Trade, Technology and Income Distribution

by

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A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

Department of Economics
Carleton University
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The undersigned hereby recommend to
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in partial fulfilment of the requirements
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Abstract

The relationship between trade, technology and income distribution is explored in three chapters.

Chapter 1 examines the effect of income distribution, both within and across countries, on the pattern of international trade. In standard trade theory, consumption is normally assumed to be homothetic. Consequently, income and its distribution would have no role in determining international trade. The chapter examines the assumption and its implications. The common assumption is statistically rejected at 1% significance level. A counter-factual experiment reveals that the demand-induced trade due to differences in income and its distribution amounts to 6.2% of world expenditure. We further demonstrate that non-homothetic taste helps explain some trade puzzles and paradoxes.

Chapter 2 examines the effect of trade and technology on skill upgrading and production efficiency for Canadian manufacturing industries. We find that both computer technology and foreign outsourcing are important in explaining the skill upgrading that occurred during 1981-1996, and that their relative importance is dependent on the ways that technology is measured. Foreign outsourcing is found to have induced significant cost reduction for the Canadian manufacturing sector.

Chapter 3 examines the role of trade and technology to the increasing wage gap between the skilled and non-skilled workers in Canada during the 80s and 90s. It adopts the two-stage mandated wage regression in its investigation. The first stage endogenizes product price changes and productivity growth. We find some evidence of the “pro-competitive” effect of trade on domestic product market – both import price competition and foreign outsourcing are significant in increasing productivity and reducing domestic product prices. We also find that the competitiveness of a market and the adoption of computer technology increase productivity. The second stage estimates the wage impact. The net effect of foreign factors on wage inequality is very small, only about one-tenth or less of the effect of high technology.

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Executive Summary

The thesis explores the empirical relationship between trade, technology and income distribution. It consists of three parts, each of which contains its own introduction, analysis and conclusion.

Chapter 1 examines the effect of income distribution, both across and within countries, on the pattern of international trade. The standard trade theory mainly focuses on the production-side explanation of trade while maintaining the assumption of identical and homothetic preferences. Homothetic preferences mean that for given prices, commodities are consumed in the same proportion everywhere, independent of income and income distribution.

The chapter examines the above assumption and its implications, using a flexible Almost Ideal Demand System. The estimated demand system deviates substantially from the homothetic preference assumption, in both statistical and economic terms. The assumption of homothetic preferences is statistically rejected at 1% significant level. A counter-factual experiment reveals that the demand-induced trade due to differences in income and income distribution amounts to 3.89% and 2.24% of total world expenditure respectively. It is further demonstrated that non-homothetic taste could explain some trade puzzles and paradoxes.

Chapter 2 examines the effects of high technology (information and communication technology) and trade (foreign outsourcing) on skill upgrading and production efficiency for Canadian manufacturing industries over the period of 1981-1996. Since the 1980s, there has been an increase in the relative demand for skilled labour. Several decomposition analyses find that the vast majority of the shift towards skilled labour is due to within-industry skill upgrading (the increased use of skilled labour within industries), which is further found to have strong positive correlation with the expenditure in R&D and in computer technology. It is therefore argued that skill-biased technological change rather than trade is the major cause of the increased demand for skilled labour.

However, trade may be just as important as high technology in affecting within-industry skill upgrading. In response to increased foreign competition, firms may switch from domestic low-skill intensive producers to foreign suppliers in the low-wage countries, or reallocate part of the low-skill intensive production process overseas, thereby leading to an increased demand of skilled worker at home industries.

The first objective of the chapter is therefore to re-examine the issue – the relative importance of trade (in the form of foreign outsourcing) and high-technology (computer and other information and communication technology) on skill upgrading in the Canadian manufacturing sector. Our second objective is to examine the

efficiency impact of trade and technology. To do so, we extend the conventional cost share regressions to a system of equations and adopt the GMM system estimation method, which allows us to evaluate the skill-upgrading and the production efficiency effects simultaneously.

The empirical results support the idea that both computer technology and foreign outsourcing (within the same two digit industries) are strongly biased towards the use of more skilled non-production workers. Both are important in explaining the skill upgrading during the period of 1981-1996. Their relative importance is, however, dependent on how high-technology is measured. Using high-tech investment shares means that high technology's contribution to skill upgrading is approximately twice as much as foreign outsourcing, while using high-tech capital service shares means that high technology's contribution is only about half of foreign outsourcing.

For the efficiency effect, we find that narrow foreign outsourcing (within the same two-digit industry) induces significant cost reduction and efficiency gain for the Canadian manufacturing sector. The efficiency impact of high technology is found to be sensitive to the way that high technology is measured.

