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ASSESSING THE ECONOMIC IMPACT OF MINIMUM WAGE INCREASES ON THE WASHINGTON ECONOMY: A GENERAL EQUILIBRIUM APPROACH

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ABSTRACT

Washington voters passed Initiative Measure No. 688 on November 3, 1998. This bill increased Washington's minimum wage to $5.70 on January 1, 1999.and to $6.50 on January 1, 2000. The Initiative required that future annual changes in Washington's minimum wage be indexed to inflation in the BLS Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W). As of 2005, Washington had the highest minimum wage in the nation at $7.35 per hour. Eleven other states have minimum wages above the Federal minimum wage of $5.15 per hour; however, Oregon is the only other state with an inflation-indexed minimum wage, which was $7.05 per hour in 2004. A computable general equilibrium (CGE) model of the Washington economy was used to examine the economic impact of increases in Washington's minimum wage. Results from the short-run model indicated that a five percent increase in Washington's minimum wage would cause a loss of 1909 minimum wage jobs (2.5 percent of baseline minimum wage jobs) but the wage bill for minimum wage workers would increase by $22.61 million (2.38 percent of the baseline minimum wage bill). The loss in the total wage and capital bill for the state economy was $14.04 million. The predicted change in gross state product was roughly 0.007 percent. Tracing the impact of increases in the minimum wage across the size distribution of household income, low income households in Washington experienced an increase in welfare and there was a slight decrease in welfare for high income households.

Keywords: **Washington's minimum wage, the Washington CGE model, Two-level CES production functions, elasticity of labor-capital substitution, welfare change.**

JEL Classification: R13

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A GENERAL EQUILIBRIUM ANALYSIS OF THE ECONOMIC IMPACT OF MINIMUM WAGE CHANGES ON THE WASHINGTON ECONOMY

I. INTRODUCTION

Washington voters passed Initiative Measure No. 688 on November 3, 1998. This bill increased Washington's minimum wage to $5.70 on January 1, 1999 and to $6.50 on January 1, 2000. The Initiative required that future annual changes in Washington's minimum wage be indexed to inflation in the BLS Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W). As of 2005, Washington had the highest minimum wage in the nation at $7.35 per hour.

Although a number of studies have been done on the economic impact of minimum wages at the national level, individual state studies are more limited and have focused on specific industries rather than the entire economy. Studies of the minimum wage in Washington have described the distribution of minimum wage workers across the economy (Glenn 2003) and compared the number of minimum wage jobs in the Washington and Oregon eating and drinking industry to minimum wage changes in each state (Bailey 2004). In the Vedders and Gallaway study (2003), a regression analysis of Washington unemployment rates prior to the enactment of the 1998 law was used to predict that Washington's minimum wage resulted in the loss of over 31,000 Washington jobs by the year 2002.

Given the controversial nature of minimum wage in general and its high visibility as a labor policy issue in Washington, we were interested in is an economic framework that would allow the examination of likely impacts of the minimum wage on minimum wage workers as well as producers in the broader economy. Our approach was to examine the economy-wide effects of changes in Washington's minimum wage using a general equilibrium model. We were particularly interested in the economic impact of minimum wage changes on both minimum wage workers and upon the competitive position of Washington industries. A computable general equilibrium (CGE) model of the Washington economy was used to examine the effects of the minimum wage changes in both the short-run and the long-run under different assumptions regarding factor market behavior and labor/capital elasticity of substitution. CGE models are an ideal tool for looking at the impact of the minimum wage because of their ability to isolate the just the wage shock and examine the impact of the shock across the entire economy. Only a CGE model is able to capture both the direct and secondary effects of minimum wage changes. By measuring changes in production, prices, factor usage, household income and consumption, the model is able to estimate welfare effect on both low income households and other households as well.

The next section presents a brief review of the literature, followed by a discussion of the theoretical model, a review of the data used in the analyses and a description of the empirical model. A discussion of the results and finally major conclusions follows.

II. LITERATURE REVIEW

Based on a 1983 survey, Brown et al. (1983) found (for studies conducted between 1973 and 1983) that a 10 percent increase in the minimum wage would result in a 1 to 3 percent reduction in teenage employment. However another contemporary study——by Meyer & Wise (1983) could not find evidence in favor of significant increased earning or decreased employment. Baker, Benjamin & Stanger (1999) examined the effects of minimum wage legislation in Canada over the period 1975-93. Based on a low frequency variation analysis of the data, they found that for teenagers a 10 percent increase in the minimum wage was associated with roughly a 2.5 percent decrease in employment. However, the high-frequency variation analysis showed that the elasticity is positive and insignificant. Using panel data on state minimum wage laws and economic conditions for the years 1973 to 1989, Neumark and Washer (1992) revaluated the effects of the minimum wage on employment. They too found that a 10% increase in the minimum wage causes a decline of 1% to 2% in employment among teenagers and a decline of 1.5% to 2% in employment for young adults, similar to the ranges suggested by earlier time-series studies. Neumark and Wascher (1992) claimed to have found empirical support for 3 propositions: 1. A higher minimum wage leads to a lower teenage employment-population rate. 2. The effect of the minimum wage on employment can be seen within a year, but becomes stronger after 2 years. 3. In states with legal subminimum wages, a significant fraction of teenage employees are paid a subminimum wage, and the availability of a subminimum wage blunts the disemployment effect of the minimum wage. However, subsequent analysis of Neumark and Wascher's data raised a challenge to the view of the minimum wage that they espoused. The Card et al. (April 1994) analysis of the same data showed that state-specific minimum wage increases during the 1970s and 1980s had no systematic effect on teenage employment.

Using data from a longitudinal survey of fast food restaurants in Texas, Katz and Kruger (1992) examined the impact of changes in the federal minimum wage on the low-wage labor market. The authors came up with four main conclusions. First, the survey results indicated that less than 5 percent of fast food restaurants used the new youth sub-minimum wage even though the vast majority paid a starting wage below the new hourly minimum wage immediately before the new minimum went into effect. Second, although some restaurants increased wages by an amount exceeding that necessary to comply with higher minimum wages in both 1990 and 1991, increases in the federal minimum wage at the time greatly compressed the distribution of starting wages in the Texas fast food industry. Third, *employment increased relatively in those firms likely to have been most affected by the 1991 minimum wage increase*. Fourth, changes in the prices of meals appeared to be unrelated to mandated wage changes. These findings were not consistent with the conventional views of the effects of increases in a binding minimum wage.

