A Dual Definition for the Factor Content of Trade

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Draft Version. Preliminary and incomplete. Do not quote.
March 2005

Abstract

In this paper, first we introduce a dual definition of the Factor Content of Trade using the concept of the Equivalent Autarky Equilibrium, Deardorff and Staiger (1988) with a more general technology. A relationship for the difference in factor rewards between a trading equilibrium and its Equivalent Autarky Equilibrium is derived-by a quadratic approximation following Diewert (1976) and Diewert (2002)-under the assumption of balanced trade, involving FCT. The dual representation of technology is used for the US economy, a revenue function, instead of the usual cost function following Kohli (1991) and (1993). After estimating the revenue function for the US economy the Factor Content of Trade for each factor is calculated for the period 1970 to 1991.

JEL classification: F11, F16 and J31.
Keywords: international trade, relative wages, Factor Content of Trade, revenue function.

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The possible relationship between international trade and wage inequality in developed countries has been a very important and regularly debated topic for both academics and politicians the last decade. Unskilled workers in many developed countries and especially in US have seen a significant decline in their relative wages, while at the same time international trade increased considerably. Hence, some of the participants of the above discussion named international trade as the most likely candidate to explain this decline of relative wages. Trade economists have approached from two different angles this question of whether international trade is the main and solely reason explaining the increased wage inequality experienced by the US and other developed economies over the last thirty years.

The first is based on the traditional Stolper-Samuelson theorem, where changes in product prices cause changes in factor rewards. Leamer (1997), following this approach, represented technology with cost functions and showed that there is an effect of declining prices of unskilled labour intensive products due to international trade that can explain wage inequality. Also Harrigan and Balaban (1999) followed the same approach but used a revenue function to describe the technology of the US economy. They found that relative price and relative factor supply changes explain wage inequality, but they mainly attributed these changes to technological change and not to trade.

The second approach, followed by Borjas et al (1992), Katz and Murphy (1992), Wood (1994) and Baldwin and Cain (1997), has focused on the Factor Content of Trade (FCT) theorem of Vanek (1968). In FCT studies, the volume of net exports is transformed into input quantities with the use of an input requirement matrix. Then a partial equilibrium model is used that calculates the effect of these changes of input quantities on relative factor rewards. The technology representation in all of these studies has been a cost function and they conclude, with the exception of Wood, that trade has a very small impact on explaining wage inequality. According to their findings, it is technological change that induced the change in relative wages.

But this second approach has also generated a debate on the question whether the Factor Content approach is the appropriate tool to measure the effect of international trade on relative wages from a theoretical point of view, Deardorff (2000), Panagariya (2000), Krugman (2000) and Leamer (2000). FCT studies have been heavily criticised on the ground that they lack a solid theoretical foundation and especially that FCT is not related with factor prices. The main argument, Panagariya (2000) and Leamer (2000), was that FCT calculates quantities of indirectly exported and imported factors via international trade but according to the Stolper-Samuelson theorem, it is product prices, not factor quantities, which are related with factor prices. But that criticism was incorrect according to Deardorff (2000) and Krugman (2000), since Deardorff and Staiger (1988) had already provided a theoretical framework introducing the concept of the ‘'Equivalent Autarkic Equilibrium" and showing under which assumptions the FCT and relative wages are related.

The first contribution of the paper is that allows for a more general technology in the economy relative to previous studies. In particular, it does not assume that the revenue function is non-joint in output quantities. This implies that the revenue function is not locally independent of inputs and consequently endowments affect factor rewards. Under this more general technology, the FCT needs to be redefined.

The second contribution of the paper is that we introduce a new definition for the FCT in the case of non-jointness in output quantities. FCT is still the difference of input quantities between a trading equilibrium and its Equivalent Autarky one. But now it is equal to the product of the inverse matrix of the cross derivative of the revenue function and the vector of net exports plus another matrix that reflects the difference in techniques between the trading and the Equivalent Autarky equilibrium due to different input quantities.

It is also proved that an Equivalent Autarky Equilibrium exists for the economy in the absence of non-jointness in output quantities. Then the difference in factor rewards between a trading equilibrium and its Equivalent Autarky Equilibrium is derived following Diewert (1976) and Diewert (2002), that involves the FCT

The dual representation of technology is implemented, revenue (GNP) function, for the reason that treats product prices and endowments as exogenous which is in agreement with the standard neoclassical trade theory. The functional form of the revenue (GDP) function that is used, discussed in Kohli (1991) and Kohli (1993), is the Symmetric Normalised Quadratic revenue function augmented by time. After estimating the revenue function for the US economy using an Iterative Seemingly Unrelated Regressions method the Factor Content of Trade for each factor is calculated for the US economy from 1970 to 1991.

