the use of this instrumental variable, writing, “Some economists are tempted to treat lagged variables as exogenous. But a variable is not necessarily exogenous just because it is predetermined” (303). He goes on to argue that the use of any instrument whatsoever in an economic growth regression “does not seem feasible” due to the fact that there are few good instruments, if any exist, that are suitable. If an instrumental variable is used when OLS is valid then there will be large ramifications on the variance of the IV estimators. Wooldridge (2009) notes that, “IV variance is always larger than the OLS variance (when OLS is valid)” (511). Therefore, if an instrumental variable regression is run when it is inappropriate to use this method, then the instrumental variables will be found to be less significant than they truly are, causing researchers to potentially reach the wrong conclusions. Thus, it can be seen from these arguments that the best measure for the labor supply is to leave the immigrant share as a stock and regress that variable on wages.
With these two views in mind, both regressions using the stock of the immigrant supply as well as instruments for the immigrant share will be run. The model that will be used for the OLS regressions follows from the growth rate of each of the marginal product of labor:

\[
\bar{WAGE} = \beta_0 + \beta_1 \bar{A} + \beta_2 \bar{K} + \beta_3 \bar{N} + \beta_4 \bar{N}_{D_b} + \beta_5 \bar{N}_{F_b} + \beta_6 \bar{N}_{D(-b)} + \beta_7 \bar{N}_{F(-b)} + \beta_8 X + \varepsilon
\]

There is only one regression equation (instead of 4) due to the limited data on wages, which is described in more depth in section V. The variable X stands in place for various combinations of other variables that have been proven to affect economic growth, immigration, and wages. These variables include unemployment rates, openness to trade measures, as well as proxies for labor market institutions and immigration policies. The variable \( \varepsilon \) stands for the error term in this regression.

There have been many studies including Knack and Keefer (1995), Hall and Jones (2008) and Jaggers and Marshall (2000) who have shown that measures that proxy for the institutional quality of a country is significant in determining their economic growth. However, due to the fact that this study uses a very homogenized group of countries there would not be sufficient variation in the proxy variable to warrant including it in the model. This argument is supported by Glaesar et al. (2004), and therefore a measure for institutional quality has been excluded from this model.

Note that the growth rate of the total labor force stock has appeared in the regression. This was done so that both the “size” and “composition” effect of immigration can be accounted for. It can be seen that immigrants who enter a new labor force exert two forces on the wages of natives. The first force is one of “size,” mainly that as immigrants enter the labor force the amount of workers increase, which
exerts a downward pressure on wages. This size effect is in accordance with the predictions of the Solow model. Thus, the expected sign of the “size” effect of immigration is expected to be negative relative to wages. The next force that immigrants exert on wages comes from the “composition” effect. In understanding the composition effect, it is helpful to imagine immigrants and emigrants as the trade (importing and exporting) of human capital. Here, the word trade is used with one caveat: a country can decide how much and what type of human capital enters the country but cannot control the human capital that leaves the country (unless the country is ruled by a dictator, which none of the countries in this study are). High skilled immigrants are seen as increasing the human capital composition of the receiving country. Thus as the share of high skilled immigrants relative to the labor force increased, this would have a positive effect on average wages as high skilled workers receive higher earnings relative to low-skilled workers. Conversely, if low-skilled immigrants increased relative to the labor force, then the “composition” effect would exert a downward pressure on wages. For low-skilled immigration the “size” and “composition” effects are both negative, so the overall expected impact of low-skilled immigration is expected to be negative. However, the “size” and “composition” effects for high-skilled immigration exert forces in opposite directions, and it is clear that both of these effects must be accounted for to see if the data supports this hypothesis.

To see how the both the “size” and “composition” effects are accounted for in this regression model, a short derivation is provided here. One begins with the share of high and low-skilled immigration as a share of the labor force, mainly $\frac{N_{PH}}{N}$ and $\frac{N_{PL}}{N}$. 

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Now calculating the growth rates of these variables returns $\bar{N}_{F_{th}} - \bar{N}$ and $\bar{N}_{F_{tl}} - \bar{N}$ respectively. Substituting this into a regression equation produces the following equation:

$$\bar{WAGE} = \beta_0 + \beta_1 \bar{A} + \beta_2 \bar{K} + \beta_3 \bar{N}_{Db} + \beta_4 (\bar{N}_{Fb} - \bar{N}) + \beta_5 \bar{N}_{D_{(-b)}} + \beta_6 (\bar{N}_{F_{(-b)}} - \bar{N}) + \beta_7 X + \varepsilon$$

Distributing and isolating the labor force variable gives the new equation:

$$\bar{WAGE} = \beta_0 + \beta_1 \bar{A} + \beta_2 \bar{K} - (\beta_4 + \beta_6) \bar{N} + \beta_3 \bar{N}_{Db} + \beta_4 \bar{N}_{Fb} + \beta_5 \bar{N}_{D_{(-b)}} + \beta_6 \bar{N}_{F_{(-b)}} + \beta_7 X + \varepsilon$$

One can rename the estimator $-(\beta_4 + \beta_6)$ as its own beta coefficient, which now returns the originally proposed regression equation. It can be seen here that the coefficient of the labor force stock captures the “size” effect of immigration where as the coefficients on each of the immigration variables captures the “composition” effect of high and low-skilled immigration respectively. The expected sign on the labor force coefficient is negative as the size effect exerts a downward force on wages while the coefficient for high-skilled immigration is expected to be positive while the coefficient of the low-skilled immigration is expected to be negative. These signs correspond to their respective “composition” effect on wages.

The model for the 2SLS regressions is structured very similarly to those of the OLS regressions with one major difference. As in Altonji and Card (1991), the stock of high and low-skilled immigrants in 1990 will act as the instrumental variable for the growth rate in the high and low skilled immigrant share from 1990 to 2000. The immigrant share, $\left( \frac{N_{F_{tb}}}{N} \right)$, is the endogenous variable in this case and must be remain as one variable so as to account for all of the endogeneity. One cannot decompose it to
account for both the “size” and “composition” effect as in the OLS case, as the instrumental variable will not be capturing the desired effect.

In light of this, the 2SLS regressions will follow the format:

\[
WAGE = \beta_0 + \beta_1 \bar{A} + \beta_2 \bar{K} + \beta_3 \bar{N}_{D_b} + \beta_4 \left( \frac{\bar{N}_{F_b}}{N} \right) + \beta_5 \bar{N}_{D_{(-b)}} + \beta_6 \left( \frac{\bar{N}_{F_{(-b)}}}{N} \right) + \beta_7 X + \epsilon
\]

Where, again X is defined to include various variables that affect economic growth, immigration, and wages.

In addition to these techniques a third method, which is rarely used in the literature, will also be utilized. This method is known as the simultaneous equation method (SEM). A SEM regression is used if there is assumed to be simultaneity in one or more of the explanatory variables. This means that the values of the endogenous explanatory variables are determined at the same time as the dependent variable. The idea behind the simultaneity of wages and the immigrant supply is evident from the expected relationship between the two variables. Higher earnings provide incentive for immigrants to migrate to that area, however as immigrants enter the labor force this pressure is assumed to have a downward pressure on wages. This relationship continues, increasing immigration followed by decreasing wages, until equilibrium is reached. It is because of this potential relationship that a simultaneous equation method is utilized in this thesis.

In implementing a SEM regression, multiple regressions (the number will depend upon how many endogenous variables are in the model) will be run at the same time, and iterations will occur until equilibrium is found. In this case, there are
three endogenous variables: wage growth and the growth of the high and low-skilled immigrant shares. The regressions are based on the following models:

\[ \bar{WAGE} = \beta_0 + \beta_1\bar{A} + \beta_2\bar{R} + \beta_3\bar{N}_{D_b} + \beta_4 \left( \frac{\bar{N}_{Fb}}{N} \right) + \beta_5\bar{N}_{D(-b)} + \beta_6 \left( \frac{\bar{N}_{F(-b)}}{N} \right) + \beta_7X + \epsilon \]

\[ \left( \frac{\bar{N}_{FH}}{N} \right) = \beta_0 + \beta_1\bar{WAGE} + \beta_2\bar{N}_{D_H} + \beta_3\bar{N}_{D_L} + \beta_4X + \epsilon \]

And:

\[ \left( \frac{\bar{N}_{FL}}{N} \right) = \beta_0 + \beta_1\bar{WAGE} + \beta_2\bar{N}_{D_H} + \beta_3\bar{N}_{D_L} + \beta_4X + \epsilon \]

Here, the variable X is defined in a similar fashion to that in the OLS and 2SLS regressions to include various variables that affect economic growth, immigration, and wages.

The wage regression is set up similarly to the regressions used in both the OLS and 2SLS techniques but only includes growth accounting and openness to trade as the explanatory variables. As for the immigrant share regressions, they will use the remaining explanatory variables, mainly the growth of wages, labor market quality proxy, policy variables and the change in the unemployment rate, along with the growth of the native workers stocks and the institutional quality proxy. Different combinations of these variables will be included in the various regressions.

V. Data

V.1 Dataset Overview

In this thesis, a cross-section dataset is compiled for twenty-five countries, all members of the Organization for Economic Co-operation and Development (OECD), covering the years 1990 – 2000. A list of the countries included in this dataset can be
found in the table A.3 of the appendix, along with descriptive statistics and variable definitions. As mentioned earlier, the main dependent variable in the following regressions is that of average annual wage growth in each of the twenty-five OECD countries. In light of this, the growth rate of each variable is calculated from 1990 to 2000, causing there to be 25 observations in this regression. Due to the absences of some observations, in the case that data from either 1990 or 2000 was missing, growth rates were calculated for the closest available range of data. In accordance with the Solow model, the levels of each variable were found for both 1990 and 2000 (or as close as possible when necessary), except for index or dummy variables, then the growth rates were calculated.

It is important to note that this dataset is rather small and under perfect circumstances most can agree that it is preferable to have a much larger dataset which covers a much broader time span. Unfortunately, this is not the case as this dataset is confined by the existing data. This problem will be described in greater detail in the third subsection. The limiting factor on the data is the existence of data which partitions each of the native, immigrant, and emigrant labor force by each individual’s skill level. Such data has only recently been started to be collected, which is why it is only available for the years 1990 and 2000. The data used in this thesis comes from the dataset compiled by Docquier, Ozden, and Peri (2010) which was only made public in December of 2010.