A study of New Jersey and Pennsylvania's restaurant industry, found that a rise in the minimum wage did not reduce employment (Card & Kruger, September1994). They found that relative to the stores in Pennsylvania (where no rise in wages took place), fast food restaurants in New Jersey (where the minimum wage increased from $4.25 to $5.05 per hour) increased employment by 13 percent). They also compared employment growth at stores in New Jersey that were initially paying high wages (and were unaffected by the new law) to employment changes at lower-wage stores. Stores that were unaffected by the minimum wage had the same employment growth as stores in Pennsylvania, while stores that had to increase their wages increased their employment. Later, Neumark and Washer (1995) re-evaluated the evidence from Card and Krueger's (CK) New Jersey-Pennsylvania minimum wage experiment, using new data based on actual payroll records from 230 Burger King, KFC, Wendy's, and Roy Rogers restaurants in New Jersey and Pennsylvania. They compared results using this payroll data to CK's data, which were collected by telephone surveys. They found that the data collected by CK appear to indicate greater employment variation over the eight-month period between their surveys than do the payroll data. For example, in the full sample the standard deviation of employment change in CK's data is three times as large as that in the payroll data. Second, estimates of the employment effect of the New Jersey minimum wage increase from the payroll data lead to the opposite conclusion from that reached by CK. For comparable sets of restaurants, differences-in-differences estimates using CK's data imply that the New Jersey minimum wage increase (of 18.8 percent) resulted in an employment increase of 17.6 percent relative to the Pennsylvania control group, an elasticity of 0.93. In contrast, estimates based on the payroll data suggest that the New Jersey minimum wage increase led to a 4.6 percent decrease in employment in New Jersey relative to the Pennsylvania control group. This decrease is statistically significant at the five-percent level and implies an elasticity of employment with respect to the minimum wage of -0.24. However, in a later re-analysis based on a longitudinal sample and a repeated-cross-section sample, Card and Kruger (2000) found a similar or slightly faster employment growth in New Jersey relative to eastern Pennsylvania after the rise in New Jersey's minimum wage. They also used ES-202 data to measure the effects of the 1996 increase in the federal minimum wage, which raised the minimum wage in Pennsylvania but not in New Jersey, and found no indication of relative employment losses in Pennsylvania. Studying the industry-based data between 1975 and 1992, Dickens et al. (1999) found that the minimum wage compressed the distribution of earnings but did not have a negative impact on employment.

The above-mentioned studies assumed a partial equilibrium framework. General equilibrium models have also been employed to examine the economic impact of alternative labor market policies including minimum wage studies. Most studies using a computable general equilibrium (CGE) approach are done at the national level. Though the studies based on a CGE approach are essentially similar, they differ from each other in problem orientation and model specification. In a study made of the Estonian Labor market, Hinnosaar (2004-5) used a general equilibrium model to compare the impact of different labor market policies on unemployment and employment. This study measured the impact of increase in benefit replacement rates, tax allowances and unions bargaining power in the wage bargaining process on the overall economy. In this model, each industry uses only one type of labor, either low-skilled or high-skilled (which differs by productivity). As union bargaining power increases, the wage of low-skilled labor increases, which leads to decrease in the high-skilled workers' wage, and an increase in unemployment, a decrease in employment for both skill groups and a decrease in production and consumption. As overall price increases, demand is reduced, which further translates into decrease in employment and production.

In a study made on the impact of Tourism industry on the Jamaica and Trinidad & Tobago economies, Savard (2005) assumed formal and informal labor markets and some unemployment. Each labor category was linked together by the possibility of moving from one category to another. In his model, changes in the real wage takes place through the adjustment in producers' price since the nominal wage is fixed and it is fixed above the natural equilibrium level. Nominal wage rigidity creates an excess supply of labor in the formal sector and the real wage determines the total demand for labor in the formal sector. When demand decreases formal workers are laid off and they can then decide to work in the informal sector or to be unemployed if their reservation wage (the minimum wage a worker is willing to work for) is higher than the informal sector wage. Balancing this supply behavior with demand will determine the informal sector wage. The unemployed can be divided into two sub-groups: rationed and waiting unemployed. An increase in formal sector labor and an increase in the informal sector wage will contribute to lowering unemployment. The impact of tourism on the two different Caribbean countries produce similar effects but the relative importance of the tourism sector in Jamaica contributes to producing more favorable effects in the economy in general and in the tourism sector specifically. In both countries, the simulation produces positive effect on the output of the tourism sector and positive effect on important variables in the economy such as the GDP and government income. The simulation has a negative impact on employment but this negative effect is quite small and is likely to be attenuated by growth effects in the tourism sector, which cannot capture in the model the amount of similarities, which explains why the results are relatively comparable.

Carneiro and Arbachel (2006) used a CGE model and assessed the effects of trade liberalization and changes in the minimum wage on macroeconomic indicators (employment, poverty and inequality) in Brazil. The production functions in their model employs three factors: labor, capital and intermediate inputs, and there are total eight different types of laborers, based on their status of labor contract and schooling. The minimum wage enters into their model indirectly. Carneiro and Arbachel found that trade liberalization contributes to improved economic welfare by means of greater output, lower domestic prices, and higher labor demand, but that the benefits tend be appropriated by the most skilled workers in the most trade-oriented sectors, as opposed to the predictions of the Hecksher-Ohlin and Stolper-Samuelson (HOS) theorems.

In a study made on labor market rigidities in developing countries, Decaluwe et al. (2000) found that the presence of a minimum nominal wage for the formal workers may reduce the gains stemming from the customs union reform. They used a multi-country and multi-sectoral computable general equilibrium model (CGE) of UEMOA (the Western African Economic and Monetary Union) countries to assess the impact of customs union reform. Their main focus, however, was on the economic impact of minimum wage rigidity rather than a change in the minimum wage.

Turning to Washington state minimum wage research, in a study of Oregon and Washington restaurant & drinking establishments, Scott Bailey and Eric Moore (2004) investigated whether minimum wage increases in each state affected employment, hiring, separations, and wages of young workers in this industry. They chose workers between ages 14 to 18 for their study. They found that in general, employment fell by more (increased by less) in the state with the increasing minimum wage. Also, in general, separations fell by more (increased by less) in the state with the increasing minimum wage, and earnings increased by more (fell by less) in the state increasing minimum wage. In Oregon, teen jobs were declining before the minimum wage was increased. However, in Washington, there did appear to be some negative impact from raising the minimum wage. In both states, the effects of the recession were much stronger than the minimum wage effect.

Schotzko and Holland (2005) reviewed the minimum and average, wage rate data from several states that are significant competitors with the Washington potato industry. Their study suggests that labor market conditions are sufficiently different to make it difficult translate differences in minimum wage rates and average wage rates into differences in employer cost per hour. A closer look at conditions in Idaho, the most important competitor of the WA State potato industry, indicates that the steady growth in the Washington minimum wage rate has resulted in a fresh potato market cost disadvantage relative to Idaho. The authors found while the improvement in wage rates caused by the escalating minimum wage rate will improve incomes for some individuals that improvement would come at a cost in the form of lost jobs in the packing of fresh potatoes. The eastern Washington communities in which these jobs are currently located are limited in their ability to attract new businesses, and may suffer a reduction in community viability.

According to a study by Krista Glenn (2003), in WA state minimum wage workers tend to be concentrated in just a few industries as follows: Accommodation and Food services, Retail sales, Agriculture, Forestry and Fishing and Health Care and Social Assistance. Together these four industries account for 30 percent of all jobs in Washington, but 70 percent of all minimum wage workers. The study also found that minimum wage workers tend to be concentrated in specific occupations across industries such as food preparation and serving workers, clerks, attendants, cashiers, agricultural crop workers, home health aids, child care workers, and building and grounds cleaning workers, and a large proportion of minimum wage workers in Washington either work part time or in temporary or seasonal jobs. A larger percentage of workers in small firms earn minimum wage than do workers in large firms.