2. The Model

A General Equilibrium model is implemented. Both sides of the economy, the supply and the demand, are initially considered in order to derive the relationships that characterize the environment within the economy is operating. In the supply side, technology is represented by a revenue function, instead of the usual cost functions. The use of duality and more specifically the implementation of revenue function is preferred because it complies with the standard assumptions made in international trade theory that product prices and endowments are given while factor prices and outputs are the endogenous variables to be determined.

Let $F(y, v, \tau) = 0$ be a transformation function for an economy with a linearly homogeneous technology, which produces $y = (y_1, ...y_n)$ goods with the use of the same number of $v = (v_1, ...v_m)$ inputs $(n = m)$ in a perfect competitive environment where τ is a time index that captures technological change. Then, at given international prices $p = (p_1, ...p_n)$ and domestic inputs v, there exists a competitive production equilibrium. In such equilibrium we can think of the economy as one that maximises the value of total output subject to the technological and endowment constraints. In other words there is a revenue or GDP function such that:

$$R(p,v,\tau) = \max_{y}\left\{\sum_{i=1}^{n} p_i y_i \ : F\left(y,v,\tau\right) = 0\right\} \tag{1}$$

Under the above assumptions, the revenue function $R(p,v,\tau)$ is increasing, linearly homogeneous and concave in v and non-decreasing, linearly homogeneous and convex in p. In addition if $R(p,v,\tau)$ is differentiable then equilibrium output and factor rewards are given by:

$$y(p,v,\tau) = R_p(p,v,\tau) \tag{2}$$

$$w(p,v,\tau) = R_v(p,v,\tau) \tag{3}$$

On the demand side, the economy's preferences defined over the n goods could be represented by an expenditure function, which is continuous and once differentiable on prices:

$$E(p,u) = \min_{c}\left\{pc : \ g(c) \geq u\right\} \tag{4}$$

where u is the level of utility and $c = (c_1, ...c_n)$ is the consumption bundle. By differentiating $E(p,u)$ with respect to p we get the consumption vector of the economy:

$$c(p,u) = E_p(p,u) \tag{5}$$

where $E_p(p,u)$ is the first partial derivative of the expenditure function with respect to product prices.

2.1 The Trading Equilibrium

Assume now the case where the economy is in a trading equilibrium and at the same time trade is balanced, then the following should be true[3]:

$$R(p^t, v^t, \tau) = E(p^t, u^t) \tag{6}$$

that is the total value of production should be equal to the total expenditure for the economy. From Hotelling's and Shepherd's Lemma, Diewert (1974), the difference between production and consumption should give the economy's vector of net exports:

$$T = R_p(p^t, v^t, \tau) - E_p(p^t, u^t) \tag{7}$$

where T is the net exports vector. From (7) it is obvious that net exports depend on product prices, endowments, technological change and the level of utility.

[3] A t superscript denotes values of the trading equilibrium

2.2 A New Definition for the Factor Content of Trade and the Existence of an Equivalent Autarky Equilibrium

We prove that under the above assumptions there exists a new equilibrium (Equivalent Autarky Equilibrium) with the same product prices, where production equals consumption. The economy can reach this new equilibrium by subtracting from its initial endowments the Factor Content of net exports. The Factor Content of net exports is defined as the additional endowments that are necessary for the economy in order to produce its consumption vector at given product prices. Let's assume the endowments in this new EAE are v^e. In the Equivalent Autarky Equilibrium the economy is producing what it desires to consume, having no incentive to trade with other countries. Hence, the vector of net exports is going to be a vector of zeroes, which means that production and consumption are equalised for every good produced, which is shown in (8)

$$R_p(p^t, v^e, \tau) = E_p(p^t, u^t) \tag{8}$$

In the Equivalent Autarky Equilibrium, we assume that preferences' technology remains the same and because product prices are also unchanged the vector of consumption is unaltered. Under the assumption of balanced trade, GDP should be equal to the economy's total expenditure (same as in the trading equilibrium). Hence, again the value of production should equal the value of consumption in this new equilibrium

$$R(p^t, v^e, \tau) = E(p^t, u^t) \tag{9}$$

From (6) and (9) it is clear that the revenue in the trading equilibrium is the same as the one in the Equivalent Autarky Equilibrium:, which implies that the total value of production has not changed between the two equilibria, despite the different endowment vectors. Substituting (8) into (7) we get a new relationship for the net exports vector in the trading equilibrium:

$$T = R_p(p^t, v^t, \tau) - R_p(p^t, v^e, \tau) \tag{10}$$

Hence, as long as $\left| \frac{\partial^2 R(p,v,\tau)}{\partial p \partial v} \neq 0 \right|$, we can solve (10) for v^e, from the Implicit Function Theorem $\Longrightarrow \exists\ v^e = g(p^t, v^t, \tau)$. Hence, there exists a vector of endowments v^e as a function of product prices, the endowments of the trading equilibrium and technology. Then we show that the production of $R_p(p^t, v^t, \tau)$ and $R_p(p^t, v^e, \tau)$ are supported by the same product prices p^t. We know that:

$$p^t R_p(p^t, v^t, \tau) = p^t R_p(p^t, v^e, \tau) \tag{11}$$

since $p^t T = 0$ because we are assuming balanced trade.