The dependent variable in this thesis is the wages received by each worker in their corresponding country. This variable will be discussed at length in the second subsection. The explanatory variables of primary interest are those included in the
growth accounting equation, mainly total factor productivity, the capital stock, and the labor supply. These variables will be expounded upon in the third subsection and have been fashioned according to the production function outlined in section IV. Other confounding factors will be added to the regression as well. These variables include other dynamics, which have been found to describe economic growth and will be explained at length in the fourth subsection.

V.2 Wages

As in Docquier, Ozden, and Peri (2010) and in accordance with the national approach, workers are seen as being able to move freely within each country so as to eliminate any wage differentials. This view, along with the assumption that factors of production are paid their marginal products allows one to equate wage growth with the growth of the marginal product of labor. As can be seen from the analysis in section IV, since there are four labor inputs there are also four marginal products (one for each labor input). Thus, it is clear that the ideal data on wages would be to have wages for native-born workers based on their skill level along with wages for immigrant workers based on their skill level. Unfortunately, since data that disaggregates immigrants based on their skill level is brand new, such a disaggregation of the wage data does not currently exist.

Research in this field is still relatively new and so the method of dealing with this wage problem has not been agreed upon. Docquier, Ozden, and Peri (2010) decided to assume their production function framework was correct, solve for the marginal product of labor, and set that value equal to the wage of each labor aggregate. However, this approach is not suited for this thesis. The research in this
thesis is designed to observe whether the data corresponds with this relationship. If one were to assume it in order to create the dependent variable, then the results would only verify that the dependent variable was constructed correctly and not whether an economy truly upholds to this relationship. Thus, the factor proportions approach has shown the validity of using this production function and this thesis will show how well it is in describing wage growth.

For the purpose of this thesis, average annual wages will be used. This wage data was taken from the OECD and is in terms of 2008 United States dollars with Purchasing Power Parity accounted for as well as 2008 constant prices. This choice is strongly supported by Bosworth and Collins (2003) who write that international prices are “strongly preferred” to national prices converted using an exchange rate when dealing with country comparisons in economic growth (126). Wage data was collected for 1990 and 2000 and the growth rate was then calculated. In some cases wage data was absent from some countries in 1990 and so the next closest year was taken to proxy for that time interval. These instances occurred for Czech Republic, Greece, Hungary, Poland, Portugal, and Slovakia whose wage data was collected in 1994, 1995, 1995, 1995, 1995, and 1994 respectively.

It will be shown here that by using average annual wage, the relationships from the growth of the marginal product of labor will still be upheld. Using statistical regressions allows the researcher to observe *ceteris paribus* effects, thus when one looks at the low-skilled immigrant coefficient we know that it represents changes in wages due solely to changes in the low-skilled immigrant stock. Therefore, when the stock of low-skilled immigrants changes, we know that it should affect all four wage
aggregates but mainly those of low-skilled workers. Thus, the theory tells us that if low-skilled immigrants were to increase then it should lower the wages of low-skilled workers. Since statistical regressions allow one to observe ceteris paribus effects, the wage of high-skilled workers should remain relatively unchanged and therefore the change in average wages should also decrease. This example can also be told to cover a change in any of the labor inputs. Therefore, due to the ceteris paribus nature of the regression, average annual wages will still uphold the desired relationship in theory.

V.3 Growth Accounting Variables Description and Measurement

Total factor productivity, or simply TFP, has been widely quoted as being the “measure of our ignorance about the causes of economic growth” (Abramovitz 1956, 11). The main reason for this title is due to the fact that TFP, sometimes referred to as multifactor productivity (MFP) as noted by Hulten (2009), is calculated as a residual. The following equation, which is widely used, comes from Hulten (2001) and illustrates how TFP is calculated (7):

$$\mathcal{R}_t = \frac{\dot{Q}_t}{Q_t} - s_t^K \frac{\dot{K}_t}{K_t} - s_t^L \frac{\dot{L}_t}{L_t} = \frac{\dot{A}_t}{A_t}$$

Here, $\mathcal{R}_t$ is defined as the Solow residual, $\frac{\dot{Q}_t}{Q_t}$ is the growth of real Gross Domestic Product (GDP), $s_t^K$ is the capital share, $\frac{\dot{K}_t}{K_t}$ is the growth of the capital stock, $s_t^L$ is the labor share, $\frac{\dot{L}_t}{L_t}$ is the growth of the labor stock, and $\frac{\dot{A}_t}{A_t}$ is the growth of total factor productivity. The situation this formula depicts is one where TFP growth is the amount of growth in real GDP which has not been explained by both capital and labor factors. Hutlen (2001) explains what could cause real GDP to grow outside of the
factors of production, mainly TFP “covers many components, some wanted (such as the effects of technical and organizational innovation), others unwanted (such as measurement error, omitted variables, aggregation bias, and model misspecification)” (7). Although, Hulten (2009) makes it clear that TFP includes a wide variety of topics, it is most often attributed and referred to as the growth in real GDP due to technological advancement. It is this variable to which economists who support the theory of endogenous growth models attribute the most influence on economic growth. Due to its role in accounting for technological advancement, which is accredited with creating a more efficient production process, TFP growth is often referred to as “productivity growth” or just simply “productivity” by many endogenous growth theorists, including Klenow and Rodriguez-Clare (1997).

In this dataset, TFP is calculated according to the equation laid out by Hulten (2001). Data on real GDP was collected from the World Bank and is in terms of constant 2000 U.S. dollars. Information for real GDP was collected for the years 1990 and 2000 for all twenty-five countries. Next, data was collected on the capital stock according to the perpetual inventory method for the years 1990 and 2000. The methodology behind this procedure will be explained in greater detail when discussing the construction of the capital stock variable later in this subsection. Finally, labor force information was taken from the dataset provided by Docquier, Ozden, and Peri (2010). Now in order to calculate TFP growth one final piece of information is needed to be decided upon: the value for the capital share. Values of the capital share vary, but in this thesis the capital share is set to 0.33. This value is also supported by Jones (2008) as can be seen on page 24 and has been utilized by
numerous studies including Gollin (2002), Hall and Jones (1998), Ortega and Peri (2009), and Young (1995). In setting the capital share to be 0.33, the labor share has been effectively set as well. Namely, it is one minus the capital share (as the production function exhibits constant returns to scale and is in a Cobb-Douglas format), which is simply 0.67. Using the above information, the growth rate of total factor productivity was calculated for the years 1990 to 2000 and is labeled $GTFP$ in the regressions.

The capital stock of a country is an aggregate that accounts for the entirety of a country’s capital currently in use. This variable plays a major role in macroeconomic research, but data on this topic is not readily available. There are several reasons why data on this subject is sparse, which Paul Schreyer and Colin Webb from the OECD describe. Firstly, only a limited number of OECD countries publish capital stock data on a regular basis. Secondly, comparing capital stocks across countries is uncertain. Finally, there are different ways of computing the capital stock with each computation designed for a specific usage (Schreyer and Webb 2006, 1). With this in mind, any scholar working with the capital stock must decide what measure is best suited for their research.

Bosworth and Collins (2003) note that there are two approaches to measuring the growth of the capital stock, either to use a proxy created by using the investment rate (Investment divided by GDP) or to construct a measure of the capital stock. The first method involves this equation such as can be found on page 125 of Bosworth and Collins (2003):

$$\Delta \ln K = \frac{I}{Y} \frac{Y}{K} - \delta$$
Here the growth rate of the capital stock is equal to the investment rate, \( \frac{I}{Y} \), multiplied by the capital-output ratio, \( \frac{Y}{K} \), all minus the depreciation rate, \( \delta \). In this method a constant capital-output ratio is assumed, so that the only variation in the growth rate of the capital stock is generated by the investment rate. This method was utilized in Mankiw, Romer, and Weil (1992). Bosworth and Collins (2003) note that the advantage of this approach eliminates the “measurement problem” of how to initialize the capital stock (125). However, this approach is not without its disadvantages; Bosworth and Collins (2003) state that a constant capital-output ratio is a strong assumption.

The other approach to calculating the growth rate of the capital stock is to construct a measure of the capital stock itself. This can be done in many ways, and the method utilized in this thesis and described here is that of the perpetual inventory method with geometric depreciation. This method is supported by Hulten (2009) and is employed by Bosworth and Collins (2003), Ortega and Peri (2009), and Young (1995). The reason this method is used over the investment rate approach is due to the fact change in the capital stock is “the better measure of the contribution of capital to output growth” (Bosworth and Collins 2003, 126). The key to this method is to understand how the capital stock grows. According to the perpetual inventory method, the capital stock is equal to the capital stock in the preceding period plus investment minus depreciation of the capital stock in the preceding period. An equation for this is given in Bosworth and Collins (2003):

\[
K_t = K_{t-1} + I_t - \delta * K_{t-1}
\]
With this equation, two more questions need to be answered to calculate a value for the capital stock. One, how does one initialize the capital stock and two, what depreciation rate does one use? To answer the first question, this thesis uses the same approach as in Ortega and Peri (2009) and Young (1995). This technique assumes “that the growth rate of investment in the first five years of the national accounts investment series is representative of the growth of investment prior to the beginning of the series” (Young 1995, 651 – 652). Young (1995) writes this in terms of an equation, namely:

\[ C_j(0) = \sum_{i=0}^{\infty} I_{j,i-1} (1 + \delta_j)^i = \sum_{i=0}^{\infty} I_{0,j} (1 - g_j)^{-i-1}(1 + \delta_j)^i = \frac{I_{0,j}}{g_j + \delta_j} \]

where “\( I_{0,j} \) is the first year of investment data for asset \( j \), \( \delta_j \) is the depreciation rate for asset \( j \), and \( g_j \) is the average growth of investment in asset \( j \) in the first five years of the investment series” (Young 1995, 652). In this thesis, aggregate investment is used, which simplifies this equation to:

\[ C(0) = \frac{I_0}{g + \delta} \]

Such that the capital stock at time zero is equal to investment at time zero divided by the growth rate of investment in the first five years of the series plus depreciation. In accordance with Ortega and Peri (2009), investment data (in thousands) was collected from the Penn World Tables (PWT) Version 6.3 and the capital stock was initialized in 1970 for most countries. Due to the absence of investment data for some countries the capital stock was forced to be initialized at a later date. These countries include Portugal and Slovakia, which were initialized in 1990 and 1987, respectively.
To answer the second question on how to calculate the depreciation rate, this paper again uses a method similar to Ortega and Peri (2009) and Young (1995). Geometric depreciation rates of various assets were taken from Hulten and Wykoff’s (1981) table 2 and Jorgenson and Sullivan’s (1996) table 9.1. Next, the unweighted average of every asset in the two studies combined was calculated and used as the aggregate depreciation rate. This technique is used by both Ortega and Peri (2009) and Young (1995). Under the best conditions, a weighted average should have been calculated so as to account for the relative amount of assets used by each country. As the amount of each asset used varies from country to country, so would the aggregate depreciation rate. However, data on this topic is not readily available through most online databases, which makes such a calculation excruciatingly difficult. Fortunately, Young (1992) and Young (1995) show that results are not sensitive to moderate changes in the depreciation rate, which justifies the use of an unweighted average.