In another study made on the economic impact of the WA minimum wage, Vedder and Gallaway (2003) estimated that job loss as a result of minimum wage rise (between 1999and 2002) was likely to be not less than 24,000 (0.8 percent of the labor force) and may be as high as 48,000 — after correcting for the impact of the business cycle turndown. Some occupations relying heavily on relatively less skilled labor were particularly impacted. The restaurant industry was estimated to suffer more job losses than most industries, and if the shortening of hours were taken into account, the employment effects may well be double or triple as severe as was typical of other industries. According to Vedder and Gallaway Agriculture, competing in highly competitive markets where farmers have no control over price, probably suffered not only from job loss, but from the profit squeeze that the minimum wage imposed, as evidenced by a noticeable drop in the number of farm proprietors (unlike in earlier periods, where the number had grown).

The critics of Washington's minimum wage law have repeatedly pointed to the state's relatively high minimum wage as a cause of its higher than average unemployment rate. However, the analysis by Watkins (2004) argued for an absence of such causal connection. In a longitudinal study, the United States as a whole and Washington State in particular, continued to lose jobs since the official end of the recession in November 2001, but Washington has lost jobs at a lower rate than the national average. In fact, 8 of the 11 states that had a minimum wage above the federal level in 2003 were doing better at job creation than the United States as a whole. The jobs that Washington lost were concentrated in high wage sectors, especially manufacturing. Low-wage sectors of WA state economy have done relatively well, and are even experiencing some job growth. At the same time, Washington's working age population is estimated to be growing at a faster pace than the national average. Washington's unemployment rate has been consistently above the national average for decades, *including during periods when the state minimum wage matched the federal level.* Since 1970, Washington's annual unemployment rate fell below the national rate in only 3 years – 1990, 1991, and 1997.

In general, the research reviewed in this section tends to indicate that raising the minimum wage decreases employment and hours worked, but there was virtually nothing said on the overall effect of a rise in minimum wage on the broader economy or the welfare of households. To address these issues, we employ a state of Washington, Computational General Equilibrium (CGE) model.

III. THE WASHINGTON CGE MODEL – DISCUSSION OF THE THEORETICAL MODEL

CGE models are multi-sector models of the economy. They are based on Walrasian general equilibrium models of market-clearing on both the product and the factor markets. CGE models have been primarily used to analyze tax and trade policies, but have also been used to examine the economic impact of minimum wages at the national level. As in any neo-classical model, producers are assumed to be profit maximizers, and in typical CGE methodology they can sell their output either on the domestic market or on the export market, based on relative prices. Households maximize utility by consuming a mix of domestic and imported goods. The composition of domestic supply depends on the relative prices of domestic products and imports.

In the Washington CGE model, households are modeled as a representative agent assumed to have Stone-Geary preferences and industries are modeled as representative producers assumed to have CES production technologies. There is endogenous determination of equilibrium prices (commodity prices and factor prices to clear the product and factor markets. Specific functional forms are used to capture the behavior of economic agents. The parameters of these functions are obtained by 'calibration' to a dataset (usually a Social Accounting Matrix – a matrix showing income and expenditure flows in an economy) for a given year.

Like many other CGE models, a constant elasticity of substitution (CES) type production function was used to model producer behavior. The Leontief-cum-CES production function for a given industry has the following features – fixed proportions of intermediate inputs, but capital/ labor substitution for primary factors for a given industry. The Leontief part of the production function ensures "weak separability" between primary (labor and capital) and intermediate factors. The demand for labor and capital is derived from the first-order conditions of profit maximization taking into account the value-added or net price. In this study, two classes of labor were identified—minimum wage labor and all other labor. The production function was configured to allow substitution between other labor and capital at the first level and then substitution between that aggregate and minimum wage labor. For a formal statement of this process see Appendix 3.

CGE models of trade allow for imperfect substitution between state produced goods and goods from the rest of the U.S. and the rest of the world. An Armington function is used to capture the substitution possibilities between state produced goods and imported goods for both firms and households. In other words, the Armington aggregate is a composite good consisting of state produce and imported goods. The Armington function is of the CES type. The higher the value of the Armington elasticity, the easier is the substitution between state-produced and imported goods.

Since this is a regional model, we have used the Armington function at two levels – in the first stage we allow for substitution between domestic goods (produced in Washington) and imported goods; in the second stage we differentiate between domestic imports (imports from rest of the United States) and foreign imports (imports from rest of the world), and allow substitution to take place between them. The foreign exchange rate is assumed fixed. Government expenditure and investment are exogenous in the model.

As mentioned before, there is endogenous determination of prices to clear all the markets. Initially, consumer prices of domestic goods and imports, the world price of exports, and the exchange rate are all set equal to one. The price of foreign imports (from rest of the world) is assumed exogenous, that is, the world price is given. In this setting we are therefore make the "small" country assumption that Washington's production does not affect import prices. The consumer price index is set to be the numeraire.

The export supply function, derived from a constant elasticity of transformation (CET) function, specifies the value of exports as a function of the ratio of state level and international export prices. The CET function defines the production possibilities available to a given industry assuming exported products are differentiated from state marketed products produced by a given industry. The regional export composite is a function of the price of exports to rest of the U.S. and foreign sources.

The price of a foreign produced commodity is a function of the world price, and the foreign exchange rate. Import demand is the first-order condition obtained from the cost minimization problem of buying a given amount of the composite commodity. Composite commodity supply (Armington aggregate) is a function of the price of imports and the price of regionally produced goods. The regional import composite is a function of the price of imports from rest of the U.S. and foreign sources.

Most of the parameters of the model are calibrated from the SAM, however, the Armington elasticities, the constant elasticity of transformation (CET) elasticities (counterparts of the Armington elasticities on the export side), the elasticity of capital/labor substitution in production, the household income elasticity, and the export demand elasticity are all free parameter to be specified by the model user.

GAMS software (using the PATH solver) was used to construct and solve this model, a simultaneous system of non-linear equations. The GAMS code representing the model equations is available from the author's web page. The model is initially solved to replicate the base year SAM by appropriately calibrating the parameters of the model. A 2002 social accounting matrix (SAM) for the state of Washington from the IMPLAN (Impact Analysis for Planning) database was used to construct a 28-sector model of the Washington economy (see Appendix 1 for the industry aggregation scheme). The CET elasticities were set equal to 2 for the traded sectors, while they were set equal to 0.5 for the non-traded sectors. Armington elasticities were taken from the literature more will be said of assumed values of the elasticities of capital/labor substitution a key parameter for this study.

IV. DATA - THE MINIMUM-WAGE LABOR MARKET IN WASHINGTON

The most comprehensive description of the minimum wage labor market (Glenn 2003) in Washington reported that minimum wage workers were highly concentrated in a few industries and in specific occupations within those industries. These minimum wage workers are often part-time, temporary, or seasonal. These industries and occupations with the exception of agriculture and food processing tend to be somewhat more concentrated in urban areas than in rural areas, but given the importance of agriculture and food processing in rural areas a larger proportion of total jobs are minimum wage jobs in rural areas.