Despite the sensitivity of the impacts of high-technology, it is fair to conclude from chapter 2 that foreign outsourcing contributes significantly to the skill upgrading and the efficiency gain of the Canadian manufacturing sector during 1981-1996.

Chapter 3 examines how and to what extent trade and technology have contributed to the increasing wage gap between the skilled and non-skilled workers in Canada during the 1980s and 1990s. It adopts the two-stage mandated wage regression in its investigation.

In the first stage, we endogenize product price changes and productivity growth. Using a simple oligopoly model with differentiated products, we derive the structural equations for product price changes and productivity growth. Several interesting results emerge. We find some evidence of the “pro-competitive” effect of trade on domestic product market – both import price competition and foreign outsourcing (within the same two-digit industries) are significant in increasing productivity and reducing domestic product prices. We also find some support for the notion that the competitiveness of a market (measured by concentration ratio) and the adoption of computer technology increase productivity.

In the second stage, we estimate the wage impact of trade and technology through their induced product price changes and productivity growth. Foreign outsourcing is found to have increased wage inequality (significance unknown for both 80s and 90s). Import price competition is found to have reduced wage inequality (insignificant in the 80s and significance unknown in the 90s). The impact of computer technology depends on how we measure technology. Using computer investment shares lead to significant impact of computers on rising wage inequality,

while using computer capital service shares lead to insignificant effect on wages. Other information and communication technology (ICT), whether measured as investment shares or capital service shares, has insignificant effect on the rising wage gap in both decades. In general, the net effect of foreign factors (import price competition and foreign outsourcing) on wage inequality is very small, only about one-tenth or less of the magnitude of high technology (computers and other ICT). One should be aware, however, that the comparison is based on the imprecise point estimators with large (or unknown) standard errors.

Despite the different framework adopted in chapter 2 and 3, we reach similar conclusions. Chapter 2 is a short-run framework that is based on translog cost function, while chapter 3 is a long-run framework that is based on zero-profit conditions. However, both chapters reach similar conclusions. Foreign outsourcing contributes significantly to the increasing relative demand for skilled workers and the increasing wage gap between the skilled and non-skilled workers. Foreign outsourcing also induces significant cost reduction and productivity gain for the Canadian manufacturing sector. The results on the impact of high technology capital are sensitive to the exact measure of high technology.

The thesis as a whole shows the inter-relationship among trade, technology and income distribution. The distribution of income, within and across nations, could have an impact on the trade patterns. International trade and high technology

adoption, in turn, increase skill upgrading and production efficiency, but also corresponding income discrepancy. The study demonstrates the importance of the measurement rather than outcome. In future research, it would be worthwhile to explore other measures of high-technology adoption.

Chapter 1

Income and Income Distribution As Determinants of International Trade

I. Introduction

What are the sources of international trade? The Ricardian theory explains comparative advantage in terms of technological differences, while the Heckscher-Ohlin-Samuelson theory attributes it to the differences in factor endowments. The new trade theory further states that, even with no technological and endowment differences, trade would still take place due to increasing returns to scale, imperfect competition and product differentiation. All of them help us to understand the causes and direction of international trade, but they focus mainly on the production-side explanation of trade, and give no role to demand in determining trade flows.

For demand to have no effect on trade, identical and homothetic preferences are assumed. Homothetic preferences means that the expenditure share for each commodity is constant, independent of income level. This assumption defies reality and has been rejected by many empirical demand analyses (Deaton and Muellbauer, 1983). A rich American will not eat three hundred times more bread just because he

on food will increase, because caviar and vodka cost more than bread and water, but the total proportion of disposable income spent on food will likely decline. If taste is not homothetic, the aggregate demand structure will then be affected by income and its distribution, which in turn could affect trade patterns.

However, research on the demand-side explanation of trade flows has been limited and scattered. Linder (1961) is one of the earlier researchers who explore the role of demand, and per-capita income level in particular, in international trade. Linder hypothesizes that a product cannot achieve a comparative advantage if there is no representative demand for that product in the home market; that internal demand determines which products may be imported. Since per-capita income is an important determinant of demand structure, the more similar the per-capita income among countries, the more intensive is their trade in differentiated manufacturing goods.¹ Subsequent studies (Markusen 1986, Thursby and Thursby 1987, and Bergstrand 1989, 1990) incorporate income effect into their analytical and empirical models and find a strong support for the Linder hypothesis that the intensity of intra-industry trade is associated with the similarity of per-capita income. Kohlhagen (1977), Fortune (1979) and Francois & Kaplan (1996) further incorporate income

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¹ Using a different theoretical framework, Krugman (1981) and Helpman and Krugman (1985) also reach the same predictions as Linder (1961): that the intensity of intra-industry trade is inversely related to the difference in per-capita income. However, the channel is different. In Linder's framework it works through the demand side – differences in per-capita income between countries lead to different demand structures, while in Krugman and Helpman's framework it works through the supply side – the differences in per-capita income reflect the differences in capital-labour endowment ratio.

distribution within each country to test the Linder hypothesis. They find that the expenditure patterns and the bilateral average propensity to import is dependent on the country's income distribution as well as on differences in per-capita income between countries.