As mentioned above, this thesis uses the perpetual inventory method with geometric depreciation to calculate the capital stock for 1990 and 2000. This was done as it is believed to be the best measure to capture capital’s input to output growth. The capital stock was estimated for all 25 countries in the study. This variable is labeled $GKS$ in the regressions.

The last variables in the set of growth accounting variables lie within the domain of the labor supply. Due to formulation of the production function, this thesis called for data that disaggregated the native and migrant labor force according to its skill level (here skill and education level will be used interchangeably).
Unfortunately, this data has not been widely collected by any of the main databases, including the OECD International Migration database, the United Nations migration statistics, or the World Bank database. Many sources publish data on migrant flows to the receiving country, but as Docquier, Ozden and Peri (2010) point out, there are several flaws with this data that make it inappropriate for use in a study such as this thesis. Docquier, Ozeden, and Peri (2010) argue that these migrant flows do not account for migrants who return to their country of origin or illegal immigrants, do not define migrants the same across countries and, most importantly, do not include data on the education level of the migrants.

Although data of this nature would benefit many economists in different fields, including but not limited to research on the phenomenon known as “brain drain” as well as migration and globalization, this data has only been recently made available. This thesis uses a dataset created by Docquier, Marfoulk, Ozden and Parsons (2010), who have constructed bilateral measures for both immigrant and emigrant stocks for 195 countries covering the years 1990 and 2000. This dataset disaggregates the native, immigrant and emigrant stock of each country based on their education level and accounts for many of the flaws found in the migrant flows published by many statistical databases. An individual’s skill level is defined as follows, those with a college degree, or equivalent thereof, are considered to have high-skill while those with a high-school degree or less, or the equivalent thereof, are considered to have low-skill. This dataset was only made public in December of 2010 and, thus, is on the cutting edge of this literature. It updated and improved upon the datasets set forward by Docquier, Lowell, and Marfoulk (2009) and Docquier and
Marfoulk (2005). Because this dataset is so new data could only be collected for the years 1990 and 2000. As time goes on and demand for this type of data is shown, it is certain that this dataset will be expanded upon. For now though, one must work with the data that exists, which is why the dataset for this thesis is seemingly small. This dataset provides information on the levels of each disaggregate of the labor force (in thousands) specified by the nested CES production function which are then used to calculate the growth rates of each labor force input.

Due to the fact that this dataset divides native and immigrant workers by their skill level, it is unnecessary to include an additional measure of human capital to account for the production function used by the Augmented Solow Model. As can be seen in Barro and Lee (2010), the human capital stock looks to capture the educational composition of each country. This can then be made into a stock by multiplying the percent of individuals of a specific educational attainment by the total number of citizens in a population. This was done by Barro and Lee (2010), who showed that their stocks of educational attainment were arguably the best measures of human capital that far exceed those who use enrollment rates to proxy for the human capital stock. Barro and Lee (2010) point out that although data on enrollment rates are “widely available, these data do not adequately measure the aggregate stock of human capital available contemporaneously” (1). Barro and Lee’s earlier studies (1993, 1996, and 2001) have been cited 740 times by February 2010 according to the Social Science Citation Index. Thus it can be seen that Barro and Lee’s (2010) measure of the human capital stock is widely considered to be a very strong measure. The dataset compiled by Docquier, Ozden, and Peri (2010) follows a similar method
and creates stocks of the labor force decomposed by their educational attainment. Thus, adding another variable for human capital, like that of Barro and Lee (2010), would be redundant and add bias to the results.

For the 2SLS and SEM regressions it was necessary to calculate the share of both high and low-skilled immigrant stocks. This was done by taking the share of each immigrant stock, mainly \( \frac{N_{FH}}{N} \) and \( \frac{N_{FL}}{N} \), and applying growth accounting techniques which returned the following equations: \( \tilde{N}_{FH} - \tilde{N} \) and \( \tilde{N}_{FL} - \tilde{N} \). It was from these equations that the growth rate of the immigrant share was calculated for the years 1990 to 2000.

In the regressions, \( GnativeH \) stands for the growth rate of the high-skilled native workforce. \( Gnativel \) stands for the growth rate of the low-skilled native workforce. \( Gimmih \) stands for the growth rate of the high-skilled immigrant workforce. \( GISh \) stands for the growth rate of the high-skilled immigrant share and, finally, \( GISl \) stands for the growth rate of the low-skilled immigrant share.

\section*{V.4 Other Confounding Factors}

Another important confounding factor that has been shown to influence economic growth and wages is globalization. Betrán and Pons (2004) show that an increase in globalization, due to an increase in trade or migration, leads to an increase in wage inequality between skilled and unskilled workers. Here, globalization is accounted for by including variables that measure openness to both trade and migration as was done in Betrán and Pons (2004). Following Betrán and Pons (2004), openness to trade has been constructed using a simple ratio, trade over GDP. Other studies have shown that an increase in trade has implications for wages. One of
such studies is that of Krugman (2008), who found that increased importation led to an increase in wage inequality in the United States and other developing countries. Data on this variable was collected from the OECD database for all 25 countries for the years 1990 and 2000. Hungary and Slovakia did not have trade data for the year 1990 and so the next closest year was accepted, which was 1991 and 1993 respectively. The growth rate of this ratio was calculated for the years 1990 and 2000 and is labeled $GTRADE$ in the regressions.

The next variable, which measures openness to migration, is the second of the two measures which captures the effects of globalization. The variable has been created using the same methodology as Ferrieri (2005). This measure goes beyond using the simple ratio to measure openness, as was done for international trade as it takes not only a country’s weight in the given topic but also compares each country’s degree of openness relative to the country with the maximum degree of openness for the topic in the world. Mathematically, this index is calculated as given by Ferrieri (2005) on page 247:

$$Index = \left( \frac{V_i}{V_{MAX}} \right)^{(1-\zeta)-(1-\eta)}$$

Where $V_i$ is the value of the immigrant stock-to-population ratio for country $i$, $V_{MAX}$ is the maximum value of the immigrant stock-to-population ratio in any country over time, $\zeta$ is ratio of a country’s immigrant stock relative to the world immigrant stock and, finally, $\eta$ is the ratio of a country’s population relative to the world population. Ferrieri (2005) devised such a measure in order to capture both the “capacity effect” and the “size effect.” The “capacity effect” is the result of the fraction $\frac{V_i}{V_{MAX}}$, whereas
the “size effect” takes into account “the share of each country in the world aggregates concerned” (Ferrieri 2005, 247). In this manner the index was calculated for the years 1990 and 2000. Data for $V_i$ was taken from the World Bank. The value for $V_{\text{MAX}}$ was set to 77.2 percent which was the value of the immigrant-to-population ratio (in terms of percentage) for the United Arab Emirates in 1990. This value was also used by Ferrieri (2005). In order to create $\zeta$, data was collected on the immigrant stock from the World Bank and the Migrant stock was supplied by the United Nations Population Division. In order to create $\eta$, data on each country’s population level was taken from Barro and Lee (2010) and the world population was supplied by the OECD. Once the index was constructed for 1990 and 2000 the growth rate was then calculated. The variable is labeled $GMIGOPEN$ in the regressions.

Betrán and Pons (2004) also include variables that account for each county’s ability to respond to globalization. In this thesis, variables that account for immigration policy changes are being added to the model in order to capture a government’s interaction with the growing trend of globalization. Two measures for immigration policies have been included in this thesis. The first measure is an index used to account for the severity of immigration laws on the entry of new immigrants into the country. This index was first proposed by Ortega and Peri (2009). In calculating this index, a negative one was added to the index whenever an immigration policy was adopted that “loosened” entry laws, i.e., any policy that lowered requirements for entry or allowed for more immigrants to enter the country. Conversely, a positive one was added to the index for any policy that was seen to
“tighten” entry laws, i.e., any policy that increased requirements or lowered their immigrant quota. The index calculated by Ortega and Peri (2009) is used in this thesis, but their indexes do not cover every country in this study. In this light, this thesis used the work of Mayda and Patel (2004), who created a resource that includes the migration policies decided upon by many developed countries and the years these policies were put into place, to extend the index for the remaining countries in this study. Unfortunately, Mayda and Patel (2004) did not include any policy information on Korea and so the index was set to zero for every year. Now the index has been calculated for the years 1990 and 2000, and like the other variables it is necessary to find the growth in this variable to see how it explains the growth of wages. Unfortunately, the index is set to zero in many instances for the year 1990, and thus using a growth formula like \( \frac{B-A}{A} \), where B is the value in the second period and A is the value in the first period, would be impossible as one cannot divide by zero. Thus, to rectify this problem the change in the index was recorded and will be utilized instead of the growth rate. Here, the change in the index has been labeled CHTIGHTNESS in the regressions.