We also have to show that at the new endowments v^e and new factor prices w^e the income generated is the same as at (v^t, w^t). From linear homogeneity in inputs we have:

$$R_v(p^t, v^t, \tau) v^t = R(p^t, v^t, \tau) \tag{12}$$

$$R_v(p^t, v^e, \tau)v^e = R(p^t, v^e, \tau) \tag{13}$$

But because of balanced trade we have that $R(p^t, v^t, \tau) = R(p^t, v^e, \tau)$. Hence, the income in the economy is the same in both equilibria.

2.2 Quadratic Approximation

Define the Factor Content of Trade for equilibrium $s = 0, 1$ as:

$$FCT^s = v^{ts} - v^{es} \tag{14}$$

That is the difference between the actual endowments v^{ts} in the trading equilibrium t at period s and the endowments v^{es} in the Equivalent Autarky Equilibrium e at period s for given product prices and technology. Now assume two trading equilibria $R(p^{t0}, v^{t0}, \tau^{t0})$ and $R(p^{t1}, v^{t1}, \tau^{t1})$ and their Equivalent Autarky Equilibria $R(p^{t0}, v^{e0}, \tau^{t0})$ and $R(p^{t1}, v^{e1}, \tau^{t1})$ respectively. The vectors of factor rewards in all equilibria are given:

$$R_v(p^{t0}, v^{t0}, \tau^{t0}) = w^{t0} \tag{15}$$

$$R_v(p^{t0}, v^{e0}, \tau^{t0}) = w^{e0} \tag{16}$$

$$R_v(p^{t1}, v^{t1}, \tau^{t1}) = w^{t1} \tag{17}$$

$$R_v(p^{t1}, v^{e1}, \tau^{t1}) = w^{e1} \tag{18}$$

The difference in factor rewards between the two Equivalent Autarky Equilibria can be approximated by a first order quadratic approximation Diewert (1976) and Diewert (2002):

$$\begin{aligned} w^{e1} - w^{e0} = & \frac{1}{2}\left[R_{vp}(p^{t1}, v^{e1}, \tau^{t1}) + R_{vp}(p^{t0}, v^{e0}, \tau^{t0})\right] \cdot \left[p^{t1} - p^{t0}\right] \\ & + \frac{1}{2}\left[R_{vv}(p^{t1}, v^{e1}, \tau^{t1}) + R_{vv}(p^{t0}, v^{e0}, \tau^{t0})\right] \cdot \left[v^{e1} - v^{e0}\right] \\ & + \frac{1}{2}\left[R_{vt}(p^{t1}, v^{e1}, \tau^{t1}) + R_{vt}(p^{t0}, v^{e0}, \tau^{t0})\right] \cdot \left[\tau^{t1} - \tau^{t0}\right] \end{aligned} \tag{19}$$

while the difference in factor rewards between each trading equilibrium and its Equivalent Autarky one is given again by a first order quadratic approximation:

$$w^{ts} - w^{es} = \frac{1}{2}\left[R_{vv}(p^{ts}, v^{ts}, \tau^{ts}) + R_{vv}(p^{ts}, v^{es}, \tau^{ts})\right] \cdot \left[v^{ts} - v^{es}\right] \tag{20}$$

where $s = 0, 1$.

3. Econometric Specification

The functional form of the revenue (GDP) function that is used, discussed in Kohli (1991) and Kohli (1993), is the Symmetric Normalise Quadratic revenue function augmented by time:

$$\begin{aligned}
R(p,v,t) = {} & \frac{1}{2}\left(\sum_{j=1}^{M}\beta_j v_j\right)\left(\sum_{i=1}^{N}\sum_{h=1}^{N}\alpha_{ih}p_i p_h\right)\left(\sum_{i=1}^{N}a_i p_i\right)^{-1} \\
& + \sum_{i=1}^{N}\sum_{j=1}^{M}c_{ij}p_i v_j + \frac{1}{2}\left(\sum_{i=1}^{N}a_i p_i\right)\left(\sum_{j=1}^{M}\sum_{k=1}^{M}b_{jk}v_j v_k\right)\left(\sum_{j=1}^{M}\beta_j v_j\right)^{-1} \\
& + \left(\sum_{j=1}^{M}\beta_j v_j\right)\left(\sum_{i=1}^{N}d_i p_i\right)\tau + \left(\sum_{i=1}^{N}a_i p_i\right)\left(\sum_{j=1}^{M}e_j v_j\right)t \qquad (21) \\
& + \left(\sum_{i=1}^{N}a_i p_i\right)\left(\sum_{j=1}^{M}\beta_j v_j\right)\left(\frac{1}{2}h_{tt}\tau^2 + h_t\tau\right)
\end{aligned}$$

where τ represents time. There are $N(N-1)+M(M-1)+N\times M+2$ unknown parameters α_{ih}, b_{jk}, c_{ij}, d_i, e_j, h_t and h_{tt}, where $i,h = 1,...N$ and $j,k = 1,..M$. There are also $N+M$ predetermined parameters a_i and β_j. In particular, a_i and β_j are set equal to the share value of each product and input respectively at the base year. Symmetry conditions are imposed $\alpha_{ih} = \alpha_{hi}$; $b_{jk} = b_{kj}$ and the assumptions of linear homogeneity in p and v require some additional restrictions:

$$\sum_{i=1}^{N}a_i = \sum_{j=1}^{M}\beta_j = 1, \text{ and } \sum_{h=1}^{N}a_h = \sum_{k=1}^{M}b_{jk} = \sum_{i=1}^{N}d_i = \sum_{j=1}^{M}e_j = 0 \qquad (22)$$

Then by differentiating the revenue function with respect to the factor endowments we get the reward of the jth factor:

$$\begin{aligned}
w_j = {} & \frac{1}{2}\beta_j\left(\sum_{i=1}^{N}\sum_{h=1}^{N}\alpha_{ih}p_i p_h\right)\left(\sum_{i=1}^{N}a_i p_i\right)^{-1} \\
& + \left(\sum_{i=1}^{N}a_i p_i\right)\left(\sum_{k=1}^{M}b_{jk}v_k\right)\left(\sum_{j=1}^{M}\beta_j v_j\right)^{-1} \\
& - \frac{1}{2}\beta_j\left(\sum_{i=1}^{N}a_i p_i\right)\left(\sum_{j=1}^{M}\sum_{k=1}^{M}b_{jk}v_j v_k\right)\left(\sum_{j=1}^{M}\beta_j v_j\right)^{-2} \qquad (23) \\
& + \sum_{i=1}^{N}c_{ij}p_i + \beta_j\left(\sum_{i=1}^{N}d_i p_i\right)\tau \\
& + e_j\left(\sum_{i=1}^{N}a_i p_i\right)\tau + \beta_j\left(\sum_{i=1}^{N}a_i p_i\right)h_t\tau + \frac{1}{2}\beta_j\left(\sum_{i=1}^{N}a_i p_i\right)h_{tt}\tau^2
\end{aligned}$$

Similarly, by differentiating the revenue function with respect to the product prices we get the *ith* output of the good:

$$
\begin{aligned}
y_i \quad = \quad & \frac{1}{2}a_i\left(\sum_{j=1}^{M}\sum_{k=1}^{M}b_{jk}v_jv_k\right)\left(\sum_{j=1}^{M}\beta_jv_j\right)^{-1} \\
& +\left(\sum_{j=1}^{M}\beta_jv_j\right)\left(\sum_{h=1}^{N}\alpha_{ih}p_h\right)\left(\sum_{i=1}^{N}a_ip_i\right)^{-1} \\
& -\frac{1}{2}a_i\left(\sum_{j=1}^{M}\beta_jv_j\right)\left(\sum_{i=1}^{N}\sum_{h=1}^{N}\alpha_{ih}p_ip_h\right)\left(\sum_{i=1}^{N}a_ip_i\right)^{-2} \\
& +\sum_{j=1}^{M}c_{ij}v_j+d_i\left(\sum_{j=1}^{M}\beta_jv_j\right)\tau \\
& +a_i\left(\sum_{j=1}^{M}e_jv_j\right)\tau+a_i\left(\sum_{j=1}^{M}\beta_jv_j\right)h_t\tau+\frac{1}{2}\left(\sum_{j=1}^{M}\beta_jv_j\right)h_{tt}\tau^2
\end{aligned} \tag{24}
$$

All the parameters of the revenue function (21) are included in (23) and (24), hence by estimating (23) and (24) we can obtain an estimate of (21). The factor rewards and output supplies equations will be estimated by adding a random disturbance in each of them, with the usual classical assumptions. (23) has M and (24) has N equations all of which are linearly independent. Hence, a system of $M+N$ equations is going to be estimated with the above restrictions using the iterative version of Seemingly Unrelated Regression Estimator method.