The above studies have thus focused on the effects of demand structures on intra-industry trade among similar countries. The studies of the demand effect on inter-industry trade are scarce, except for Kenen (1968), Hunter and Markusen (1988), and Hunter (1991). Kenen (1968) provides a diagrammatic analysis of how the distribution of income within a country can affect the pattern of international trade. He shows that factor scarcity can only be interpreted in the light of demand conditions, and stresses the role of demand and distribution of income in the pattern of international specialization. Hunter and Markusen (1988) and Hunter (1991) demonstrate how differences in average per-capita income between countries can serve as a basis of trade. Using a Linear Expenditure System (LES), they show that the assumption of homothetic preferences is statistically rejected and the non-homothetic preferences are able to explain a significant proportion of world trade. However, their results depend crucially on the demand system estimated. The LES system not only assumes Hicksian substitutes of all commodities, but also assumes that the country's aggregate demand does not depend on domestic income distribution. In his comment on Hunter and Markusen (1988)'s study, Schembri (1988) points out several areas that need improving and suggests using a more

flexible demand system, adopting a system estimation technique, and incorporating the distribution of income in each country into the consumption expenditure model.

The purpose of the paper is to extend Hunter and Markusen (1988)'s framework to examine the impact of non-homothetic preference on the pattern of inter-industry trade. In particular, we are interested in the effect of income distribution on demand and trade. To do so, we use the Almost Ideal Demand System (AIDS). AIDS is a much more flexible functional form of demand system than the LES used by Hunter and Markusen (1988). It does not impose equal distribution of income within each country, and thus allows us to investigate the role of income distribution in international trade. We limit our focus on inter-industry trade rather than on intra-industry trade, partly because of data limitation, and partly because this is the area where not much study has been done.

The remainder of the paper is organized as follows. In section II, we start by demonstrating analytically how non-homothetic preferences, in particular how cross-country differences in income and income distribution, could give rise to demand-induced trade.

We proceed to demonstrate empirically the statistical and economic significance of non-homothetic preferences on inter-industry trade. We first test in section III the statistical significance of homothetic preferences. The assumption is statistically

rejected at 1% significance level. This indicates that the level of income and its distribution do have an impact upon consumption patterns, and thus sheds doubt on the validity of the homothetic preferences commonly assumed in trade models. The rejection of homothetic taste is the same as in Hunter and Markusen (1988). However, the result here should be more convincing, since we use a more flexible demand system that does not impose the equal distribution of income within each country, and a system estimation technique that yields more efficient estimators. Section IV further assess the economic significance of non-homothetic preferences. A counter-factual experiment shows that the demand-induced trade due to differences in income and its distribution amounts to 3.89% and 2.24% of world expenditure respectively.

Section V explores the implications of non-homothetic tastes in explaining the puzzles and paradoxes related to Heckscher-Ohlin-Vanek (HOV) model. By modifying the HOV model with non-homothetic preferences, we demonstrate the possibility of lower factor content of trade than HOV predicts, and the possibility for Leontief Paradox to occur if factor absorption dominates its relative abundance. It is also shown that the modified model improves the HOV prediction and could explain the ‘missing trade’ puzzle and ‘endowment’ paradox as identified by Trefler (1995). It outperforms Trefler’s Armington home-bias modification in reducing ‘endowment’ paradox, but does not perform as well in explaining the ‘missing trade’ puzzle. Section VI presents the conclusions.

II. Income and Its Distribution as a Basis for Trade

In this section, we demonstrate analytically how non-homothetic preferences, especially how income and its distribution, could affect trade. To do so, we use a simple two-country (home and foreign), two-commodity (luxury good and necessity good) and two-factor (capital and labour) framework. Assume good 1 (C_1) is a luxury good with an income elasticity of demand greater than one, and good 2 (C_2) is a necessity good with an income elasticity of demand less than one. To highlight the demand effects on trade, we assume away all the production-side factors that could potentially cause trade. Therefore we assume that technology and production functions are identical across countries, that there is no imperfection in markets, and that each country is endowed with the same proportion of goods 1 and 2.