The final measure used to control for immigration policy is a dummy variable designed to account for the Maastricht Treaty. The Maastricht Treaty was a treaty signed by many European Union members that facilitated free labor mobility to all countries who signed the agreement and, as Ortega and Peri (2009) note, it led to the introduction of the Euro which may have led to decreased costs of migration within the member states. The Maastricht Treaty was signed in 1992 and thus the dummy variable, labeled MAASTRICHT, was set equal to one for all countries who signed the
treaty and zero otherwise. This variable is included in the study, as it was found to be statistically significant by Ortega and Peri (2009), thereby showing that the Maastricht Treaty has played a significant role in the decision of migrants in leaving their native country.

Another confounding factor that is controlled for in this model is that of the unemployment rate in a given country. This has been done in order to account for any business cycle fluctuations that may affect economic growth and GDP. Data on unemployment rate were taken from the OECD. The OECD database did not have information for every country and thus data was also collected from the World Bank and from the United Nations. The unemployment rates for Austria, Poland, Slovakia, and Switzerland were taken from the World Bank whereas the unemployment rate for Hungary in 1990 was taken from the United Nations. Here, the unemployment rates are defined as the percentage of the labor force that are unemployed and looking for work. As this variable is already in percentage terms, the change of the unemployment rate was calculated for the years 1990 to 2000 and is labeled as $\textit{GUNEM}$ in the regressions.

\section*{IV. Results}

After running the regressions, the following results were found. Three sets of regressions were run using different techniques. The first technique is that of Ordinary Least Squares (OLS), where the immigrant share is assumed to be exogenous. Eight regressions are run using this technique, each accounting for various other factors that affect economic growth, immigration and wages along with
the growth accounting variables. The second technique is that of Two Staged Least Squares (2SLS), where the growth rate of the high and low-skilled immigrant share for 1990 to 2000 is instrumented with the high and low-skilled immigrant stock in 1990, as was done in Altonji and Card (1991) among others. Four regressions are run using this technique, each accounting for various factors that affect economic growth, immigration and wages in addition to the growth accounting variables. The final technique utilized is that of the Simultaneous Equations Method (SEM). Four regressions will be run using this technique which implement the same IV for the immigrant share will be used as in the 2SLS approach. This will account for the potential simultaneity between wages and the immigrant shares. In all, sixteen regressions were run; the results from the regressions can be found in Tables B.1 through B.5 in the appendix.

Let one first examine the results from the regressions using the OLS technique. In the first regression considered, labeled OLS1 in table B.1 of the appendix, only the growth accounting variables are accounted for in determined wage growth. Here, three variables are found to be statistically significant, $GTFP$, $GKS$, and $GIMMIL$, at the 5 percent, 1 percent and 10 percent levels, respectively. Along with the significant variables, it is important to note that the coefficient of every variable corresponds with their predicted sign from the economic theory. Both total factor productivity and the capital stock have a positive coefficient. This is intuitive as increasing both T.F.P and the capital stock means that an economy is becoming more capital intensive in their production. In this case, capital may be substituted for labor, in which case one would expect wages to increase as the labor supply
diminished. Of course, this regression is a *ceteris paribus* and so it is assumed that the coefficients of the capital stock and TFP are interpreted such that the labor supply remains constant. However, it is not unreasonable to think that capital would be substituted for labor in a more capital-intensive economy and therefore this story provides answer as to why the capital stock and TFP have positive effects on wage growth.

The coefficients on all of the labor supply variables also correspond to the economic theory of both the “size” and “composition” effects. The coefficient on the total labor force variable is decidedly negative which is consistent with the “size” effect. While not significant, the “size” is determined to be roughly a 4.5 percent decrease in wages if the labor force, while maintaining its educational and immigralional composition, were to increase by 10 percent. The “compositional” effects are also upheld. Both *GNATIVEH* and *GIMMIH* have positive coefficients, whereas *GNATIVEL* and *GIMMIL* have negative coefficients. It can be seen that increasing the growth rate of low-skilled immigrant share by 10 percent will decrease average wage growth by approximately 1.1 percent. Conversely, increasing the growth rate of high-skilled immigration by 10 percent corresponds to a 0.6 percent increase in average wage growth.

A White Test, testing for heteroskedasticity, was carried out and returned a P-value of .4508, which indicates that the null hypothesis of homoskedasticity cannot be rejected. In this light we reject the presence of heteroskedasticity in the model. Because of the small sample size in the regression and the notion that in the absence of heteroskedasticity, OLS t statistics have exact t distributions, and so including
heteroskedasticity robust standard errors in the regression would cause an error in the variance of the variables. Therefore, a regression with robust standard errors is not included. A White test was also carried out for every other regression which used the OLS technique and every test returned insignificant P-values. Thus, it is concluded that heteroskedasticity was present in none of the regressions and that the reported t statistics are valid, assuming that immigration is exogenous.

Regression OLS2 in table B.2 of the appendix now includes the measures accounting for the effects of globalization. These variables measure the openness of each country to both trade and migration. GTRADE is significant at the 5 percent level and has a negative coefficient. The effect of trade on wages depends on what is being traded. If the goods that are being traded are capital intensive, then one should see the openness to trade variable as having a negative effect on wages as was seen in Krugman (2008). The sample of countries in this study are all members of the OECD and, therefore, it is assumed that they all partake in the trade of capital intensive goods and thus the coefficient of GTRADE should be negative. This assumption is verified by the results. GMIGOPEN can be seen as the variable that captures a country’s openness to trade of labor intensive goods, mainly labor itself. Thus, just as the coefficient of GTRADE is expected to negative, the coefficient of GMIGOPEN is expected to be positive. The results verify this expectation; however, GMIGOPEN itself is not significant. The coefficients and significance levels of the other variables remain roughly unchanged from OLS1, except for both GIMMIH and GIMMIL become more statistically significant, reaching the 5 percent level, which means that
as more of the wage variation was explained, the more significant the immigration variables became.

The next regression, labeled OLS3 in table B.1 of the appendix, includes measures of immigration policy to the regression which correspond to each country’s reaction to globalization as well as accounting for a change in the migration landscape. These measures influence the number and type of immigrants allowed to enter each country and thus need to be accounted for as they affect the key explanatory variables. The two variables which account for immigration policy are that of CHTIGHTNESS and MAASTRICHT. Both are found to be significant at the 10 percent level and have negative coefficients. These results are in accordance with Ortega and Peri (2009). This result verifies the theory, the reason why is as follows. The coefficient of MAASTRICHT is saying that wage growth is lower in countries who signed the Maastricht Treaty and higher for those who did not. Intuitively, this makes sense, as the Maastricht Treaty was implemented so that there would be free labor migration between the countries who signed it. Thus, the Maastricht Treaty can be seen as allowing the number of immigrants of the signing countries to increase which exerts a downward pressure on wages.

It can be seen that immigration policies directly affect immigration, and therefore indirectly affect wages. In this light, both of the coefficients of MAASTRICHT and CHTIGHTNESS variable can be interpreted using the “size” affect, just as the immigration variables are. Interpreting the coefficient of CHTIGHTNESS, one can see that as the variable increases by one, it decreases wage growth by 2.6 percent. This can be seen due to the fact that entry laws are becoming
stricter but immigrants are still allowed to enter the country and therefore increase the size of the labor force. Because the entry laws are becoming tighter, CHTIGHTNESS can be seen as having a smaller “size” effect when compared to MAASTRICHT which explains why MAASTRICHT has a more negative coefficient. Another interpretation of these coefficients includes the idea that these variables may be picking up the domestic sentiment toward immigrants as is noted by Hatton (2010). Thus, as policies become stricter, the attitude towards immigration is believed to become harsher, which may result in the lowering of wages paid to immigrants in order to provide a disincentive to migrate.

Overall, this regression, OLS3, returned the largest adjusted $R^2$ term of 0.7235, which is slightly lower than the results of Mankiw, Romer, and Weil (1992), who showed that the Solow model explained nearly 80 percent of economic growth. The inclusion of the immigration policy had a huge, beneficial effect on the significance of the other variables in the model. TFP, capital stock, low-skilled immigrant and openness to trade growth all increased in significance to the 1 percent level. The growth of high-skilled immigrants remained at the 5 percent significance level. As the significance of TFP growth increased its impact on wage growth did as well. The “size” effect decreased in size (became less negative). The “compositional” effects of native workers also decreased in relative magnitude, while the “compositional” effects of immigrant workers increased. It is important to note here that the coefficient for the growth of the low-skilled native supply is no longer negative, but rather a 10 percent increase in its growth leads to a 1.4 percent increase in average wage growth. This contradicts the theory which states that as low skilled
labor increases, there should be a downward pressure on wages. The reason as to why this coefficient has become positive may lie within the concept of labor productivity which had been dropped from the equation up until this point. It is assumed that low-skilled native workers are more productive in their work in comparison to low-skilled immigrant workers. In light of this, these native workers have the ability to ask for a higher wage in comparison to low-skilled immigrant workers to compensate them for this increase in productivity. Thus it can be seen that as the low-skilled immigrant share decreases and the low-skilled native share increases this has the potential possibility of actually increasing wages.

Moving to regression OLS4 in table B.1 of the appendix, this regression includes a measure of the change in the unemployment rate to account for business cycles in a country. With the inclusion of this variable, the adjusted $R^2$ term immediately drops to 0.7098. The immigration policy variables become insignificant and the growth of low-skilled immigrants drops to the 5 percent significance level. None of the coefficients have changed in sign and the magnitudes have all remained roughly the same in comparison to OLS3. It is important to note that CHUNEM is insignificant and its coefficient is really small. Here, it appears that the change in the unemployment rate has no affect on wages and its inclusion in the model causes there to be severe bias on the other explanatory variables. This result appears to be in accordance with the Keynesian notion of sticky wages. Here, the data is illustrating that when an economy is in a time of recession and the amount of unemployed individuals rises, one will witness no effective change on wages. It appears that rather than lowering wages, companies will choose to lay off workers instead. This
effectively gets the “misery out of the door” rather than having employees grumbling over pay cuts (Bewley 1999, 16). This coincides with the findings of Bewley (1999) who conducted a survey of more than 300 “business people, labor leaders, counselors of the unemployed, and business consultants” (1).