The revenue function must satisfy the conditions for concavity on inputs and convexity on product prices. The necessary and sufficient condition for global concavity in inputs is that matrix $B=[b_{jk}]$ be negative semi-definite and for global convexity that matrix $A=[a_{ih}]$ be positive semi-definite. If these are not satisfied then they are imposed following Diewert and Wales (1987) without removing the flexibility properties of the revenue function.

3. Data Construction and Description

Data are collected for the 2-digit SIC87 classification for US manufacturing for the period 1968 to 1991. The estimated model consists of three aggregate products and three factors of production. The aggregate products are exportable, importable and non-tradable and the factors are capital, skilled labour and unskilled labour. Initially the products are divided between tradables and non-tradables. A product is tradable if the ratio of the value of its exports plus imports divided by its GDP is above 10%, otherwise is treated as non-tradable. Then the tradable products are grouped to exportables and importables depending on whether their net exports are positive or negative respectively. Trade data at the 2-digit SIC87 level were obtained online from the Centre for International Data at the University of California Davis[4].

Data for the value and price of capital and labour, at a 2-digit SIC87 analysis are obtained from Dale Jorgenson's database[5]. The value added is constructed for these three aggregate goods. Data for output deflator are obtained from the Bureau of Economic Analysis[4]. Because these are available from 1977 onwards, the values of output deflators for years before 1977 are obtained by interpolation assuming a constant growth rate equal to the growth rate between 1977 and 1978.

From the Current Population Surveys: March Individual-Level Extracts, 1968-1992 (ICPSR 6171) we get data on the educational level of labour, wages per hour, status and days worked for full time and part workers in 2-digit SIC industries. With this information it is possible to separate workers into skilled and unskilled. Following Beaudry and Green (2003) a worker is treated as skilled if he or she spent more than nine years in education. Then we calculate the total number of days worked for both occupational groups and by assuming that a working day consists of eight hours and that a full time worker works for 2000 hours per year we calculate the number of equivalent full time workers in the sample[5]. Then we sum the value of wages for each occupational group for a year and we divide by the number of equivalent full time workers times 2000 in order to calculate the full time equivalent hourly wage for each group respectively. After that, we calculate the share of full time equivalent skilled and unskilled workers relative to the total number of full time equivalent workers. The same is applied for the calculation of the shares of wages of both occupational groups in the sample. These shares are multiplied with the total number of all workers and total wages obtained from Jorgenson's dataset in order to get the number and wages for skilled and unskilled workers in US manufacturing[6].

The aggregation for goods is achieved in three stages[7]. First, the value added for each aggregate good is found by summing the value added of all goods belonging in this aggregate group. An aggregate price is constructed for each aggregate good by calculating its weighted average price, using as weights the share of value of each 2-digit SIC good relative to the total value of each aggregate good. Finally, the aggregate quantity of output is calculated by dividing the value added of each aggregate good by its aggregate price. The same method applies for calculating aggregate price and quantity for capital , skilled and unskilled labour, since the data from Jorgenson's database are in a 2-digit SIC87 analysis.

The assumption of balanced trade is not satisfied by the data. For that

[4] http://data.econ.ucdavis.edu/international/index.html

[5] http://post.economics.harvard.edu/faculty/jorgenson/data/35klem.html

[4] www.bea.doc.gov

[5] Following Harrigan and Balaban (1999), self-employed workers are excluded since they tend to give inaccurate information about their income and wages.

[6] These calculations are based on the assumption that the information obtained from the sample provided from CPS is representative for the whole US manufacturing.

[7] Table 2 shows the SIC categories that are included in each aggregate good.

reason, the actual trade volumes for each good is adjusted according to its share of output relative to total revenue in the economy in order to guarantee balanced trade. By solving (10) for v^e and then using (14) the Factor Content of Trade for each factor is calculated under this more general technology for the US economy for the period 1969 to 1991.

4. Estimation

Prices and quantities have been normalised to be one in the base year 1969. The likely issue of endogeneity in product prices is tackled by performing an OLS regression for each product price having as explanatory variables one year lagged product prices and input quantities. The obtained fitted values for the product prices are then used for the estimation of the system (23) and (24). The parameters a_E, a_N, a_I and β_K, β_S, β_U have been set equal to the values of the product share and the factor share at the base year respectively. Then an error is appended in each equation and an Iterative SURE method is implemented for all six equations with symmetry and restrictions (22) imposed to estimate the parameters.