1. Per-capita income as a basis for trade

To simplify matters we first assume total equality of income within each country and consider how per-capita income can serve as a basis for trade. In Figure 1.1, HH and FF are the production possibility frontiers for the home and the foreign country respectively. At relative product price P (P_1/P_2), the endowment points for the home and foreign country are at A and A^* . Note that since each country is endowed with the same proportion of goods 1 and 2, A and A^* lie along the ray OX .

If preferences are homothetic, the proportion of consumption will be constant at different income levels. Therefore, OX is also the income-consumption path, with consumption points coinciding with the endowment points A and A^* . Both markets clear at the relative price P , and there is no incentive for trade.

If preferences are non-homothetic, the income-expansion path is nonlinear, consuming proportionally more of luxury good C_1 than necessity good C_2 as income increases. The income-expansion path is ray OC . At the given relative price P , the home market clears at autarky A . In the foreign country, however, higher per-capita income induces relatively higher consumption of the luxury good 1. The endowment point for the foreign country is at A^* and the consumption point at C^* . There is an excess demand for good 1. Therefore, the autarkic relative price of the luxury good 1 will be higher in the foreign country than at home. Under free trade, the home country will export and the foreign country will import the luxury good 1. This demand-induced trade is due to differences in per-capita income. It may explain why undeveloped countries export luxury foods to industrial countries and neglect growing necessity food for consumption at home.

2. Income distribution as a basis for trade

Next we consider how income distribution within each country could affect trade. In the right panel of Figure 1.2, let mm' be the average per-capita income line and MM'

the aggregate national income line. The slope of mm' and MM' is the relative price of good 1 to good 2 ($P=P_1/P_2$). OC is the income-expansion path. To simplify, assume there are two individuals in the economy. If there is income equality in the home country, then both consume at b . The aggregate consumption bundle is thus at B . If we proceed to the other extreme and suppose there is total inequality in the foreign country, so that individual 1 owns all the endowment and consumes at point B^* while individual 2 has zero endowment and consumes at origin O , then the aggregate consumption bundle is at B^* . If the discrepancy is not so dramatic, the aggregate consumption bundle will be between points B and B^* . Slopes of OB and OB^* measure the relative consumption ratio (C_1/C_2). Note that increasing income discrepancy for a given national income level increases the relative consumption of luxury good 1 as one moves from point B to B^* .

The left panel of Figure 1.2 draws the usual production possibility frontier QQ . National income measured in good 2 is OM and in good 1 is OJ or OM' where $JO=OM'$. At relative price P , the production (or endowment) points for both countries are at A . Assume home markets clear at P . Therefore the mirror image of the consumption point B for the home country coincides with the endowment point A . The foreign country, however, consumes at point C^* (the mirror image of B^*). There is an excess demand for luxury good 1. Hence the foreign country has relatively higher prices for good 1 in autarky. Under free trade, the home country with a more equal distribution of income exports the luxury good 1, and the foreign

country with a higher inequality of income imports the luxury good 1. This demand-induced trade is due to differences in the distribution of income, even though both countries are identical in all other aspects.

III. Testing Homothetic Preferences

In the previous section, we demonstrate analytically how non-homothetic preferences could give rise to demand-induced trade. In this section, we test empirically the validity of homothetic preferences that is commonly assumed in trade models.

A casual examination of the plots in Figure 1.3 already indicates that the assumption is invalid. Figure 1.3 plots the expenditure share against the real per-capita income for the eleven commodities. Homothetic preferences would mean that the proportion spent on various goods is constant, independent of one's income. The plots should therefore be horizontal lines. Clearly this is not the case. The proportions spent on food, beverages-tobacco, and clothing-footwear decrease as income rises, while other proportions increase.

This becomes even clearer when we divide 34 countries into six groups according to their per capita income level (Table 1.1). The dividing lines are placed at points where there are notable gaps in income level. Table 1.2 shows the average percentage of income spent on the eleven commodities for the six groups of countries. As income increases, the budget share on food declines sharply from 50% in the poor countries (Group I) to 13% in the rich ones (Group VI). Gross Rent, Medical Care, Transportation & Communications, and Education, are clearly luxury

goods, as their shares steadily increase as income rises. In Maslow (1954)'s theory of human motivation bread is a deficiency need and the others are abundance needs.

To test the assumption of homothetic preferences, we use a flexible demand function - Almost Ideal Demand System (AIDS). AIDS is a much more flexible functional form of demand system than the LES used by Hunter and Markusen (1988). It does not impose equal distribution of income within each country, and thus allows us to investigate the role of both per-capita income and income distribution in international trade. The section starts by introducing the AIDS model, followed by reporting the data and the empirical results.