The next four regressions are carried out using instrumental variables and the 2SLS technique in order to account for the potential endogeneity of the immigrant share. These regressions use the immigrant stock of high and low-skill in 1990 as an instrument for the growth of high and low-skilled immigrant share from 1990 to 2000, as was explained in section IV. A similar method was used in Altonji and Card (1991). It is important to note that $R^2$ and adjusted $R^2$ terms have been included in table B.3 but will not be used to compare the measure of fit between 2SLS and OLS regressions as the $R^2$ cannot be interpreted as a fitting measure for the 2SLS case.

The first 2SLS regression run is similar to regression OLS1 in which it only includes the growth accounting variables. This regression is labeled IV1 in table B.3 of the appendix. The results from this regression are slightly different than those of OLS1. The only variable that is statistically significant is the growth rate of the capital stock, which is significant at the 1 percent level. All of the variables have maintained their expected signs, however some of the magnitudes are of the coefficients differ. The impact of the low-skilled natives is now measured at negative 0.3405 which is much

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2 Four more OLS regressions were run that excluded the variable $GLF$. This was done so as to account for wage growth exactly as it was represented by the marginal product of labor from the Solow model production function. The results from these regressions can be found in table B.2 of the appendix. The results found in these regressions strongly support those regressions which included GLF. This speaks to the robustness of the findings and strengthens their implications. Again, White Tests were run to check for any heteroskedasticity in any of the regressions in table B.2 of the appendix, but none were found and therefore the reported t-statistics are accurate.
higher than what it was in OLS1. This has the same effect on low-skilled immigrants as well.

The next regression, labeled IV2 in table B.3, adds the proxies for globalization. Again, the results are similar to OLS2, however $GIMMIH$ and $GIMMIL$ remain insignificant. Here the significance level of $GTFP$ has increased to the 1 percent level, along with $GKS$, which is more significant than it was in OLS2. $GTRADE$ is also recorded as being significant at the 5 percent level, which remains consistent with past results. Regression IV3 includes the immigration policy variables and again the results are similar to those of OLS3, except the immigrant shares remain insignificant. The openness to trade variable has now become significant at the 1 percent level while the immigration policy variables are significant at the 5 percent level, which is more significant that they were in OLS3. It is also important to note that the sign of the low-skilled native workers has remained negative, which is in contradiction to the results from OLS3. It is also interesting to notice the significance levels of the immigrant shares. $GIMMIH$ has a P-value of 0.184, while $GIMMIL$ has a P-value of 0.130. One can see that these variables are nearly significant at the 10 percent level. A more in depth discussion on the significance of these P-values will be carried out after the final regression has been explained.

The last 2SLS regression is labeled IV4 in table B.3 in the appendix. It includes the variable of the change in the unemployment rate in order to account for business cycles. The inclusion of this variable had similar effects on IV4 as it did on OLS4. Both of the policy variables became insignificant and the significance of the
institutional proxy variable decreased to the 5 percent level. Again, \textit{CHUNEM} is found to be insignificant and to have a very small coefficient which once more is supported by the findings of Bewley (1999).

What do all of these 2SLS regressions mean? Looking more closely at the results it becomes clear that there is weak evidence that the immigrant share is endogenous in this sample. This conclusion has been reached for several reasons. The main reason for this frame of thinking comes from the results found in regression IV3. Recall that the immigration policy variables were significant at the 5 percent level. Now, as was mentioned earlier, it is clear that immigration policies are designed to affect immigrants and not wages and that the policies’ affect on wages was indirect. However, the indirect effect of the policies on wages is being found as significant in this regression, but what about the direct effect? Here, the variables for the immigrant share of both high and low-skilled labor (this is the direct effect of immigration on wages) were found to be insignificant, although just barely as the P-values were recorded at 0.184 and 0.130. The reason why only the indirect effect, and not the direct effect, was found to be significant could lie within the formulation of the 2SLS parameters. As was mentioned in section IV, the variance of the IV parameters is larger than those of OLS when OLS is valid, and therefore the variables were not endogenous. If this was the case, and OLS were valid, then the use of 2SLS would have major consequences on the IV estimators. In IV3, if OLS is valid then the iv estimators of \textit{GISH} and \textit{GISL} would have calculated variance that is much greater than the true model states. This added variance would decrease the significance of the IV’s and potentially cause the variables to appear insignificant.
when in actuality they really should be. This scenario is believed to have been what happened to cause the direct effect of immigration to appear irrelevant in describing wage growth. This hypothesis was tested by running Durbin and Wu-Hausman tests to check for endogeneity of the immigrant share in every single 2SLS regression run. The results of each test came back that one could not reject the null hypothesis of exogeneity. This is in accordance with Aydemir and Borjas (2010); Borjas, Freeman, and Katz (1997); Longhi, Nijkamp, and Poot (2005); and Mankiw (1995). The results of these tests further support the idea that there is weak evidence for the endogeneity of the immigrant share in this sample and therefore the regressions should be run using OLS.

The results from the SEM regressions reinforce the findings that evidence for the endogeneity of the immigrant shares in this sample is weak. A comment is necessary before each regression is analyzed. It can be seen that the best method to compare these regressions is their log-likelihood value. This value is typically a negative number and the larger (less negative) the number gets the better it describes the dependent variable. In this case, however, the log-likelihood values are positive. This may seem peculiar at first and indicative that the regressions are inaccurate. However, because these values are rare does not mean they are wrong. It is perfectly acceptable to obtain positive log-likelihood values and they are interpreted the same as their negative counterparts.

Let one begin by looking at the regression labeled SEM1 in table B.4 of the appendix. In this regression wage growth is regressed on the growth accounting variables and the openness to trade measure, while the immigrant shares are regressed
on all of the explanatory variables except for the measure of trade openness. One can see that the results from the wage regression are similar to those found from the OLS and 2SLS methods. All of the coefficients have their expected sign, including the labor aggregates and the similar variables are significant. $G_{TFP}$, $G_{KS}$, and $G_{TRADE}$ are all significant at the 1 percent level, while $GNATIVEL$ and $GISL$ are significant at the 10 percent level. In this case this regression is stating that low-skilled labor has the greatest effect on wage growth. As for the immigrant share regressions, wage growth (the explanatory variable of interest) is not significant and the only variable that is significant in both immigrant share regressions is that of $GMIGOPEN$, which is significant at the 1 percent level. For the high-skilled immigrant share, the growth rate of high skilled natives is significant at the 10 percent level and has a negative coefficient, which is a signal that native worker growth drives away immigrants. However, growth of wages has a negative coefficient and the growth of TFP does as well, which makes one consider that the growth of the capital stock and TFP do not affect immigrant share growth. This idea is supported by the study of Ortega and Peri (2009), who do not include these measures in their study of migration flows.

Thus in the second regression, SEM2, these two growth accounting variables are removed. The results from this regression were similar to those of SEM1. The regression for wage growth remained the same in terms of the signs on the coefficients. $GNATIVEL$ became insignificant while $GISH$ gained significance at the 10 percent level. The openness to trade variable dropped in significance to the 10 percent level. As for the immigrant share regressions the results stayed relatively the
same with one change, GNATIVEH grew in significance to the 5 percent level. The growth of wages remained insignificant for both immigrant shares.

In the third SEM regression, labeled SEM3 in table B.5 of the appendix, which includes the institutional quality proxy in all of the three regressions, and regression SEM4 in table B.5 of the appendix, which takes omits the native workers of the opposite skill-level in each of the immigrant share, both report results similar to those of regression SEM1 and SEM2. The robustness of the wage growth regression results continue to make themselves evident as the significance and coefficients of the key explanatory variables (i.e. the growth accounting variables) have shown to be strong no matter what various other factors are accounted for in the model. The results from the immigrant share regressions also seem to be robust in illustrating that only the growth in labor market quality is a significant variable for both shares, while high-skilled natives were consistently significant in the high-skilled immigrant share regressions. In all four SEM regressions, wage growth was not a significant variable in explaining the growth rate of either immigrant share, while the wage regressions again showed their robustness in providing stable results that were similar to OLS estimates. In light of this fact, it has been concluded that this provides evidence that the argument that the immigrant share is endogenous based on the fact that they are attracted to higher wages appears to be weak in this sample of countries and time periods. This coincides with the result from the 2SLS regressions, which found all of same variables to be significant in comparison to the OLS estimates, except for the immigrant shares which was due mainly to a high reported variance. The fact that evidence in this sample is weak does not mean that wages do not affect immigrants to
migrate. Rather, it shows that the best and most appropriate technique to account for immigrations’ affect on wages is that of Ordinary Least Squares in this case.

V. Globalization of Labor

With the results from the regressions in hand, one can now turn to the growing debate over whether there should be free labor mobility. Most of the work in the immigration literature has been in opposition to the globalization of labor and it wasn’t until Lant Pritchett came out with his book titled Let Their People Come in 2006 that the debate took full force. In truth, the debate is still young and has not reached its climax with many academics weighing in on either side. However, as time ensues and as more research has been carried out, Pritchett has rallied some supporters and the debate is growing.

The argument for the globalization of labor is similar to the argument made in support of free trade. To illustrate this, let one look at a simple graph of one good, with price on the y-axis and quantity on the x-axis. The graph is of the demand and supply for that good in the domestic market of one country (here the specific country is of no importance and therefore will go unnamed) which is open to free trade. This graph can be found in table C.2 of the appendix. On this graph it can be seen that the equilibrium exists when supply equals demand. Formally, this occurs at point \((P_A, Q_3)\). This is the equilibrium for the country if it were in a closed economy. If trade is allowed to occur, one can see that this country can import this good from the rest of the world at the world market price, labeled \(P_W\). For the sake of this example, let \(P_W\) be below \(P_A\), which would incentivize consumers to buy imports of this good (it is
equally likely that $P_W$ is above $P_A$, in that case the country would export the good).

Here, consumers choose consume at quantity $Q_5$ while producers only supply $Q_1$—the difference is made up by importing from abroad. Here, it can be seen that producers lose regions B and E to consumer surplus. It is also important to note that regions C, F, G, L, and M are domestic resources that are no longer being utilized in the production of the good. These resources include capital, like plants and equipment, but it also includes workers. Therefore, when free trade is introduced, some domestic workers lose their jobs if the free trade price is below the domestic equilibrium price.