Table 1 below shows the estimated parameters and the log likelihood. The revenue function is linearly homogeneous in prices and inputs and concave in inputs, but initially convexity in prices was not satisfied. Following the method proposed by Diewert and Wales (1988) we impose convexity for product prices. The joint null hypothesis of non-jointness in output quantities is rejected at a 5% level of significance using an LR test (LR(2)=18.9), which is in accordance with the more general technology used above. In addition, the effect of technological change is significant.(LR(2)=63.9)

The estimated parameters of the revenue function (21) are used in order to calculate the FCT for each input. In particular, solving equation (10) for v^e and then using equation (14), allow us to obtain the FCT for each input in the US for the period 1970 to 1991.

5. Results

Figures 1, 2 and 3 graph the FCT for each factor from 1970 to 1991 based on (14). Tables 3, and 4 present the price elasticities of output (ϵ_{ih}) and input elasticities of factor rewards (ω_{jk}) respectively.

From Figure 1, we observe that FCT of capital was positive and quite stable till 1981, then it decreased the next year and became negative. After 1982 has been continuously positive with a very sharp increase from 1982 to 1987, followed by an important fall in its value. From Figure 2 we can see that the FCT of Skilled Labour was negative for the first two years of the sample and then had an important increase till 1979 and was positive. The next year had a large decrease(negative value), followed by a steady increase till 1982. For the next six years since 1982 the FCT of Skilled Labour had a very significant decrease, but the last two years of the sample it increased significantly, reaching a value very close to zero in 1991. Figure 3 illustrates that the FCT of Unskilled Labour has been negative for the most of the years in the sample period with the exception of 1970, 1972, 1973 and 1982, when it was slightly above zero. It reached a minimum in 1987 and then increased for three consequently years, but still being negative. The three Figures make clear that, for most of the years in the sample period more unskilled labour and less capital would have been employed in a hypothetical Equivalent Autarky Equilibrium, where the economy can satisfy domestic demand without trade. While for Skilled Labour the picture is mixed. For about the first ten years, less Skilled Labour would have been employed in an Equivalent Autarky Equilibrium than in the actual economy and the opposite for the remaining years.

Table 3 presents the average price elasticities of output, where it is clear that convexity is satisfied since the own price elasticities are all positive. All elasticities are well below unity and most of them significant. The highest value of 0.68 is for the own price elasticity for non-tradables. It is also evident that changes in the prices for the exportables or importables induce changes of the same sign in the supply of both outputs. While the supply of non-tradable decreases when either of the price of the two others goods increases. From Table 4 it is clear that concavity is satisfied, because the own input elasticities for each factor reward is negative and the highest value in absolute terms is for the own input elasticity for the reward to capital with 0.692. From the signs of the off diagonal elasticities, we observe that increases in the quantitiy of an input result in increases for the factor rewards of all the other inputs.

6.Conclusion

In this paper, first we introduced a dual definition for the Factor Content of Trade following Deardorff and Staiger (1988) allowing for a more general technology. In particular, we allowed for a technology that it is not non-joint in output quantities and this more general technology was supported by the data in the US economy for the period 1968 to 1991. In addition, we derived a relationship that links differences in factor rewards between a trading equilibrium and its Equivalent Autarky one with the FCT. Finally, we have calculated the FCT for capital, skilled labour and unskilled labour with this more general technology for the US economy from 1970 to 1991. From the FCT of these factors, we observe that more unskilled labour and less capital would have been employed if the US economy was operating in its hypothetical Equivalent Autarky Equilibrium, while for skilled labour the picture is mixed. It would have been employed less for the first half of the period and more for the second half.

References

1. Baldwin, R. E. and Cain, G.G., ''Shifts in relative wages: the role of trade, technology and factor endowments", NBER working paper 5394, 1997.

2. Borjas, G., Freeman, R. and Katz, L., ''On the labour market effects of immigration and trade", In: Borjas, G. and Freeman, R. (Eds), Immigration and the Work Force, University of Chicago and NBER, Chicago, 1992.Centre for International Data at UC Davis.

3. Deardorff, A. and Staiger, R., ''An interpretation of the factor content of trade", Journal of International Economics, vol. 24, 93-107, 1988.

4. Deardorff, A., ''Factor prices and factor content of trade revisited: what is the use?", Journal of International Economics, vol 50, 73-90, 2000.

5. Diewert W. E., ''Exact and Superlative Index Numbers", Journal of Econometrics, vol. 4, 114-145, 1976.

6. Diewert W. E., ''The Quadratic Approximation Lemma and Decomposition of Superlative Indexes", Journal of Economic and Social Measurement, vol. 28, 63-88, 2002.

7. Harrigan, J. and Balaban, R. A., '' U.S. wages in general equilibrium: The effects of prices, technology, and factor supplies, 1963-1991", Federal Reserve Bank of New York Staff Report, no. 64, 1999.

