Applying System Dynamics Modeling to Innovation's Effects on Wages

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Abstract

Using system dynamics modeling tools, this paper explains the effects of innovations on relative international wages based on two countries. The Heckscher-Ohlin model of international trade is the bases factor-proportions theory. The paper also incorporates related research by Stolper & Samuelson, Vernon, Krugman and Dollar.

System Dynamics Modeling is being used to demonstrate of innovation's effects on wages because this type of modeling permits a visual representation of the cause and effects of innovation on wages in an international trade environment.

The paper demonstrates the effects of innovation and technology adoption on relatives wage differential between the countries. It demonstrates the importance of innovation as a tool to maintain wages in a capital-abundant country and the importance of technology adoption in a labor-abundant country.

Software Tools Used:

Models for this paper were developed using Ventana Systems, Inc "Vensim® PLE Plus for Windows"

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Introduction

The intent of this paper is to explain innovations effects on wages using system dynamics modeling tools. It uses Heckscher-Ohlin model of resources and international trade as the bases factor-proportions theory. It also incorporates research by Stolper & Samuelson, Vernon, Krugman and Dollar.

System Dynamics Modeling is being used to demonstrate of innovation's effects on wages because this type of modeling permits a visual representation of the cause and effects of innovation on wages in an international trade environment. This approach permits the development of a system structure based on a pattern of observed behavior. (Kirkwood, 1998)

Literature Review

Heckscher-Ohlin model of international trade is the bases factor-proportions theory. The principle to the theory of trade between nations is based on resource differences between the countries. (Krugman, 1991) The model shows a country will have a comparative advantage when it has a relative abundance of the resource, which drives international trade. The model is based on two suppositions (Kenen, 1994):

1) Goods differ in their factor requirements. Cars require more capital per worker than cloth or furniture. Space shuttles require more capital then cars. This provides a method to order items by the amount of factors required to produce.

2) Countries differ in the factor endowments. Some countries will have more capital per workers and other countries will have less. Therefore, countries can be ranked by factor abundance.

An abundant factor is a resource which a country has comparatively large supply, where a scarce factor is a resource which a country has comparatively small supply. In general it is observed that the owners of the country's abundant factor gain from trade and the owners of the scarce factor do not gain from trade. Prior to trade the relative prices of the goods have a larger difference based on each countries abundance and scarcity of the factors. As trade occurs, the relative prices of the goods start to converge. As it continues, it leads to equalization of factor prices. (Krugman, 1991)

Stolper and Samuelson extended the theory to include the effects of trade on factor pricing and income distribution. Stolper – Samuelson theorem states that opening trade between a two countries will raise the relative price of labor in the labor-abundant country and reduce it in the capital-abundant country (Kenen, 1994).

Raymond Vernon (1966) presented the product life cycle theory as it relates to international investment and trade. Vernon's paper brought a new prospective to the international product cycle. According to Vernon's theory, the production location for a product is dependent on its stage in the product life cycle. In Vernon's product life cycle, a product will go thru phases, which are introduction, growth, maturity and decline. As the product is going thru the phases, the production location will shift from a high-income country, to multiple countries, then to a low labor cost country. The high-income country would be considered to be capital-abundant and the low labor cost country would be considered the labor-abundant country.

Vernon's theory shifted the focus from comparative cost to innovation, economies of scale and the roles of ignorance and uncertainty as influences on trade patterns. One of Vernon's base assumption of was that the firms "in any of advanced countries of the world are not distinguishably different from firms in any other advanced country in terms of access to scientific knowledge and capacity to comprehend scientific principles." The base hypotheses of his research was that investment in less-developed countries will occur in industries which require a high labor content to produce the product. It was assumed that at the early stage in the production, while the volume is low, the manufacturing process lacks standardization. The lack of standardization in turn delays the capital investment because of the degree of uncertainty is still high.

In the early development phase, a product is new. It is being developed to meet a perceived need, with the intent of providing the firm a competitive advantage. At this period, the product's characteristics are evolving and the initial users are considered earlier adopters. At this period in time, the production occurs within the domestic location and is common to occur at the same facility where the development is occurring. During the early development phase some of the product may be exported.