In order to combat this, countries have devised protectionist policies in order to safeguard domestic markets. One example of a protectionist policy is that of a tariff put on an imported good. The idea is to place a tax, of size $t$, on each imported good, thus raising the cost of importing to that country. In doing this, it effectively raises the world market price to $P_{W+t}$. Now, consumers choose to consume $Q_4$ and producers increase production to $Q_2$. This results in producers gaining region E in surplus while regions F and L are now domestic resources now utilized in the production of the good. Regions F and L include capital but it also includes jobs that have now been created (or rescued, depending on the point of view) in the domestic market as a result of the protectionist policy. It is from this result that these policies were given the name protectionist policies as they defend the domestic job market. The Government benefits from this policy too as it gains regions G and H in tax revenue. But note that regions F and I, which used to be a part of consumer surplus when there was free trade, is no longer attributed to any domestic participant in the economy. These regions are known as dead weight loss (DWL) and it is because
these regions exists that proponents of free trade argue in favor of the globalization of trade because surplus is maximized, i.e., there is no dead weight loss. In opposition, academics argue in favor of protectionist policies because of their ability to maintain domestic resources and jobs. It can be seen that this argument comes down to which should be valued higher: to maximize domestic and global surplus or to protect domestic jobs, resources and some might say traditions?

The argument for the globalization of labor is quite similar to that of the debate over free trade and ultimately it boils down to a similar question: is it more important to maximize global income or to protect domestic wages, jobs and resources? Pritchett (2006) argues that international mobility will strengthen global welfare and admits that there will be “winners and losers in rich countries” but notes this is the case with most economic policies (2). In the case of the example given above, producers clearly won from the protectionist policies, while consumers lost. In this case, rich countries would suffer while less developed nations would benefit, and the reason rich countries should buy into such a policy is that “it is the right thing to do” according to Pritchett (2006). Pritchett is not alone in his argument. Hanson (2008) agrees that free labor mobility “improves the allocative efficiency in the world economy” (35). In summarizing Pritchett’s (2006) argument, DeParle (2007) writes “if goods and money can travel, why can’t workers follow? What’s so special about borders?” Well, it seems that borders do matter to those that live inside of them. DeParle (2007) also includes a list of arguments made against free labor mobility such as “an army of guest workers would erode Western sovereignty, depress domestic wages, abet terrorism, drain developing countries of talent, separate poor
parents from their kids and destroy the West’s cultural cohesion.” Thus, it can be seen that, like in the debate over free trade, it comes down to which point of view is the most appropriate. Those opposing the globalization of labor argue that policies should be made with the current citizens in mind, as in Borjas (1999) where as those in favor of free labor mobility should focus on the poor citizens of less developed countries and work toward maximized global welfare, as in Pritchett (2006).

In light of this “policy deadlock,” as he calls it; Pritchett (2006) has devised a proposal that he feels will be agreeable to both parties (2). Pritchett (2006) cites a World Bank study (2005) that estimated the effects of a hypothetical event in which rich countries allowed a 3 percent rise in their labor force through the acquisition of low-skilled labor from less developed nations, then poor country citizens would realize gains of $300 billion. The study went on to add that the cost to rich countries would actually result in a gain of $51 billion. In this scenario, it is a win-win situation for both parties involved. Poor country citizens are allowed to earn higher wages while developed countries citizens who expect a loss will in actuality receive a gain. DeParle (2007) describes Pritchett’s (2006) proposal in more detail as it differs slightly from the study by the World Bank (2005). DeParle (2007) writes that increasing the rich nations’ labor force by 3 percent would result in an influx of 16 million workers. The workers are only to be given temporary status so as to compromise with those who oppose the proposal, and the workers from the poor countries would constantly change over the 3 to 5 year period so as to maximize the amount of the less developed nations’ citizens affected by this policy.
Up until this point there have not been many studies that have been conducted on international migration. As Hanson (2008) notes, “the literature does not allow one to do much more than make presumptions,” as “there remain many unknowns in evaluating migration’s impact” (35). This thesis now presents a method of calculating the cost of immigration on developed countries, a similar set of countries that Pritchett (2006) proposes accepts the world’s poor, and this method does not depict as beneficial an impact as Pritchett (2006) describes. The following estimates are taken from regression OLS3. Pritchett (2006) assumes that all of the immigrants from less developed countries are low-skilled workers. Thus it can be seen that this immigration will have both a “size” effect and a “compositional” effect. In terms of the size effect, if each country’s labor force grew 3 percent, yet its composition stayed the same, then they would experience a decrease in average annual wages of 1.19112162 percent. If it is assumed that all of the immigrants increased the low-skilled immigrant share but kept the labor force the same, then the country would experience a decrease in annual average wages of 0.54748176. Adding these two effects will give one the upper bound for wage growth decrease, while the lower bound will be set to the value of the “size” effect. This gives one the range that wage growth could decrease anywhere from 1.73860338 to 1.19112162 percent. This result clearly shows that countries will experience a loss in average annual wages if Pritchett’s proposal is accepted, which is in opposition to the figure that citizens of developed countries will experience a net gain of $51 billion.

The purpose of this study and of the analysis of Pritchett’s (2006) proposal is to show that the evidence suggests that immigration, especially immigration of low-
skilled workers imposes a cost on each country’s current residents. In this study the cost is measured in the loss of the growth rate of average annual wages. The results from this regression do not argue in favor or against a certain immigration policy over another, rather they just offer a technique to measure the cost of each policy on the wages received by their labor force. This new research gives policy makers another tool with which to wield so that they can make the most well-informed decisions and allow them to better reach their desired goal.

VI. Conclusion

The purpose of this study is to test the neoclassical production function, adjusted to incorporate current immigration literature, along with the assumption that comes out of competitive economics, which is that factors of production are paid their marginal products. The production function used in this thesis is that of a nested CES production function which is common in the immigration literature and has been used by the studies of (2003), Borjas, Freeman, and Katz (1997), Borjas and Katz (2007), Card (2009), D’Amuri, Ottaviano, and Peri (2008), Docquier, Ozden, and Peri (2010), Ottaviano and Peri (2006), and Ottaviano and Peri (2008). The Solow Model is based upon a production function that has constant returns to scale. This type of production function implies that the factors of production have diminishing returns. Due to the fact that there is diminishing marginal product of labor in the model, it is evident that if labor were to decrease then the marginal product of labor would increase. If one includes an additional assumption that factors of production are paid their marginal product, then it is evident that a decrease in labor would increase
wages. When the imperfect substitutability of the immigrant supply along with the skill levels of the labor force is considered, one can see that immigration now has a “size” and “compositional” effect on wages. This forms the basis of what this paper is attempting to test. Does a decrease in the labor supply really increase wages? Is an influx of low-skilled immigrants as detrimental to wages as everyone believes it is? This thesis looks to tackle these questions by extending the current economic growth and immigration literatures.

In this thesis, one of the major obstacles to consider was how to deal with the potential endogeneity of the immigrant share. There have been many techniques used to capture this endogeneity and it is clear that no consensus has been found on which method is the most appropriate. There are some academics, like Borjas, Freeman, and Katz (1997), Longhi, Nijkamp, and Poot (2005), Mankiw (1995), and Schoeni (1997), who argue that the evidence for endogeneity is weak and that therefore using an instrumental variable would cause there to be too much variance in the estimator and a decrease in significance would be found. In light of this debate, two sets of regressions are run: one is set using OLS and assumes that the immigrant share is exogenous, and the other uses the 2SLS approach with the immigrant stock in 1990, instrumenting for the growth rate of the immigrant share from 1990 to 2000 as in Altonji and Card (1991).

After the results from the two sets of regressions were run, two points became clear: that evidence for the endogeneity of the immigrant share was weak and that the data supports the neoclassical production function in describing economic growth. The conclusion on the issue of the potential endogeneity of the immigrant share was
reached after observing the results from a 2SLS regression, which showed that immigration policy variables were significant at the 5 percent level, while the immigrant share itself was not significant. The argument used in this case follows that immigration policies directly affect the immigrant share, which in turn are expected to affect wages. Therefore if the indirect effect on wages from the immigration policy variables was found to be significant then why was the direct effect not found to be significant? The answer was found that using an instrumental variable in this case was inappropriate as it increased the variance of the immigrant share and made it appear insignificant. Results from the SEM analysis support this argument by showing that wage growth was never a significant factor in describing growth in either immigrant share in any of the four SEM regressions. Thus, using the 2SLS approach is not valid and therefore the OLS results were found to measure the correct effect of immigration on wages.

The results from the OLS regressions showed, with robustness, that the assumptions of the neoclassical growth model were found to be accurately described by the data. Growth in total factor productivity, the capital stock, and both high and low-skilled immigrant stocks were found to be significant no matter what other economic growth variables were accounted for. This points to the robustness of the results and the strength of such a production function. In addition to finding the key explanatory variables statistically significant, these regressions also verified that the model correctly predicted the expected effects of each variable on wages, specifically both the “size” and “composition” effect of immigration was properly calculated by the model. The “size” effect of immigration on wages was measured to be a 3.97
decrease in wage growth due to a 10 percent increase in the labor force. While the “composition” effects of high-skilled immigrants was found to be a 1.18 increase in wage growth due to a 10 percent increase, while low-skilled immigrants were found to have an effect of a 1.82 percent decrease in wage growth from a 10 percent increase.

The results from these regressions were then extended to analyze the policy proposal of Pritchett (2006), who stated that if rich countries were to increase their labor forces by 3 percent, they would benefit by gaining $51 billion, while the less developed citizens who participated in the program would receive benefits of $300 billion. The scenario that Pritchett (2006) created seemed to be a win-win situation for both parties involved, in which ultimately the world would benefit.

Unfortunately, the analysis from this study does not support Pritchett’s (2006) statement for how the rich countries will be affected by this policy. The results from this study showed that such an increase in the unskilled immigrant stock would have consequences on the average wages earned in each country, more specifically wage growth would drop anywhere between 1.74 to 1.19 percent. Thus, it is evident that there is a cost to implementing this policy that rich nations must consider before making their decision.