8. Katz, L. and Murphy, K., ''Changes in relative wages, 1963-1987: supply and demand factors", Quarterly Journal of Economics, CVII, 36-78, 1992.

9. Kohli, U., '' Technology, Duality, and Foreign Trade: The GNP Function Approach to Modelling Imports and Exports", London: Harvester Wheatsheaf and Ann Arbor, MI: University of Michigan Press, 1991.

10. Kohli, U., ''A Symmetric Normalised Quadratic GNP function and the US Demand for Imports and Supply of Exports", International Economic Review, vol. 34, 243-255, 1993.

11. Krugman, P., '' Technology, trade and factor prices", Journal of International Economics, vol. 50, 51-71, 2000.

12. Leamer, E., ''In Search of Stolper-Samuelson Effects on U.S. Wages", In Collins Susan (Ed), Imports, Exports and the American Worker, pp. 141-214, Brookings, 1997.

13. Leamer, E., ''What's the use of factor contents?", Journal of International Economics, vol. 50, 17-49, 2000.

14. Panagariya, A., ''Evaluating the factor-content approach to measuring the effect of trade on wage inequality", Journal of International Economics, vol. 50, 91-116, 2000.

15. Vanek, J., ‘’The factor proportions theory: the n-factor cases", Kyklos, vol. 21, 749-756, 1968.

16. Wood, A., ‘’How trade hurt unskilled workers", Journal of Economic Perspectives, vol. 9, 57-80, 1995.

Appendix :

Table 1: Parameter Estimates

Parameter	**Estimate**	**t-stat**	**Parameter**	**Estimate**	**t-stat**
e_K	661.317	2.149	c_{IS}	-7969.48	-1.999
e_S	104486.	1.571	c_{IU}	51781.7	8.604
b_{KK}	-42753.3	3.750	c_{NK}	15014.3	6.330
b_{KS}	2091.23	0.531	c_{NS}	9534.23	5.021
b_{SS}	-11694.7	-2.648	c_{NU}	20925.2	7.956
c_{EK}	24049.6	5.058	d_E	1761.75	4.075
c_{ES}	40500.4	10.786	d_I	-236.543	-0.716
c_{EU}	38231.9	6.987	h_{tt}	7796.82	8.401
c_{IK}	7281.04	1.380	h_t	-196.93	-2.410
log likelihood	-1325.58				

Hypothesis Testing	**Test Statistic**	$\chi^2_{0.5}$ **critical values**
Non-jointness	LR(2)=18.9	5.991
Technological change	LR(2)=63.9	5.991

Table 2: SIC CODES FOR AGGREGATE GOODS

Aggregate Good	**SIC Code Category**
Exportable	Food & Kindred Products (SIC 20) Chemicals & Allied Products (SIC 28) Industrial & Commerc Machinery & Computer Equip. (SIC 35) Electronic & Other Electric. Equip. (SIC 36) Transportation Equipment (SIC 37) Instruments, Photographic, Medical & Optical Goods (SIC 38)
Importable	Textile Mill Products (SIC 22) Apparel & Other Finished Products (SIC 23) Lumber & Wood Products (SIC 24) Paper & Allied Products (SIC 26) Petroleum Refining & Related Industries (SIC 29) Leather & Leather Products (SIC 31) Primary Metal Industries (SIC 33) Misc. Manufacturing Industries (SIC 39)
Nontradable	Tobacco Products (SIC 21) Furniture & Fixtures (SIC 25) Printing, Publishing & Allied Industries (SIC 27) Rubber & Misc. Plastic Products (SIC 30) Stone, Clay, Glass & Concrete Products (SIC 32) Fabricated Metal Products, Except Machinery (SIC 34)

Table 3: Price Elasticities of Output (ϵ_{ih})
(Mean values, Std. Error in parenthesis)

	Price		
	Exportable	Importable	Non-tradable
Quantity	ϵ_{iE}	ϵ_{iI}	ϵ_{iN}
Exportable	0.156	0.052	-0.208
	(0.020)	(0.002)	(0.018)
Importable	0.127	0.044	-0.171
	(0.023)	(0.015)	(0.038)
Non-tradable	-0.509	-0.170	0.680
	(0.036)	(0.016)	(0.021)

Table 4: Input Elasticities of Factor Reward (ω_{jk})
(Mean values, Std. Error in parenthesis)

	Input		
	Capital	Skilled Labour	Unskilled Labour
Factor Reward	ω_{jK}	ω_{jS}	ω_{jU}
Capital	-0.692	0.145	0.546
	(0.066)	(0.074)	(0.134)
Skilled Labour	0.132	-0.183	0.052
	(0.054)	(0.013)	(0.063)
Unskilled Labour	0.323	0.021	-0.344
	(0.016)	(0.029)	(0.038)