The distribution of minimum wage jobs and other jobs is shown across Washington industries in Table 1 (see Appendix 2 for further explanation of the procedure used to describe the labor market in this way). In 2002, there were 3.58 million full time and part time jobs in Washington, out of which 85,000 jobs were minimum wage jobs i.e. 2.39% of the total workers were employed as minimum wageworkers (Table 1). Agriculture and Food Services & Drinking Places are the only industries, where more than 10% of the jobs are of minimum wage jobs (Table 1). Also, these two sectors employ a significant percent of total minimum wage workers employed across Washington State. In particular, Food Services & Drinking Places and the Agriculture industry employ 27 and 16 percent of the total minimum-wage workers employed in the state respectively. General Merchandise Retailing, where minimum wage laborers comprise 4.49% of total employment, makes up 15 % of total state employment of minimum wage workers. In contrast, the Accommodation industry, which employs almost 10% of its total labor as minimum wage labor, makes up only 3 % of the total minimum wage workers employed across state. Except for agriculture these are predominantly industries in the service or retail sectors, which are tied to the population centers they serve. They have little ability to move their operations out of state. For example, a fast food restaurant has to be in the neighborhood where it is convenient to sell food. This holds true for hotels, stores, and hospitals as well. Agriculture is also tied to its land base in Washington. However, Washington agriculture may diminish generally due to price competition from other regions or in response to a minimum wage increase may mechanize and use fewer workers. While these industries are not generally mobile in a classic sense, their future decisions regarding investment imply that their capital is mobile in and out of the Washington economy in the long run. In that sense, the industries are mobile.

V. EMPIRICAL MODEL - SIMULATION SCENARIOS

Three simulations were conducted for the purpose of this study.

I. The first simulation was done to examine the effects of a five percent increase in the minimum wage assuming short-run factor market behavior. (Capital fixed by industry, other labor perfectly mobile across sectors and minimum wage labor perfectly mobile across sectors). Minimum wage labor was assumed to be perfectly elastic in supply and other wage labor to have a labor supply elasticity of 0.5. The elasticity of substitution between other labor and capital and between the aggregate of capital and other labor and minimum wage labor both assumed to be 0.5 (See Appendix 3). The model thus captures a fixed capital endowment for the Washington economy and represents expected labor market adjustments in the relatively short-run given the assumption of fixed sector specific capital.

II. The second simulation was also conducted with the same five-percent increase in the minimum wage, but under the assumptions of long-run factor market behavior, which assumes that capital is perfectly mobile across industry and the region, other labor is perfectly mobile across industries (and the region) and minimum-wage labor is perfectly mobile across industries (and the region). Minimum wage labor is assumed to be perfectly elastic in supply and other wage labor and capital are assumed to have a supply elasticity of 0.5. The elasticity of substitution between other labor and capital and between the aggregate of capital and other labor and minimum wage labor remained at 0.5 as in scenario 1.

III. In the third simulation the wage shock and factor supply elasticities were the same as in scenario 2, but the elasticity of substitution of capital for other labor and for that aggregate with minimum wage labor was assumed to be highly elastic (10.0) meaning that the substitution of capital for labor is very easy. In this case we expect to see much more job loss in response to the minimum wage increase as more capital is substituted for labor. The percentage loss in jobs will be more than the percentage gain in wages so that the minimum wage bill should decrease in response to the minimum wage increase. Empirical values of the elasticity of capital/labor substitution are typically in the .3 to 2.0 range so this experiment with a very high elasticity is not supported by empirical work, but is of interest in order to view the simulated economic response.

VI. DISCUSSION OF RESULTS

The Economic Impact of a Minimum Wage Increase

In the CGE model, the wage shock is presented as an upward shift in horizontal supply curve for minimum wage labor. In direct response producers will reduce minimum wage employment to the point where the new minimum wage labor supply curve intersects the producers' demand for minimum wage labor curve. However, this labor demand curve is endogenous and will shift as a function of changes in industry output price and the price of other inputs used in a given industry's production process. At the same time producers will attempt to substitute other labor and capital for the now more expensive minimum wage labor. The ease of substitution is a function of the specified elasticities of labor/capital substitution.

Scenario I

In scenario-I, the counter-factual minimum wage job loss for the Washington economy was 2,127 jobs out of the baseline 85,500 jobs (Table 2) or a loss of 2.49 percent of total minimum wage jobs (Table 2). The greatest loss occurs in those sectors employing large numbers of minimum wage workers, namely Agriculture and Food Service and Drinking Places, but as all industries employ some minimum wage workers, minimum wage jobs are lost in all industries. However, given the minimum wage increase, the minimum wage bill increased by $25.32 million or 2.39 percent (Table 6). This result was expected and is a function of the assumed inelasticity of factor substitution.

In spite of the ability to substitute other labor and capital for minimum wage labor, there was a net loss of other labor of 340 jobs out of the baseline 3,499.000 jobs or about 0.0097 percent of other labor jobs (Table 3). Here there is a mix of industries with employment gains and employment losses. Industries with minimal use of minimum wage labor such as manufacturing are able to maintain their competitiveness and substitute other labor for minimum wage labor and increase employment of other labor. For industries using a more significant amount of minimum wage labor the minimum wage increase results in reductions in supply (competitiveness) that limits the substitution of other labor for minimum wage labor resulting in a reduction of other labor employment in those industries.

Supply decreases for various sectors, e.g. Agriculture and Food Services & Drinking as a function of the increase in labor cost stemming from the minimum wage increase (Table 5). These are the major sectors that employ a high proportion of minimum-wage laborer. In response to the minimum wage increases, these sectors reduce their employment, which results in less production (given the fixed capital). The decrease in supply was approximately $22 million for Agriculture and $20 million for Food Service & Drinking Places (Table 5). While these are large numbers, in each case the percent change in each of those industries's baseline supply is less than one-half of one percent (Table 5).

Not all industries experienced a loss in supply. Industries with little minimum wage employment in some cases actually increased supply (Table 5). This comes from general equilibrium effects that actually result in a small increase in commodity demand and the substitution of other labor for higher cost minimum wage labor to meet the increase in demand. The demand increase can stem from increased income from low-income households who actually gain nominal income from the minimum wage shock or from increased competitiveness in national or international markets due to lower overall industry intermediate input costs.

The change in Gross Domestic Product (GDP) at factor cost consisted of an increase of $26 million increase in the minimum wage labor wage bill, accompanied by a $26 million reduction in the other labor wage bill and a $12 million reduction in the capital bill (Table 6). The net reduction in Gross State Product was $12 million or roughly -.0052 percent of the $202 billion Gross State Product baseline total (Table 6). The wage bill for minimum wage workers was increased by 2.39 percent at the expense of a loss of .0052 percent in baseline nominal Gross State Product.

While there is an overall net loss in household welfare as a result of the wage shock, there is a gain in welfare measured as the change in equivalent variation for low and lower middle income households (HHD1 to HHD4 in Table 7). The increase in the wage bill for minimum wage workers captured by low income households is more than enough to offset the loss in other labor income and capital income to these households as well as the slight increase in Washington's consumer price index. On balance, the welfare of low-income households is increased by the minimum wage increase.

The results from Scenario I support the idea that increases in the minimum wage do increase welfare of low-income households albeit at a decrease in welfare of middle and upper income households. The loss in minimum wage jobs was more than offset by the increase in minimum wage for an overall increase in the minimum wage bill. The increase the minimum wage bill was almost exactly offset by the loss of the other labor wage bill. Some substitution of other labor for minimum wage took place but in general, there was small job loss for other labor, along with a slight decrease in the market-clearing wage for other labor. Although the focus of this research was on the economic impact of a minimum wage increase, it is important to remember that as a share of the labor force in Washington, minimum wage jobs make up only 2.40 percent of total jobs in the Washington economy.