As the market acceptance for the product starts increase, so does the demand. The product is now transitioning into its growth phase. With this transition several things occur including the growth occurs in export market and competitors enter the market. While early in this phase, the product

characteristics still vary. Due to competition and the growth in demand, a firm starts to investigate production in second country in order to reduce cost and meet demand. A firm may start losing some of its export market, when a competitor starts producing in that local market to reduce their production cost. Toward the end of the phase, product standardization has increased.

With the increased standardization, the product is entering the mature phase. Some of the characteristic of this phase is greater focus price competitiveness and an increase in capital expenditures to help improve production efficiencies. As the product price reduces, it creates a demand in emerging markets. With the additional demand, the firm starts to product in an emerging market to achieve the benefits of the lower production labor cost. Another effect occurring during this phase is the production technology is widely known, which eliminates the intellectual knowledge as a competitive advantage and complements the use of the lower labor costs. In the later part of the phase, competitor consolidation occurs.

As the product demand in the high-income developed countries starts to reduce, the product moves into the declining phase. The demand could be reduced because the product has been replaced by a newer, innovative product. During the decline phase, in order to maintain price competitiveness, the production is focused in the emerging markets. High-income developed countries, which once produced the product, now import it. Through out this phase competitors continue to exit the market because of the shrinking market demands and profits.

The prospective was further explored in Paul Krugman's (1979) paper titled "A Model of Innovation, Technology Transfer, and the World Distribution of Income." Within Krugman's paper, he develops a simple general-equilibrium model of product cycle trade. The model is based is a two country model where the "North" is considered innovative and the "South" is considered non-innovative. Developing new products is considered as innovation. The new products are initially produced in the North because it is initial a non-standardization product, it is necessary to produce it close to the source of the knowledge. As the production is standardized, it is able to be produces in the South.

The technology time lag promotes trade between the two, where the South imports the new product from the North and exports the old product to the North. To keep it in an equilibrium state, the North must continue to innovate.

Dollar (1986) contributes to the topic with a dynamic general equilibrium model of North - South trade that is based on the product cycle with the pressures of factor-price equalization of the neoclassical trade model. Within this paper the pace of innovation, diffusion and capital movement are tied to the prices determined trough trade, which implies that over time the technology and capital that nations have available are as much a result as a cause for trade.

The model provided insight that for factor prices and the terms of trade to be stable, there must be a stable ratio of the number of goods produced in each region. If the North is constantly introduce new products, to keep the model stable, there needs to be a simultaneous flow of technology to the South. International mobility of capital and technology creates a tendency toward equalization of all factor prices. As long as the North continues to innovate, strict equalization will not occur.

Dollar (1987) expands the investigation with his paper on Import Quotes and The Product Cycle. The paper is based on a dynamic general equilibrium model of the product cycle incorporated in the "North-South" trade. The use of import quotas by the North on products manufactured by the South are analyzed for the short term and long term effects His paper finds the short-term effects are predictable: real wages in the North rise as a result of the protection. It also explains "the long-run effect of the protection is to unambiguously reduce real wages in the North because the quotas artificially increase production costs in the North relative to the South, accelerating the transfer of technology and capital from North to South."

Systems Dynamics Model

Assumptions of the models

All the models share the same series of assumption. The time period of the model simulation is 30 years. The two countries participate in trade with each other. The models are based on products which follow a typical product life cycle and become standardized product. When Innovation or Technology Adoption occurs, they each have a positive effect on relative wages within the respective country.

Factor Price Equalization

For explanatory purpose the model is divided into subsections, with the first section is a basic factor price equalization model with two countries. (See Model 1) Country "A" is considered the

capital-abundant country (also know as North) and country "B" is the labor-abundant country (also know as South). Within the model, trade starts at the initial state in the model. The initial wages in country "A" are much greater than in country "B", because the labor is not abundantly available. As trade progresses the wages become to a relative wages start to converge based on Stolper – Samuelson theorem. (See Graph 1)

The basic factor price equalization model contains a pair of stock and flow diagrams, which the relative wage, rate of the country "A" declines as a first-order effect because of the reduced labor demand. Concurrently the relative wage rate of country "B" increases as a first-order effect based on the increase in demand for the labor. The wage differential is the current wage of country "A" minus the current wage of country "B".