The motivation of this thesis was not policy driven. It is only meant to extend the literature of immigration to include a broader set of countries and measure the effects of immigration and its application to economic growth models. This thesis was not meant to create a platform with which to decide between which immigration policies is best suited for a given situation. It was meant to add another tool to the
arsenal of the policy maker. The results from this regression can be used to calculate the costs and benefits of immigration policies, which can then be used to compare these policies against other deciding factors. It is important to note that this thesis has not included any sociological implications on the change of the immigrant share for each country. These factors must also be given a large amount of weight when deciding upon a policy to implement. As Pritchett (2006) makes clear, there may be a cost associated with immigration but there are benefits as well and in some cases these benefits far exceed the costs.

This thesis uses average annual wages as its main dependent variable, so that the results from these regressions must be stated as such. In light of this, it is not possible to see whose wages are affected by immigration. It might be the case that low-skilled immigrant workers accept lower wages than low-skilled native workers, but that the wages of low-skilled native workers are unaffected by an increase in the low-skilled immigrant share. It is because of this inability to parse out whose wage is affected by immigration that this thesis can make no claim as to how the wages of native workers are affected; rather it can only comment on the wages received by the labor force as a whole.

As future studies into this field of economics are being developed, there are a few areas in this thesis that may be improved upon. A few of the improvements were discussed in section IV, which included the idea of running a separate regression for each country so as to relax the assumption that every country has the same elasticities of substitution between high and low skilled workers as well as native and immigrant laborers. Another possible extension of this thesis would include running different
regressions on the wage paid to each labor aggregate. Of course this regression is not possible until more detailed data becomes available, but it allows one to capture the predictions of the production function more accurately. One can also run regressions on sub-samples of the countries used to further check for robustness. This method was not utilized in this thesis, as the observation number was already small and therefore deceasing it anymore would add bias to the results. Finally, when more data becomes available, it will be more appropriate to use a broader time span and more than two years of data for future economic growth regressions.
IV. References


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Docquier, Frédéric, Marfouk, Abdeslam, Özden, Çağlar, and Parsons, Christopher, “Geographic Gender and Skill Structure of International Migration.” Report written for the Economic Research Forum, 2010


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I. Appendix

X.A Data

<table>
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<th>Table A.1: Variable Description</th>
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</tr>
<tr>
<td>Independent</td>
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<tr>
<td>Variable</td>
</tr>
<tr>
<td>------------</td>
</tr>
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</tr>
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<td>CHUNEM</td>
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*note all growth rates are scaled as decimals
** note growth rates for GWAGE, GTRADE, and CHUNEM were calculated as close to the range of 1990 – 200 as possible
Table A.2:  *Descriptive Statistics*

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<th>Standard Deviation</th>
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Table A.3:  *List of Countries Included in Regression*

Countries:

- Australia
- Austria
- Belgium
- Canada
- Czech Republic
- Denmark
- Finland
- France
- Greece
- Hungary
- Ireland
- Italy
- Japan
- Korea
- Luxembourg
- Netherlands
- Norway
- Poland
- Portugal
- Slovak Republic
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States
Panel A.1 Index (CHTIGHTNESS) for Immigration Policies

Source: Ortega and Peri (2009)


Source: Ortega and Peri (2009)
Table A.4: *List of Countries in this Sample Who Signed the Maastricht Treaty*

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<td>France</td>
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### Table 8.1: OLS Regressions With Both "Size" and "Compositional" Effects

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*note that the significance level of each variable has been denoted at the 10% level (*), 5% level (**) and 1% level (***)
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*Note that the significance level of each variable has been denoted at the 10% level (*), 5% level (**) and 1% level (***)
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*note that the significance level of each variable has been denoted at the 10% level (*), 5% level (**), and 1% level (***)

** here the stock of high and low-skilled immigrants in 1990 is used as an instrument for the growth of the immigrant sh
Table B.4: SEM Regressions

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*N: The significance level of each variable has been denoted at the 10% level *, 5% level **, and 1% level ***.

**the immigrant share of both high and low skilled workers is being used in these regressions as these are the variables that are believed to be endogenous.
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*Note that the significance level of each variable has been denoted at the 10% level [***], 5% level [**] and 1% level [***].

**The immigrant share of both high and low skilled workers is being used in these regressions as these are the variables that are believed to be endogenous.
Derivation of Growth of Marginal Product of Labor

We have:

\[ Y_t = A_t K_t^\alpha N_t^{1-\alpha} \]

Where:

\[ N_t = [\theta_{ht} N_{ht}^{\frac{\sigma_{hl}-1}{\sigma_{hl}}} + \theta_{lt} N_{lt}^{\frac{\sigma_{hl}-1}{\sigma_{hl}}} ]^{\frac{\sigma_{hl}}{\sigma_{hl}-1}} \]

And:

\[ N_b = [\theta_{bt} N_{bt}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} + \theta_{fb} N_{fb}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} ]^{\frac{\sigma_{immi}}{\sigma_{immi}-1}} \]

Where:

- \( t \) stands for time
- \( b \in B = \{H, L\} \)
- \(-b\) stands for the opposite of \( b\)

So, we now have:

\[ N_t = \theta_{ht} \left[ \theta_{dh} N_{dh}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} + \theta_{fh} N_{fh}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} \right]^{\frac{\sigma_{hl}}{\sigma_{hl}-1}} \]

\[ + \theta_{lt} \left[ \theta_{dl} N_{dl}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} + \theta_{fl} N_{fl}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} \right]^{\frac{\sigma_{hl}}{\sigma_{hl}-1}} \]

Let:

\[ N_{t,\text{int}} = \theta_{ht} N_{ht}^{\frac{\sigma_{hl}-1}{\sigma_{hl}}} + \theta_{lt} N_{lt}^{\frac{\sigma_{hl}-1}{\sigma_{hl}}} \]

\[ N_{b,t,\text{int}} = \theta_{bt} N_{bt}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} + \theta_{fb} N_{fb}^{\frac{\sigma_{immi}-1}{\sigma_{immi}}} \]

We know that:

\[ \frac{w}{p} = MP_N \]

Thus:

\[ MP_{N_{bt}} = A_t K_t^{\alpha} N_t^{-\alpha} * \left( \frac{\sigma_{hl}-1}{\sigma_{hl}} \right) N_{t,\text{int}} \frac{1}{\sigma_{hl}-1} * \left( \frac{\sigma_{hl}-1}{\sigma_{hl}} \right) \theta_{bt} N_{bt}^{-1} \]

\[ * \left( \frac{\sigma_{immi}-1}{\sigma_{immi}} \right) N_{b,t,\text{int}} \frac{1}{\sigma_{immi}-1} * \left( \frac{\sigma_{immi}-1}{\sigma_{immi}} \right) \theta_{bt} N_{db}^{-1} \]

Note that: \[ [N_{\text{int}}]^{\frac{1}{\sigma}} = N_{\sigma} \] and similarly for every other case. So, we get:

\[ MP_{N_{bt}} = A_t K_t^{\alpha} N_t^{-\alpha} * N_t^{\sigma_{hl}} * \theta_{bt} N_{bt}^{\sigma_{hl}} * N_{b,t}^{\sigma_{immi}} * \theta_{bt} N_{bt}^{-1} \]

\[ MP_{N_{bt}} = A_t K_t^{\alpha} N_t^{-\alpha} * N_t^{-\sigma_{hl}} * \theta_{bt} N_{bt}^{-\sigma_{hl}} * N_{b,t}^{\sigma_{immi}} * \theta_{bt} N_{bt}^{-1} \]

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And similarly:

\[ MP_{N_Fbt} = A_t K_t^\alpha N_t^{-\alpha} \left( \frac{\sigma_{HL}}{\sigma_{HL} - 1} \right) \left( \frac{\sigma_{IMMI}}{\sigma_{IMMI} - 1} \right) \left( \frac{1}{\sigma_{bb}^{-1}} \right) \left( \frac{\sigma_{IMMI} - 1}{\sigma_{IMMI}} \right) N_{bt} \right. \]

\[ \times \left. \frac{1}{\sigma_{bb}^{-1}} \right) \left( \frac{\sigma_{IMMI}}{\sigma_{IMMI} - 1} \right) \left( \frac{1}{\sigma_{IMMI}} \right) \theta_{bt} N_{bt} \frac{1}{\sigma_{IMMI}} \]

\[ MP_{N_Fbt} = A_t K_t^\alpha N_t^{-\alpha} \left( \frac{1}{\sigma_{HL}} \right) \theta_{bt} N_{bt} \frac{1}{\sigma_{HL}} \frac{1}{\sigma_{IMMI}} \]

\[ MP_{N_Fbt} = A_t K_t^\alpha N_t^{-\alpha} \left( \frac{1}{\sigma_{HL}} \right) \theta_{bt} N_{bt} \frac{1}{\sigma_{HL}} \frac{1}{\sigma_{IMMI}} \]

Let us define \( \bar{H} \) to mean the growth rate of some variable \( H \).
Thus we have:

\[ MP_{N_{Dbt}} = \bar{A}_t + \alpha \bar{K}_t + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \bar{N}_t + \bar{\theta}_{bt} + \left( \frac{1}{\sigma_{IMMI} - 1} \right) \bar{N}_{bt} + \bar{\theta}_{Dbt} \]

\[ + \left( \frac{-1}{\sigma_{IMMI}} \right) \bar{N}_{Dbt} \]

Similarly:

\[ MP_{N_{Fbt}} = \bar{A}_t + \alpha \bar{K}_t + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \bar{N}_t + \bar{\theta}_{bt} + \left( \frac{1}{\sigma_{IMMI} - 1} \right) \bar{N}_{bt} + \bar{\theta}_{Fbt} \]

\[ + \left( \frac{-1}{\sigma_{IMMI}} \right) \bar{N}_{Fbt} \]