Scenario II

As noted previously the difference between Scenario I and Scenario II is the capital mobility assumption. In scenario I capital is assumed fixed by industry. In Scenario II capital is assumed mobile across industries with a regional supply elasticity of 0.5.

The loss of minimum wage jobs in Scenario II was slightly greater than for Scenario I, but the loss of other labor jobs increased by roughly 52 percent compared to Scenario I (Table 3) Capital moves from the industries where minimum wage labor is most important to industries where minimum wage labor is relatively small (Table 3). As a result, the variation in the change in other jobs across industries is greater in Scenario II than in Scenario I. Agriculture exhibits much greater loss in both minimum wage jobs and other labor jobs than any other sector, reflecting the fact that agriculture is an important user of minimum wage labor and is an industry that faces a nearly perfectly elastic demand curve preventing any passing of higher production costs on to agricultural buyers. As capital moves into those industries that are less damaged by the minimum wage increase the employment of other labor increases relative to labor increase observed in Scenario I when capital was assumed fixed by sector (Table 3).

The loss in gross state product (GSP) in Scenario II is almost identical to Scenario I and is a combination of several alternative forces acting on capital. Capital moves to those industries less affected by the minimum wage increase thus mitigating some of the negative impact stemming from the wage increase, but some capital also leaves the state economy leaving a smaller economic base. The net result is almost the same loss of GSP between Scenario I and II, but increased loss of employment (Tables 2 and 3) and increased loss of commodity supply

(Table 5). The story on change in equivalent variation is almost the same as in Scenario I. The welfare of lower income households is benefited by the wage increase. The welfare of higher income households is harmed by it.

Scenario III

Unlike the two other scenarios, Scenario-III which is like Scenario II except that the elasticity of capital\labor substitution was set at 10 instead of 0.5, showed a reduction in overall welfare (measured through equivalent variation) across all types (HHD1 to HHD9) consumers (Table 7). It was very easy to substitute other labor for capital and the capital-other labor aggregate for minimum wage labor. (It should be noted the value of 10 is higher than available econometric values for the capital/labor elasticity, which are in a range of 0.4 to roughly 2.5.) In response to the increase in the minimum wage, there was a great deal of minimum wage job loss (38 percent of all minimum wage jobs, Table 2) as other labor and capital are substituted for minimum wage labor. The result was a net gain, economy wide, in other labor jobs and in the employment of capital (Table 3 and Table 4).

The loss of minimum wage jobs was 32,300 compared to losses of approximately 2,200 jobs in Scenarios I and II. The percent loss in jobs, more than offsets the percent increase in the minimum wage so that the minimum wage bill declined by $367 million (Table 6). The other labor, wage bill declines by $179 and the capital bill actually increases by $3 million for a net loss of GSP by $543 million. When it is easy to substitute capital for labor, the minimum wage increase is harmful, especially to minimum wage labor, and there is a large loss minimum wage jobs, and in the minimum wage bill. This is accompanied by over a $1 Billion reduction in commodity supply (Table 5) and a large loss in GSP relative to scenarios I and II. In Scenario III, the change in equivalent variation was negative for every household group (Table 7).

VII. CONCLUSIONS

This paper illustrates a general equilibrium approach to an assessment of the economic impact of increases in Washington's minimum wage on the Washington economy. As far as we know this is the first study to use a CGE modeling approach to address the impact of minimum wage policy at the state level. Given the advancements in regional CGE modeling and the relative ease and convenience of generating general equilibrium models of state economies, and the consistency of CGE models with neoclassical theory, the approach deserves more attention. The advantage of a CGE approach over an econometric model lies in the paucity of state level time series data suitable for an econometric model and the ability of the CGE model to isolate economic impacts to just a minimum wage shock holding all other exogenous variables and parameters in the model constant.

Washington's economy generated nearly 3,600,000 full and part time jobs in 2002 (Table 1). While 85,000 of those jobs were minimum wage jobs, that figure represents only 2.40% of total employment. While minimum wage jobs are important to selected sectors, they make up a small part of the total jobs.

Results from this study showed that for when the capital\labor elasticity of substitution of is assumed to be low (0.5), that a five percent increase in Washington's minimum wage results in modest minimum wage job loss, an increase in the minimum wage bill, and in an increase in equivalent variation for Washington's low income households. This finding holds in both the short-run (capital fixed by industry) and the long-run (capital mobile across industries and state borders). The loss of gross state product from the five percent minimum wage increase was roughly $12 million or -0.006 percent of baseline GSP. These findings are consistent with the view that minimum wage increases are absorbed by the Washington economy with very little overall damage and that on balance the such increases are beneficial to minimum wage workers in the sense that minimum wage bill is increased in both the short-run and long-run. An important contribution of this study is the establishment of a range of expected job loss associated with a representative minimum wage shock of five percent increase. The range is on the order of two to perhaps four thousand jobs. This helps to explain why some econometric studies have found a positive relationship between increases in the minimum wage and the number of jobs. National cyclical effects or even price shocks in important industries can generate state level, employment effects far larger that the total economy job impacts estimated in this paper.

Only when the capital\labor elasticity of substitution of is assumed to be very high (10.0) are these findings reversed. In this case the minimum wage job loss more than offsets the wage gain and the minimum wage bill falls, GSP declines by more than $500 million and there is a negative change in equivalent variation for low income and high income households. It may be noted that the predicted job loss of approximately 32,000 jobs is on the order of the job loss estimated by Vedder and Galloway (2003). The implied capital\labor elasticity of substitution (10.0) implicit in their analysis, is greater than the high range of empirically estimated values of this elasticity.

The model used in this study was comparative static, where a single wage shock is introduced. The real world time adjustment period is on the order of one to two years. In that period, Washington's minimum wage could be adjusted several times. Given, the nature of the annual changes in Washington's minimum wage an alternative modeling approach would involve a sequence of wage shocks solved sequentially in order to capture expected economic impact of minimum wage shocks over a several year period. This would be relatively easy to do and is a logical next step in future analysis. The other item that needs attention is the values of elasticity of capital-labor substitution used in the model. Empirical capital-labor substitution values by industry are available in the literature and in future work could be incorporated into the Washington model. However, it is not believed that the results would be greatly different than the findings in scenarios one and two in this paper because the elasticities are in the same range as used in this paper.