As free trade has increased between the original European Union (EU) countries and some of the more recent Eastern European entrants into the EU, the effects of factor price equalization have been observed. For example, after the market structure changes of the former communist countries, many manufactures such as Royal Philips Electronics, Flextronics and IBM, which are based in capital-abundant countries, established plants in Hungary and other Eastern European countries, considered labor-abundant countries, to take advantage of the lower cost labor advantages offered by the countries in comparison to EU countries. The Eastern European countries experienced an economic boom. As time has progressed, the real wages in the labor-abundant countries have risen to the point where the wage differential is now less than 25%. (Business Week, 2003) Most recently it has been noted that as countries develop, salaries, taxes and other social costs go up. As this occurs, the cost factors which attracted a firm to the country have been removed and the country is approaching relative wage equilibrium. (Kole, 2007) This is what the Eastern European countries are experiencing.

Factor Price Equalization with Innovation

The next section of the model focuses the impact of innovation on wages in country "A" which considered the capital-abundant country. When the country innovates it increases the wages in the country because the knowledge to produce the product is not readily available. (See Model 2) This is considered the introduction and early growth phases of Vernon's product life cycle. The delay period in the model is the amount of time country "A" waits before starting a new, successful innovation. The market adoption time is the delay from when the product innovation

is initially introduced to the time when the market adopts the product. (Moore, 2005) If the product is successful, it will move into its growth phase.

Two of the key innovation factors which affect the relative wage differential are the innovation delay period and the market adoption time. If the time periods for both factors are delayed, then the relative wage differential is impacted.

The Innovation section of the model uses the current base wage in country "A" as the initial wage for the country. The country's base wage continues to decline until it innovates, at the point it successfully innovates. Due to the scarcity of labor with the knowledge of producing the innovation, a premium wage is paid. This in turn creates a first-order effect based on the increase in demand for the labor and creates a positive effect on the country's wage change. The market adoption time has a direct effect slope of the wage change. If the market adoption time is short, the wages increase to their new peak rate faster then if the market adoption time is long.

As the country A innovates, it positively affects the wages, which will maintain a greater wage differential between the countries. (See Graph 2) The effects of innovation on wages have been repeatedly observed within sectors of an economy. For example, the Silicon Valley area of California is know as a area which is focused on innovation, is also an area which pays the highest wages in the U.S. In 1999, the average wage in Silicon Valley was US$ 53,700, while the national average was US$ 33,770. (Thurm, 2000) The scarcity of the needed specialized knowledge is a major components which contributor to the labor differential.

When country "A" delays in innovating, it reduces the relative wage differential between the countries. For example, if country "A" delays innovating from 5 to 15 years, the relative wage differential is reduced from 45 to 28. The loss in the differential will be difficult for the country regain.

Factor Price Equalization with Innovation and Technology Adoption

The next section of the model focuses the impact of technology adoption on wages in country "B" which considered the labor-abundant country. When the market has adopted the new product, the product is becoming standards. As it becomes standardized, the cost because an increasing factor. The new product has reached the point where production starts to shift to the country "B". Country "B" adopts the new technology in order to produce the product. The

relative wages will increase which is attributed to an additional increase in demand for labor. (See Model 3)

The Technology Adoption section of the model uses the current base wage in country "B" as the initial wage for the country. The country's base wage continues to increase at the initial rate until it adopts new technology from country "A", at the point it adopts the technology, it affects the wages. Due to the scarcity of labor with the knowledge of producing the technology adoption, a premium wage is paid. This in turn creates a first-order effect based on the increase in demand for the labor and creates a positive effect on the country's wage change. If the market for the product in country "A" is slow in accepting the product, country "A" is slower in transferring it to country "B". The market adoption time also a similar affect on wage changes as it did in the innovating country. If the market adoption time is short, the wages increase to their new peak rate faster then if the market adoption time is long.

The Combined Model

The combined model merges the effects of factor price equalization with the effects of innovation and technology adoption. The current wages calculated in the factor price equalization subsection of the model are used for each country as the base relative wage rates for the innovation and technology adoption subsection of the model. Within the model, the market adoption time effects both innovation and adoption wages, since a product which is slow to develop the market acceptance will take longer to achieve the volume output become standardized.

The relative wage differential between the two countries shifts because of the effects of innovation in country "A" and technology adoption in country "B". As country "A" innovates, the relative wage differential increases, as country "B" adopts the new technology, the relative wage differential decreases, which move the relative wages toward equilibrium.

The output from simulations of the combined model shows how the relative wage differential between country "A" and country "B" are affected by the time period of innovation and how quickly the market adopts the new innovation. (See Graph #3) When the market adopts an innovation quickly, it creates a sharper change in demand for workers with the specialized knowledge, which creates a scarcity. The scarcity of the knowledgeable creates a scenario where the works are paid a premium.