Note that:

\[ \bar{N}_t \cong \]

\[ \frac{\bar{\theta}_{b(t-1)} N_{b(t-1)} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}}}{\bar{\theta}_{b(t-1)} N_{b(t-1)} + \bar{\theta}_{(b)(t-1)} N_{(b)(t-1)} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}}} \]

\[ \frac{\bar{\theta}_{(b)(t-1)} N_{(b)(t-1)} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}}}{\bar{\theta}_{b(t-1)} N_{b(t-1)} + \bar{\theta}_{(b)(t-1)} N_{(b)(t-1)} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}}} \]

and:

\[ \bar{N}_{bt} \cong \]

\[ \frac{\bar{\theta}_{D_{b(t-1)}} N_{D_{b(t-1)}} \frac{\sigma_{IMMI}^{-1}}{\sigma_{HL}}}{\bar{\theta}_{D_{b(t-1)}} N_{D_{b(t-1)}} + \bar{\theta}_{F_{b(t-1)}} N_{F_{b(t-1)}} \frac{\sigma_{IMMI}^{-1}}{\sigma_{HL}}} \]

\[ + \frac{\bar{\theta}_{F_{b(t-1)}} N_{F_{b(t-1)}} \frac{\sigma_{IMMI}^{-1}}{\sigma_{HL}}}{\bar{\theta}_{D_{b(t-1)}} N_{D_{b(t-1)}} + \bar{\theta}_{F_{b(t-1)}} N_{F_{b(t-1)}} \frac{\sigma_{IMMI}^{-1}}{\sigma_{HL}}} \]
So, we get:

\[ MP_{ND_{bt}} = \tilde{A}_t + \alpha \tilde{K}_t \]

\[ + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \left[ \frac{\theta_{b(t-1)}}{\sigma_{HL}} - \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{bt} \right] + \tilde{\theta}_{bt} \]

\[ + \frac{\theta_{(b)(t-1)}}{\sigma_{HL}} \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{bt} \]

\[ + \left( \frac{1}{\sigma_{IMMI}} \right) \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{D_{bt}} \]

\[ + \left( \frac{-1}{\sigma_{IMMI}} \right) \tilde{N}_{D_{bt}} \]

\[ MP_{ND_{bt}} = \tilde{A}_t + \alpha \tilde{K}_t + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \left[ \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{bt} \right] + \tilde{\theta}_{bt} \]

\[ + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{D_{bt}} \]

\[ + \left( \frac{1}{\sigma_{IMMI}} \right) \left( \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} + \frac{\theta_{b(t-1)}N_{b(t-1)}}{\sigma_{HL}} \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \right) \frac{\sigma_{HL}^{-1}}{\sigma_{HL}} \tilde{N}_{D_{bt}} \]

\[ + \left( \frac{-1}{\sigma_{IMMI}} \right) \tilde{N}_{D_{bt}} \]
Let:

\[ C_{bt} = \frac{\theta_{b(t-1)}N_{b(t-1)} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{b(t-1)}N_{b(t-1)} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \]

\[ C_{(-b)t} = \frac{\theta_{(-b)(t-1)}N_{(-b)(t-1)} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{b(t-1)}N_{b(t-1)} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \]

\[ C_{D_{bt}} = \frac{\theta_{D_{b(t-1)}N_{D_{b(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{D_{b(t-1)}N_{D_{b(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \sigma_{IMMI}^{-1} \sigma_{HL}^{-1}} \]

\[ C_{F_{bt}} = \frac{\theta_{F_{b(t-1)}N_{F_{b(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{F_{b(t-1)}N_{F_{b(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \sigma_{IMMI}^{-1} \sigma_{HL}^{-1}} \]

\[ C_{D_{(-b)t}} = \frac{\theta_{D_{(-b)(t-1)}N_{D_{(-b)(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{D_{(-b)(t-1)}N_{D_{(-b)(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \sigma_{IMMI}^{-1} \sigma_{HL}^{-1}} \]

\[ C_{F_{(-b)t}} = \frac{\theta_{F_{(-b)(t-1)}N_{F_{(-b)(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}}{\theta_{F_{(-b)(t-1)}N_{F_{(-b)(t-1)}} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1} \sigma_{HL}^{-1}} \sigma_{IMMI}^{-1} \sigma_{HL}^{-1}} \]

So we get:

\[ MP_{N_{D_{bt}}} = \tilde{A}_{t} + \alpha \tilde{K}_{t} \]

\[ + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \left[ C_{bt} \left( \tilde{N}_{D_{bt}} + \tilde{N}_{F_{bt}} \right) + C_{(-b)t} \left( \tilde{N}_{D_{(-b)t}} + \tilde{N}_{F_{(-b)t}} \right) \right] + \tilde{\theta}_{bt} \]

\[ + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) \left[ C_{D_{bt}} \tilde{N}_{D_{bt}} + C_{F_{bt}} \tilde{N}_{F_{bt}} \right] + \tilde{\theta}_{D_{bt}} + \left( \frac{1}{\sigma_{IMMI}} \right) \tilde{N}_{D_{bt}} \]

\[ MP_{N_{D_{bt}}} = \tilde{A}_{t} + \alpha \tilde{K}_{t} \]

\[ + \left( \frac{1}{\sigma_{HL}} - \alpha \right) \left[ C_{bt} C_{D_{bt}} \tilde{N}_{D_{bt}} + C_{bt} C_{F_{bt}} \tilde{N}_{F_{bt}} + C_{(-b)t} C_{D_{(-b)t}} \tilde{N}_{D_{(-b)t}} + C_{(-b)t} C_{F_{(-b)t}} \tilde{N}_{F_{(-b)t}} \right] + \tilde{\theta}_{bt} \]

\[ + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) \left[ C_{D_{bt}} \tilde{N}_{D_{bt}} + C_{F_{bt}} \tilde{N}_{F_{bt}} \right] + \tilde{\theta}_{D_{bt}} + \left( \frac{1}{\sigma_{IMMI}} \right) \tilde{N}_{D_{bt}} \]
\[
\overline{MP_{ND_{bt}}} = \overline{A_t} + \alpha \overline{K_t} + \overline{\theta_{bt}} + \overline{\theta_{Dbt}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{bt} C_{Dbt} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{Dbt} + \left( \frac{-1}{\sigma_{IMMI}} \right) \overline{N_{Dbt}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{bt} C_{F_{bt}} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{F_{bt}} \overline{N_{F_{bt}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{(-b)t} C_{D_{(-b)t}} \overline{N_{D_{(-b)t}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{(-b)t} C_{F_{(-b)t}} \overline{N_{F_{(-b)t}}} 
\]

Similarly:
\[
\overline{MP_{NF_{bt}}} = \overline{A_t} + \alpha \overline{K_t} \\
+ \overline{\theta_{bt}} + \overline{\theta_{F_{bt}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{bt} C_{Dbt} \overline{N_{Dbt}} + C_{bt} C_{F_{bt}} \overline{N_{F_{bt}}} + C_{(-b)t} C_{D_{(-b)t}} \overline{N_{D_{(-b)t}}} \\
+ C_{(-b)t} C_{F_{(-b)t}} \overline{N_{F_{(-b)t}}} + \overline{\theta_{bt}} \\
+ \left[ \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right] C_{Dbt} \overline{N_{Dbt}} + C_{F_{bt}} \overline{N_{F_{bt}}} + \overline{\theta_{F_{bt}}} + \left( \frac{-1}{\sigma_{IMMI}} \right) \overline{N_{F_{bt}}} 
\]

\[
\overline{MP_{NF_{bt}}} = \overline{A_t} + \alpha \overline{K_t} + \overline{\theta_{bt}} + \overline{\theta_{F_{bt}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{bt} C_{Dbt} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{Dbt} \overline{N_{Dbt}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{bt} C_{F_{bt}} + \left( \frac{1}{\sigma_{IMMI}} - \frac{1}{\sigma_{HL}} \right) C_{F_{bt}} \overline{N_{F_{bt}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{(-b)t} C_{D_{(-b)t}} \overline{N_{D_{(-b)t}}} \\
+ \left[ \frac{1}{\sigma_{HL}} - \alpha \right] C_{(-b)t} C_{F_{(-b)t}} \overline{N_{F_{(-b)t}}} 
\]
For the augmented Solow Growth model we have:

\[ Y_t = A_t K_t^\alpha H_t^\gamma N_t^{1-\alpha-\gamma} \]

Where \( N \) is defined as above:

Similarly we get:

\[
\overline{MP_{Nd_{bt}}} = \overline{A_t} + q\overline{K_t} + \gamma\overline{H_t} + \overline{\theta_{bt}} + \overline{\theta_{D_{bt}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{bt} C_{D_{bt}} + \left( \frac{1}{\sigma_{IMM1}} - \frac{1}{\sigma_{HL}} \right) C_{D_{bt}} + \left( \frac{-1}{\sigma_{IMM1}} \right) \right] \overline{N_{D_{bt}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{bt} C_{F_{bt}} + \left( \frac{1}{\sigma_{IMM1}} - \frac{1}{\sigma_{HL}} \right) C_{F_{bt}} \right] \overline{N_{F_{bt}}}
\]

\[ \overline{MP_{N_d_{bt}}} = \overline{A_t} + q\overline{K_t} + \gamma\overline{H_t} + \overline{\theta_{bt}} + \overline{\theta_{F_{bt}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{bt} C_{D_{bt}} + \left( \frac{1}{\sigma_{IMM1}} - \frac{1}{\sigma_{HL}} \right) C_{D_{bt}} \right] \overline{N_{D_{bt}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{bt} C_{F_{bt}} + \left( \frac{1}{\sigma_{IMM1}} - \frac{1}{\sigma_{HL}} \right) C_{F_{bt}} + \left( \frac{-1}{\sigma_{IMM1}} \right) \right] \overline{N_{F_{bt}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{(-b)_{bt}} C_{D_{(-b)_{bt}}} \right] \overline{N_{D_{(-b)_{bt}}}}
\]

\[
+ \left[ \left( \frac{1}{\sigma_{HL}} - \alpha - \gamma \right) C_{(-b)_{bt}} C_{F_{(-b)_{bt}}} \right] \overline{N_{F_{(-b)_{bt}}}}
\]
Table C.1  Size of the Labor Force vs. Relative Wages

Table C.2  Free Trade in One Good Economy