TABLE 1: INITIAL LABOR DEMAND ACROSS WA INDUSTRIES (YEAR 2002)

	Initial Labor Situation					
	Minimum Wage Labor	Other Labor	Minimum Labor as a % of Total Labor employed by the respective industry	Other Labor as a % of Total Labor employed by the respective industry	Minimum Labor as a % of total economy wise minimum labor	Other Labor as a % of total economy wise other labor
Agriculture	13697	87899	13.48	86.52	16.02	2.51
Forestry and logging	42	9654	0.43	99.57	0.05	0.28
Fishing, hunting and trapping	201	8374	2.34	97.66	0.24	0.24
Mining and quarrying	10	5191	0.19	99.81	0.01	0.15
Utilities	13	4971	0.26	99.74	0.02	0.14
Construction	691	242180	0.28	99.72	0.81	6.92
Manufacturing	3029	320413	0.94	99.06	3.54	9.16
Wholesale trade	1654	128563	1.27	98.73	1.93	3.67
Transportation & warehousing	1121	113019	0.98	99.02	1.31	3.23
Motor vehicles & parts	105	44913	0.23	99.77	0.12	1.28
Food & beverage stores	5257	62891	7.71	92.29	6.15	1.80
General merchandise	*12555*	*267150*	*4.49*	*95.51*	*14.68*	*7.63*
Information	1760	100900	1.71	98.29	2.06	2.88
Finance and insurance	742	141703	0.52	99.48	0.87	4.05
Real estate and rental and leasing	2311	133218	1.71	98.29	2.70	3.81
Profl., Scinc. & Tech services	1117	243352	0.46	99.54	1.31	6.95
Mgt. of company & enterprises	8	30061	0.03	99.97	0.01	0.86
Admin support & waste Mgt.	2744	156747	1.72	98.28	3.21	4.48
Education services	449	44048	1.01	98.99	0.53	1.26
Health care and social assist.*	673	191070	0.35	99.65	0.79	5.46
Nursing & residential care	1458	52920	2.68	97.32	1.71	1.51
Child day care services	1250	20507	5.75	94.25	1.46	0.59
Social assistance	1218	40537	2.92	97.08	1.42	1.16
Arts entertainment and recreation	2360	73485	3.11	96.89	2.76	2.10
Accommodation	2196	21039	9.45	90.55	2.57	0.60
Food services & drinking places	23143	193955	10.66	89.34	*27.07*	5.54
Other services**	3319	199827	1.63	98.37	3.88	5.71
Government enterprises	2377	560677	0.42	99.58	2.78	16.02
Total Labor Employed	85,500	3,499,266	2.39	97.61	100.00	100.00

*Except nursing and residential care

** Except public administration

TABLE 2: CHANGE IN EMPLOYMENT FOR MINIMUM-WAGE LABOR

	Base model	Difference in Min-Wage Labor Demand		
		Scenario I	Scenario II	Scenario III
Agriculture	13,697	-374	-429	-5127
Forestry and logging	42	-1	-1	-16
Fishing, hunting and trapping	201	-5	-5	-79
Mining and quarrying	10	0	0	-4
Utilities	13	0	0	-5
Construction	691	-17	-17	-266
Manufacturing	3,029	-73	-74	-1171
Wholesale trade	1,654	-40	-40	-638
Transportation & warehousing	1,121	-27	-27	-433
Motor vehicles & parts	105	-3	-3	-41
Food & beverage stores	5,257	-129	-129	-1993
General merchandise	12,555	-305	-305	-4783
Information	1,760	-42	-41	-681
Finance and insurance	742	-18	-18	-287
Real estate and rental and leasing	2,311	-56	-56	-895
Profl., Scinc. & Tech services	1,117	-27	-27	-431
Mgt. of company & enterprises	8	0	0	-3
Admin support & waste Mgt.	2,744	-67	-67	-1058
Education services	449	-11	-11	-173
Health care and social assist.*	673	-16	-16	-260
Nursing & residential care	1,458	-35	-35	-559
Child day care services	1,250	-30	-30	-471
Social assistance	1,218	-30	-30	-464
Arts entertainment and recreation	2,360	-58	-58	-904
Accommodation	2,196	-54	-54	-834
Food services & drinking places	23,143	-572	-574	-8555
Other services**	3,319	-80	-81	-1280
Government enterprises	2,377	-57	-57	-917
Total	85,500	-2,127	-2,184	-32,326
% job change		-2.49	-2.55	-37.81

*Except nursing and residential care
** Except public administration

TABLE 3: CHANGE IN EMPLOYMENT FOR OTHER LABOR

	Base model	Difference in Other Labor Demand		
		Scenario I	Scenario II	Scenario III
Agriculture	87,899	-278	-635	1413
Forestry and logging	9,654	0	-26	-90
Fishing, hunting and trapping	8,374	0	-15	-89
Mining and quarrying	5,191	1	3	-31
Utilities	4,971	0	-4	-37
Construction	242,180	5	10	-153
Manufacturing	320,413	10	-21	-1191
Wholesale trade	128,563	-6	-12	-375
Transportation & warehousing	113,019	1	5	-387
Motor vehicles & parts	44,913	4	7	-116
Food & beverage stores	62,891	-19	-16	526
General merchandise	267,150	-27	-13	1398
Information	100,900	14	106	-415
Finance and insurance	141,703	13	35	-577
Real estate and rental and leasing	133,218	0	-17	-650
Profl., Scinc. & Tech services	243,352	21	42	-767
Mgt. of company & enterprises	30,061	5	12	-128
Admin support & waste Mgt.	156,747	-18	-7	-356
Education services	44,048	-3	-6	-151
Health care and social assist.*	191,070	22	38	-669
Nursing & residential care	52,920	-3	0	53
Child day care services	20,507	0	0	257
Social assistance	40,537	-14	-11	194
Arts entertainment and recreation	73,485	-17	-17	150
Accommodation	21,039	-4	-4	153
Food services & drinking places	193,955	-105	-108	4575
Other services**	199,827	-4	-4	-478
Government enterprises,	560,677	64	145	-1518
Total	3,499,266	-340	-517	542
% job change		-0.0097	-0.0148	0.0155

*Except nursing and residential care

** Except public administration

TABLE 4: CHANGE IN EMPLOYMENT OF CAPITAL

	Difference in Capital Demand		
	Scenario I	Scenario II	Scenario III
Agriculture	fixed	-4.485	11.55
Forestry and logging	fixed	-2.160	-5.02
Fishing, hunting and trapping	fixed	-0.826	-3.47
Mining and quarrying	fixed	0.056	-0.47
Utilities	fixed	-0.540	-3.06
Construction	fixed	-0.115	3.43
Manufacturing	fixed	-1.167	-6.11
Wholesale trade	fixed	-0.426	-0.26
Transportation & warehousing	fixed	-0.103	-0.92
Motor vehicles & parts	fixed	0.008	0.04
Food & beverage stores	fixed	-0.137	4.11
General merchandise	fixed	-0.191	9.42
Information	fixed	8.617	-12.20
Finance and insurance	fixed	0.713	-6.89
Real estate and rental and leasing	fixed	-2.622	-22.89
Profl., Scinc. & Tech services	fixed	0.274	-1.71
Mgt. of company & enterprises	fixed	0.064	-0.35
Admin support & waste Mgt.	fixed	-0.260	0.85
Education services	fixed	-0.064	-0.16
Health care and social assist.*	fixed	0.200	-1.68
Nursing & residential care	fixed	-0.031	0.96
Child day care services	fixed	-0.013	2.12
Social assistance	fixed	-0.011	0.22
Arts entertainment and recreation	fixed	-0.206	2.87
Accommodation	fixed	-0.150	4.89
Food services & drinking places	fixed	-0.586	23.19
Other services**	fixed	-0.484	1.45
Government enterprises,	fixed	2.155	1.20
Total	fixed	-2.488	1.10