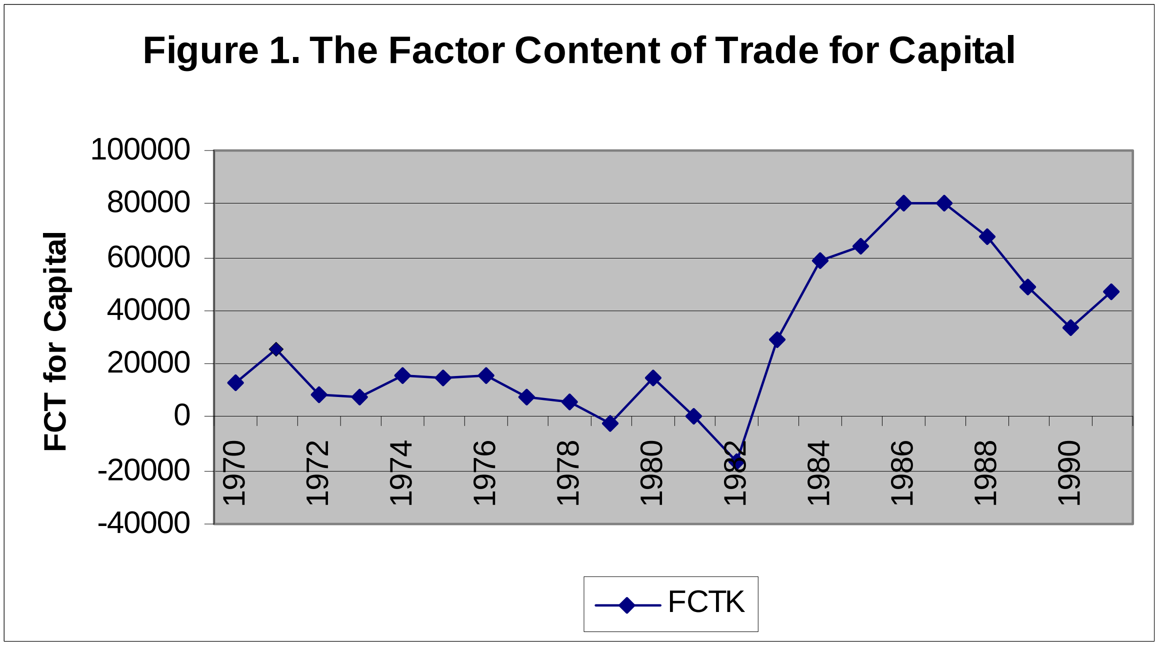
Figure 1. The Factor Content of Trade for Capital
FCT for Capital
100000
80000
60000
40000
20000
0
-20000
-40000
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
FCTK

Figure 2. The Factor Content of Trade for Skilled Labour

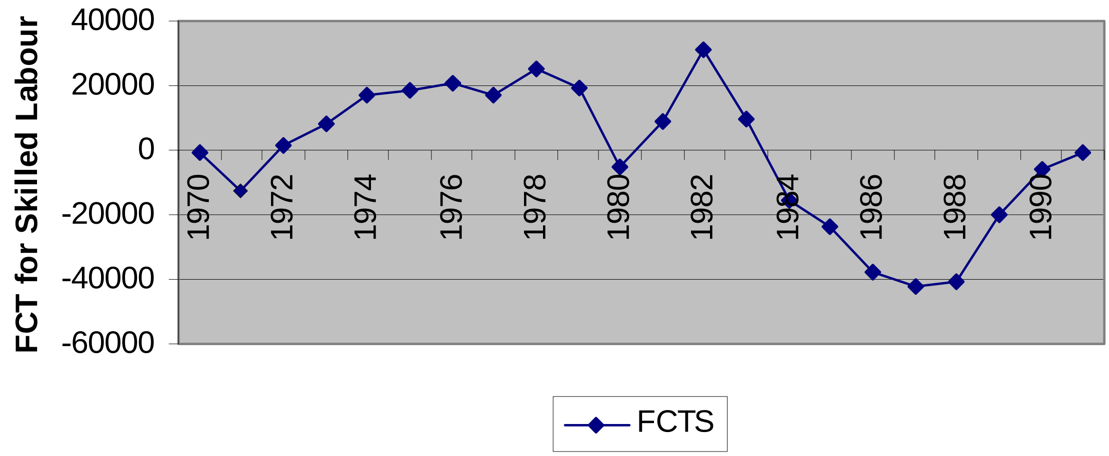

Figure 3.The Factor Content of Trade for Unskilled Labour