As firms have been focusing on globally implementing innovation and technology adoption, the global growth has been running at 5% per year, from 2004 to 20007. During this period, in order to hold down labor cost, many firms have used a strategy that has been based on producing in a low-labor costs country. The strategy is starting to create a situation where it is difficult for the firms to find workers with the specialized knowledge in both countries. (Coy, 2007) It is being experienced by firms who have been establishing operations in India and China. The scarcity of the knowledgeable is creating the scenario where the workers are pay is increase at a greater rate then anticipated.

Conclusion

Due to factor price equalization the relative wage differential between the two countries which participate in trade will converge. In order to maintain the wage differential for the capital-abundant country, it is critical for the country continue to innovation. With the United States being considered a capital-abundant country, the technology focus of Silicon Valley area in California is an example of an area which receives premium wages due its focus on innovation.

Labor-abundant countries, such as India, have embraced technology adoption in order to improve its standards of living. Since they opened their economy in 1991, they have experienced growth in cities such as Bangalore and Gurgaon. The opening to trade has improved the productivity of the workforce through investment in machinery and technology. For example between 1993 and 2000, the growth in growth domestic production averaged an increase of 6.7% verses a pervious growth rate of 5.2%. (Slater, 2004)

In order for all countries which participate in trade, is critical for the countries to innovate and adopt technology. If they do not then they will experience the lowering of their relative wages.

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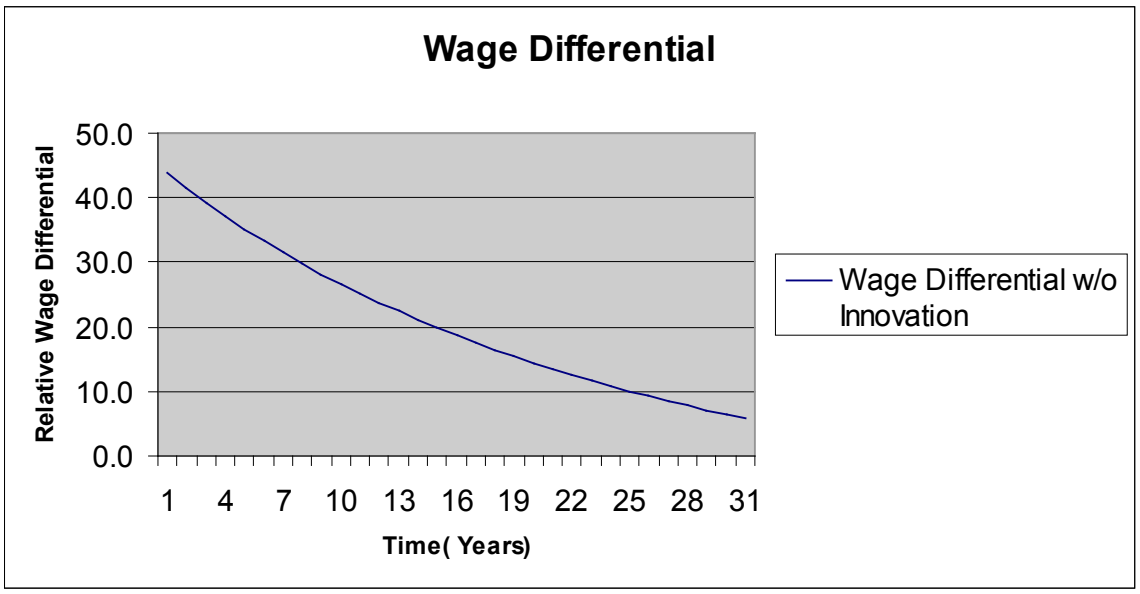
Figures, Graphs and Models:



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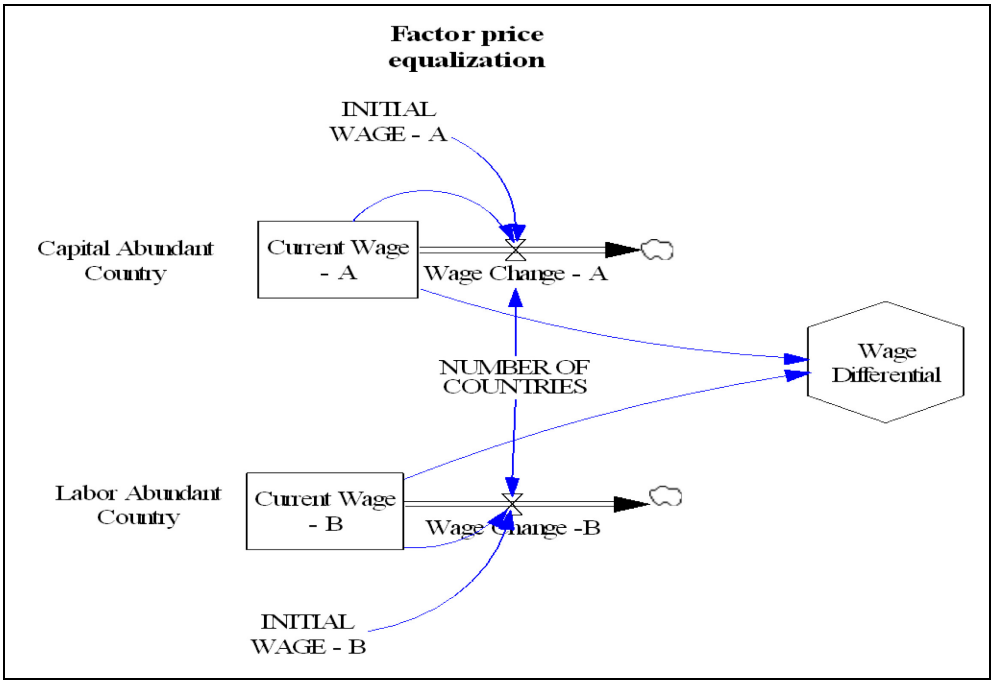
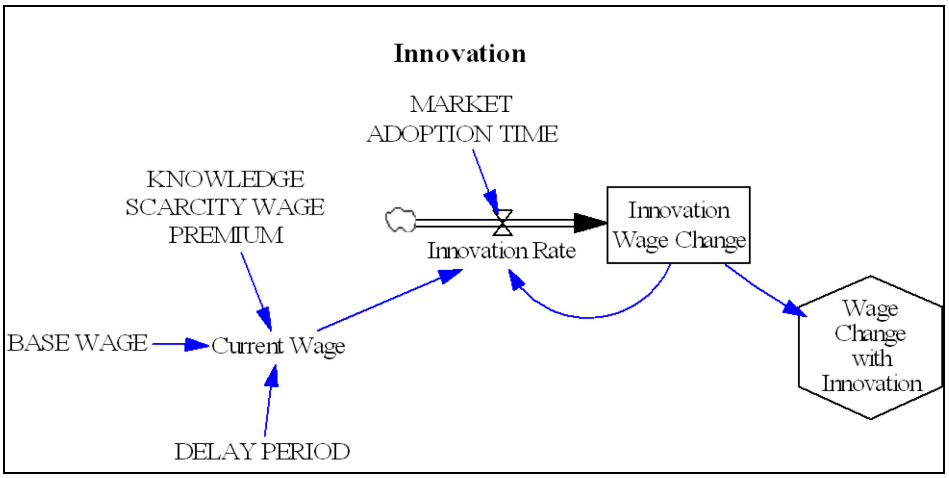


Model 1:

Appendix A



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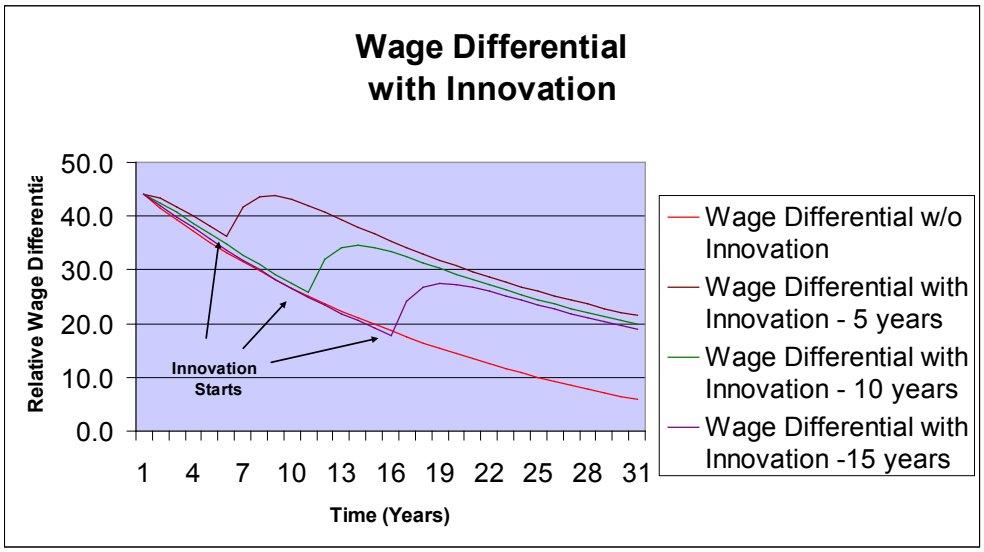
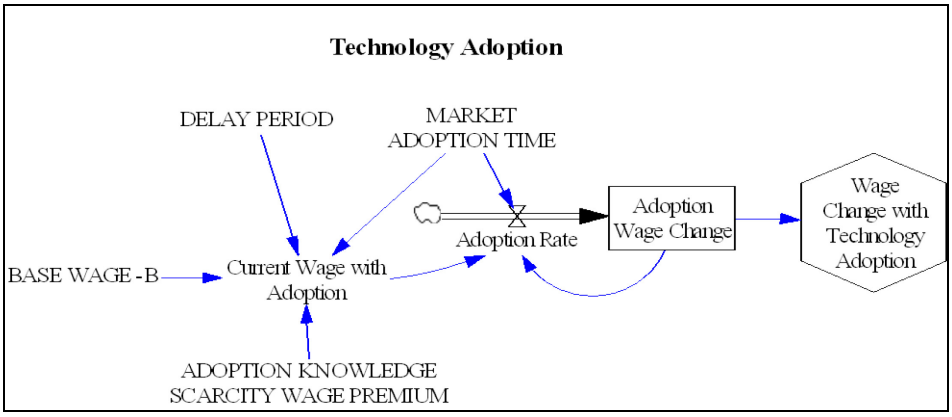


Graph 2:



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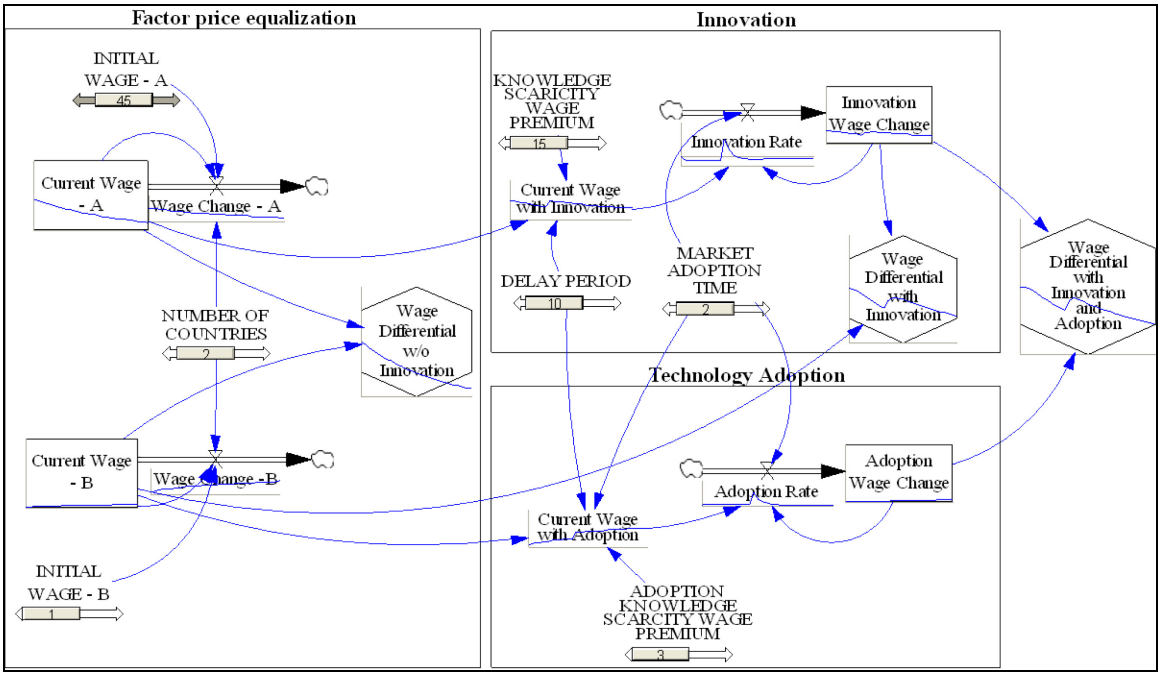