*Except nursing and residential care
** Except public administration

TABLE 5: COMMODITY SUPPLY

	Base model Supply	Change in Supply ($Million)		
		Scenario I	Scenario II	Scenario III
Agriculture	5,558.19	-22.05	-49.51	-65.50
Forestry and logging	2,213.98	-0.06	-5.98	-16.08
Fishing, hunting and trapping	1,039.75	-0.12	-2.03	-10.64
Mining and quarrying	933.13	0.07	0.34	-4.24
Utilities	7,895.12	0.22	-0.92	-24.87
Construction	23,919.97	-0.19	-0.03	-13.87
Manufacturing	79,056.26	-1.62	-10.96	-285.74
Wholesale trade	18,250.93	-1.90	-3.44	-60.81
Transportation & warehousing	14,012.11	-0.74	-0.52	-51.55
Motor vehicles & parts	3,717.61	0.25	0.47	-9.43
Food & beverage stores	4,070.27	-4.07	-4.22	-13.93
General merchandise	13,888.10	-8.76	-8.53	-43.39
Information	30,965.70	1.54	29.95	-102.91
Finance and insurance	20,539.80	0.54	3.49	-63.20
Real estate and rental and leasing	22,166.07	-1.21	-5.77	-74.41
Profl., Scinc. & Tech services	22,598.75	0.77	4.66	-62.95
Mgt. of company & enterprises	3,445.69	0.54	1.29	-13.84
Admin support & waste Mgt.	8,616.66	-2.04	-2.00	-33.84
Education services	3,015.85	-0.29	-0.16	-10.02
Health care and social assist.*	20,978.90	1.33	2.90	-61.33
Nursing & residential care	2,330.59	-0.82	-0.78	-7.93
Child day care services	735.45	-0.79	-0.80	-2.57
Social assistance	1,081.86	-0.95	-0.89	-4.00
Arts entertainment and recreation	2,937.73	-1.71	-2.17	-10.64
Accommodation	1,781.16	-1.46	-1.73	-6.16
Food services & drinking places	9,359.71	-19.66	-21.05	-43.40
Other services**	14,703.37	-2.17	-3.12	-46.80
Government enterprises,	43,981.60	2.28	8.38	-83.84
Total		-63.04	-73.13	-1,227.88

*Except nursing and residential care
** Except public administration

TABLE 6: FACTOR RETURNS AND GROSS DOMESTIC PRODUCTS

	Factor Returns and GDP ($ Million)			
	Base	Scenario I	Scenario II	Scenario III
A. Minimum Wage	1,057.87	1,083.19	1,082.53	690.55
B. Other Labor	129,662.68	129,637.42	129,634.05	129,483.86
C. Capital	71,543.56	71,531.85	71,536.10	71,546.86
GDP at factor Cost = (A+B+C)	202,264.11	202,252.46	202,252.68	201,721.27
Change in GDP as a % of Base GDP		-0.0058	-0.0057	-0.2684
	% change in Factor returns with respect to Base Scenario			
	Base	Scenario I	Scenario II	Scenario III
A. Minimum Wage		2.393	2.331	-34.723
B. Other Labor		-0.019	-0.022	-0.138
C. Capital		-0.016	-0.010	0.005
	Factor Returns as a % of GDP			
	Base	Scenario I	Scenario II	Scenario III
A. Minimum Wage	0.52	0.54	0.54	0.34
B. Other Labor	64.11	64.1	64.1	64.19
C. Capital	35.37	35.37	35.37	35.47

TABLE 7: CHANGE IN EQUIVALENT VARIATION

	Difference in Equivalent Variation		
	Scenario I	Scenario II	Scenario III
HHD1	0.50	0.51	-20.73
HHD2	1.57	1.53	-38.62
HHD3	2.36	2.29	-73.18
HHD4	0.79	0.74	-64.90
HHD5	-3.87	-3.79	-54.99
HHD6	-7.65	-7.46	-66.62
HHD7	-5.10	-4.92	-57.10
HHD8	-5.88	-5.70	-32.84
HHD9	-3.78	-3.67	-20.16

APPENDIX 1:

TABLE 7: MODEL SECTORING SCHEME.

Industry	Sectors included (Sector no. corresponds to IMPLAN 2001 sectoring scheme)
Agriculture	1-13, 18
Forestry	14, 15
Fisheries	16,17
Mining	19-29
Utilities	30,31,32
Construction	33-45
Manufacturing	46 -389
Wholesale Trade	390
Transportation & Warehousing	391- 400
Motor vehicle and parts dealers	401
Food and beverage stores	405
General merchandise and miscellaneous retail	402 - 404, 406 - 412
Information	413 - 424
Finance and insurance	425 - 430
Real estate and rental and leasing	431 - 436
Professional scientific and technical services	437 – 450
Management of companies and enterprises	451
Administrative support and waste manage	452 - 460
Education services	461, 462
Health care and social assistance excep	464 - 467
Nursing and residential care facilities	468
Child day care services	469
Social assistance except child day care	470
Arts entertainment and recreation	471 - 478
Accommodation	479, 480
Food services and drinking places	481
Other services except public administration	482 - 494
Miscellaneous	495 - 509

APPENDIX 2: ESTIMATES OF THE MINIMUM WAGE BILL BY INDUSTRY

Data from the Glenn study were combined with information from the October 2004 Survey of Current Business that showed the ratio of a given industry's full time equivalent (FTE) jobs to that same industry's full and part time jobs. This ratio was used to convert Glenn's FTE minimum wage jobs figures to estimates of full and part time minimum wage jobs by industry. It was necessary to have minimum wage employment be compatible with IMPLAN'S jobs estimates by sector, which are a simple count of full and part time jobs. The minimum wage bill by industry was estimated from Glenn's data by multiplying the industry's FTE jobs by the average hours worked per FTE job to obtain the total minimum wage hours by industry. This was multiplied by the prevailing minimum wage per hour to obtain the minimum wage bill by industry. The FTE minimum wage per year for Washington in 2002 was estimated to be $14,560.

For a given industry with a known wage bill (IMPLAN) the minimum wage bill was subtracted from the total wage bill to obtain the non-minimum or "other labor" wage bill. With this information on jobs, the wage bill and average annual wages per job, the labor market in Washington was bifurcated into two groups—minimum wage labor and other labor.

TABLE 8: DISTRIBUTIONS OF MINIMUM WAGE LABOR

Industry	Min. Wage Jobs, FTE	Min. Wage's Share of Industry's Jobs	Share of Total Min. Wage Jobs	Ratio of FT&PT Jobs to FTE1	Total Min. Wage Jobs2	Estimated Min. Wage Bill In $Millions3
Accommodation and Food Services	21,511	17.4%	29.3%	1.1727336	25,227	313.20
Retail Trade	15,069	6.4%	20.5%	1.1889956	17,917	219.40
Agriculture, Forestry, Fish & Hunt	10,592	17.3%	14.4%	1.2531753	13,274	154.22
Health Care and Social Assistance	4,107	2.1%	5.6%	1.1200137	4,600	59.80
Manufacturing	2,940	1.0%	4.0%	1.0302708	3,029	42.81
Other Services (except Pub. Admin.	2,802	4.5%	3.8%	1.1845509	3,319	40.80
Administrative, Support & Waste Management and Remediation Services	2,519	2.7%	3.4%	1.0893651	2,744	36.68
Real Estate and Rental and Leasing	2,030	5.9%	2.8%	1.1386031	2,311	29.56
Arts, Entertainment, & Recreation	1,953	8.3%	2.7%	1.2083054	2,360	28.44
Local Government	1,771	0.8%	2.4%	1.1961822	2,118	25.79
Wholesale Trade	1,645	1.5%	2.2%	1.0054795	1,654	23.95
Information	1,616	1.3%	1.6%	1.0888424	1,760	23.53
Unknown	1,154	5.1%	1.6%	N/A	N/A	16.80
Professional, Scientific, and Technical Services	1,057	1.0%	1.4%	1.0563677	1,117	15.39
Transportation and Warehousing	1,034	1.6%	1.4%	1.0838991	1,121	15.06
Finance and Insurance	693	0.8%	0.9%	1.0709324	742	10.09
Construction	683	0.6%	0.9%	1.0121616	691	9.94
Educational Services	395	2.4%	0.5%	1.1368804	449	5.75
State Government	216	0.2%	0.3%	1.1961822	258	3.14
Utilities	13	0.2%	0.0%	1.0236088	13	0.19
Mining	10	0.3%	0.0%	1.0215264	10	0.15
Management of Companies and Enterprises	7	0.8%	0.0%	1.0928962	8	0.10
Totals	73,817		99.7%		84,722	1,074.78

APPENDIX 3: TWO-LEVEL NESTED CES PRODUCTION FUNCTION WITH THREE FACTORS OF PRODUCTION

The Washington CGE model uses a combined Leontief-CES production function in which the intermediate inputs are assumed to be Leontief and the factors of production are assumed to be CES. The three factors of production are capital, minimum wage labor, and all other labor. Since there are three factors of production, it is necessary to nest the CES part of the production function using two levels. The first level combines capital and other labor while the second level combines the result of the first level with minimum wage labor and the intermediate inputs.

The first level CES production function is:

$$q_1 = A_1\left(\alpha_1 x_1^{-\rho_1} + (1-\alpha_1) x_2^{-\rho_{-1}}\right)^{\frac{-1}{\rho_1}}$$

where $x_1 =$ capital, $x_2 =$ quantity of other labor and $q_1 =$ the first level composite quantity.

The second level Leontief-CES production function is:

$$q = \frac{A_2}{1-\sum lc}\left(\alpha_2 x_3^{-\rho_2} + (1-\alpha_2) q_1^{-\rho_2}\right)^{\frac{-1}{\rho_2}}$$

where $x_3 =$ quantity of minimum wage labor and *lc* are the Leontief coefficients for the intermediate inputs. q_{L1} from the first equation can be substituted into the second equation to get the final production function.

The factor demand equations are derived by multiplying the price of value added by the partial derivatives of the production function with respect to each factor of production (Fallon & Layard 1975, Papageorgiou and Saam 2005):

$$W_1 = PV * \frac{A_1 A_2 \alpha_1 (1-\alpha_2)}{1-\sum lc} x_1^{-\rho_1-1} q_1^{-\rho_2-1}\left(\alpha_2 x_3^{-\rho_2} + (1-\alpha_2) q_1^{-\rho_2}\right)^{\frac{-1}{\rho_2}-1}\left(\alpha_1 x_1^{-\rho_1} + (1-\alpha_1) x_2^{-\rho_1}\right)^{\frac{-1}{\rho_1}-1}$$

$$W_2 = PV * \frac{A_1 A_2 (1-\alpha_1)(1-\alpha_2)}{1-\sum lc} x_2^{-\rho_1-1} q_1^{-\rho_2-1}\left(\alpha_2 x_3^{-\rho_2} + (1-\alpha_2) q_1^{-\rho_2}\right)^{\frac{-1}{\rho_2}-1}\left(\alpha_1 x_1^{-\rho_1} + (1-\alpha_1) x_2^{-\rho_1}\right)^{\frac{-1}{\rho_1}-1}$$

$$W_3 = PV * \frac{A_2 \alpha_2}{1-\sum lc} x_3^{-\rho_2-1}\left(\alpha_2 x_3^{-\rho_2} + (1-\alpha_2) q_1^{-\rho_2}\right)^{\frac{-1}{\rho_2}-1}$$

Where PV is the value added price, W_1 is the capital rental rent and W_2 and W_3 are the other and minimum wage rates.

APPENDIX 4: A REVIEW OF CES PRODUCTION FUNCTIONS (HENDERSON, JAMES AND RICHARD QUANDT. 1980. MICROECONOMIC THEORY: A MATHEMATICAL APPROACH, 3RD ED.NEW YORK: MCGRAW-HILL, PAGE 111-114)

PROPERTIES

The Washington CGE model is characterized by CES production functions that show the relationship between inputs of capital and labor and commodity output. The class of CES production functions may be expressed in the form:

$$q = A\left[\alpha x_1^{-\rho} + (1-\alpha)x_2^{-\rho}\right]^{-1/\rho} \tag{1}$$

where the parameters $\rho \geq -1,\ A > 0$ and $0 < \alpha < 1$. It is easily verified that (1) is homogeneous of degree one:

$$A\left[\alpha(tx_1)^{-\rho} + (1-\alpha)(tx_2)^{-\rho}\right]^{-1/\rho} = tA\left[\alpha x_1^{-\rho} + (1-\alpha)x_2^{-\rho}\right]^{-1/\rho}$$

The marginal products of the inputs are

$$\frac{\partial q}{\partial x_1} = \frac{\alpha}{A^\rho}\left(\frac{q}{x_1}\right)^{\rho+1} \qquad \frac{\partial q}{\partial x_2} = \frac{1-\alpha}{A^\rho}\left(\frac{q}{x_2}\right)^{\rho+1}$$

which are positive for the domain $x_1, x_2 > 0$. The rate of technical substitution is

$$RTS = \frac{\alpha}{1-\alpha}\left(\frac{x_2}{x_1}\right)^{\rho+1} \tag{2}$$

The RTS is decreasing and the isoquants convex for $\rho > -1$. This also establishes that a CES production function is regular strictly quasi-concave for the domain $x_1, x_2 > 0$.

An expression for the elasticity of substitution for production functions homogeneous of degree one is obtained as follows:

$$\sigma = \frac{f_1 f_2 (x_1 f_1 + x_2 f_2)}{f_{12}(x_1 f_1 + x_2 f_2)^2}$$

and invoking Euler's theorem,

$$\sigma = \frac{f_1 f_2}{f_{12} q} \tag{3}$$

For (1), $$f_{12} = \frac{(1+\rho)\alpha(1-\alpha)q^{1+2\rho}}{A^{2\rho}(x_1 x_2)^{1+\rho}}$$

Evaluating (3) for (1),

$$\sigma = \frac{1}{1+\rho} \qquad \rho = \frac{1-\sigma}{\sigma} \tag{4}$$

Thus, the parameter ρ is closely related to the constant elasticity of substitution. The inequality $\rho > -1$ is equivalent to $\sigma > 0$.

ISOQUANTS:

The particular shape of the convex isoquants generated by a CES function depends upon the value of σ. In the extreme there are two limits in the possible isoquant configurations as follows:

Case 1 $\sigma \to 0$, $\rho \to +\infty$**.** The RTS (3) approaches zero as rho approaches infinity and in the limit substitution is impossible. The curvature of the isoquants approaches a right angle.

Case 2 $\sigma \to +\infty$, $\rho \to -1$. In the limit the exponents of both terms on the left of (4) are one, and the isoquants are straight lines. The inputs are perfect substitutes in this limiting case (Arrow, Chenery, Minhas, and Solow 1961).

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