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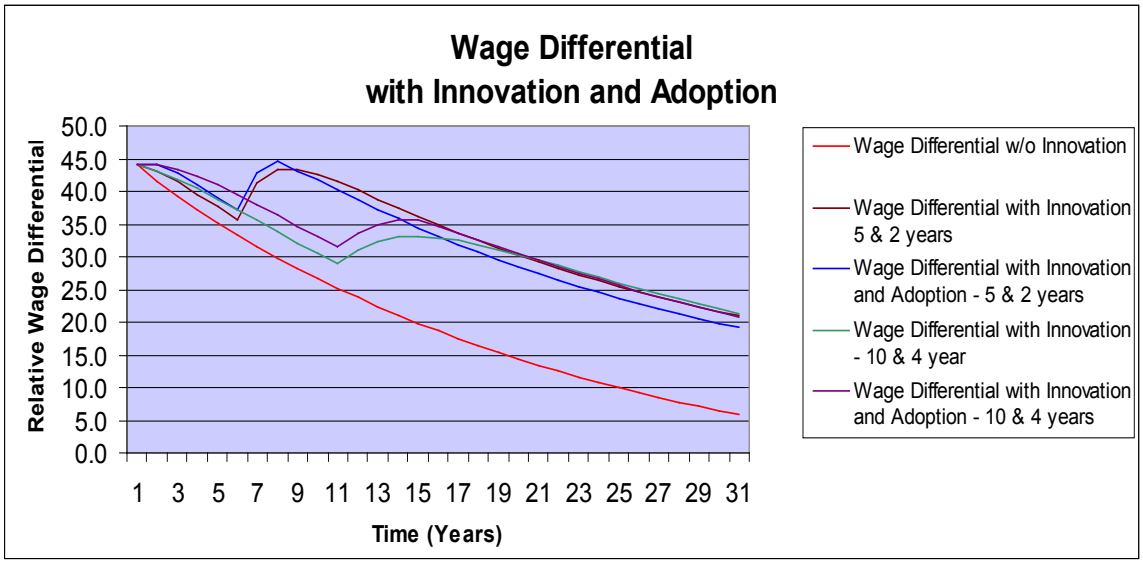

Graph 3:

Appendix B

Equations Used in Models:

(01) $W_t^a \cong \int_{t=0}^{30} W_0^a - W_{t-1}^a$ = Current Wage – A

(02) $W_t^b \cong 1/\int_{t=0}^{30} W_0^b - W_{t-1}^b$ = Current Wage – B

(03) $\Delta W \cong W_t^a - W_t^b$ = Wage Differential w/o Innovation

(04) $W_t^{ai} \cong W_t^a + W^{ba}$ = Current Wage with Innovation=
If delay time is ≥ DELAY PERIOD + MARKET ADOPTION TIME

(05) $W_t^{ba} \cong W_t^b + W^{bp}$ = Current Wage with Adoption
If delay time is ≥ DELAY PERIOD + MARKET ADOPTION TIME

(06) $\Delta W_t^{di} \cong W_t^{ai} - W_t^b$ = Wage Differential with Innovation

(07) $\Delta W_t^{dia} \cong W_t^{ai} - W_t^{ba}$ = Wage Differential with Innovation and Adoption

Additional Support Equations Used in Models:

(13) Innovation Rate= Current Wage with Innovation-Innovation Wage Change)/MARKET ADOPTION TIME

(14) Innovation Wage Change= INTEG (Innovation Rate, "INITIAL WAGE - A")

(02) Adoption Rate=
(Current Wage with Adoption-Adoption Wage Change)/MARKET ADOPTION TIME

(03) Adoption Wage Change= INTEG (Adoption Rate, "INITIAL WAGE - B")

(20) "Wage Change - A"=
NUMBER OF COUNTRIES*"Current Wage - A"/"INITIAL WAGE - A"

(21) "Wage Change -B"=
NUMBER OF COUNTRIES*"Current Wage - B"/"INITIAL WAGE - B"