1. Modeling consumer demand

We assume that consumers have identical but non-homothetic tastes. This means that individuals with the same level of income choose the same bundle of goods and services when they face the same prices. The representative individual maximizes his utility for a given level of prices and income. The dual problem for a utility-maximizing consumer is to minimize the consumption expenditure for a given level of utility, i.e.: $\min px$, s.t. $U(x)=u$, where p is a vector of commodity prices, x is a vector of quantities and u is the level of utility. The solution to the cost-minimizing problem yields the minimum expenditure function E , where $E=px=E(p,u)$. By

Shepard's Lemma, the cost-minimizing consumption bundle x and consumption share s can be expressed as $x=dE/dp$ and $s=d\ln E/d\ln p$ in vector form.

To implement the model empirically, a functional form for the expenditure function is needed. Since all the following analysis depends critically on the expenditure function, we shall briefly survey the demand literature, and present the rationale for choosing the AIDS in the study.

In the consumption literature, many functional forms have been used to model consumer demand. Most important are the linear expenditure system (Stone 1954) and various flexible demand systems. The linear expenditure system (LES) is a restrictive form because it requires that there are no inferior goods (all elasticities be greater than zero) and that consumption elasticities that are less than 1 must increase with increasing expenditure, which seems implausible for some commodities, such as food. More importantly, under LES the distribution of income within each country does not affect market demand. Since we are interested in examining how the distribution of income affects demand and trade, we need to find a demand function that is less restrictive and that allows the effect of both income level and income distribution on aggregate demand. To do so, we resort to flexible demand systems.

The basic idea of flexible demand system is to have a functional form that has enough parameters to approximate whatever the true unknown function may be.

There are many different flexible demand models, such as the Generalised Leontief (Diewert 1971, 1974), the Generalized Cobb-Douglas (Diewert 1973), the Translog model (Christensen, Jorgenson and Lau 1975; Jorgenson and Lau 1975; Jorgenson, Lau and Stoker 1980), and the Almost Ideal Demand System (Deaton and Muellbauer 1980).

Among these flexible forms of demand functions, AIDS is our choice. The reasons are as follows. First, Berndt, Darrough and Diewert (1977) compare the three flexible functional forms: the Generalized Leontief, Generalized Cobb-Douglas and the Translog. They find that the translog functional form is preferable on both theoretical and econometric grounds. Second, when we compare Translog and AIDS, we find that AIDS is preferable for our study. It preserves the generality of translog model, but also provides us the ease of incorporating income distribution into our model and makes estimation easier.

The AIDS model is briefly introduced below; for detail see Deaton and Muellbauer (1980). The AIDS expenditure function ($\log E(p, u)$) for an individual k could be written as.

$$\log E_k(p, u) = (1-u) \log\{a(p)\} + u \log\{b(p)\} \quad (1.1)$$

$$\log a(p) = \alpha_0 + \sum_i \alpha_i \log P_i + (1/2) \sum_i \sum_j (Y_{ij}' \log P_i \log P_j) \quad (1.2)$$

$$\log b(p) = \log a(p) + \beta_0 \prod_i P_i^{\beta_i} \quad (1.3)$$

where P_i or P_j are prices for commodity i or j . Utility u lies between 0 (subsistence) and 1 (bliss) so that $a(p)$ and $b(p)$ can be regarded as the costs of subsistence and bliss respectively. Substitute equations (1.2-1.3) into (1.1) so that AIDS expenditure function is written as

$$\ln E_k(p, u) = \alpha_0 + \sum_i (\alpha_i \log P_i) + (1/2) \sum_i \sum_j (Y_{ij}' \log P_i \log P_j) + u \beta_0 \prod_i P_i^{\beta_i} \quad (1.4)$$

Differentiating equation (1.4) gives the budget share of commodity i for individual k

$$s_{ik} = d \ln E / d \ln P_i = \alpha_i + \sum_j (Y_{ij} \log P_j) + \beta_i u \beta_0 \prod_i P_i^{\beta_i} \quad (1.5)$$

$$\text{where } Y_{ij} = Y_{ij}' + Y_{ji}'$$

Deriving u as a function of (p, E) from equation (1.4) and substituting the result to equation (1.5), one obtains the following expression for the expenditure share with P defined as price index

$$s_{ik} = \alpha_i + \sum_j (Y_{ij} \log P_j) + \beta_i \log(E_k/P) \quad (1.6)$$

$$\log P = \alpha_0 + \sum_i (\alpha_i \log P_i) + (1/2) \sum_i \sum_j (\beta_{ij} \log P_i \log P_j) \quad (1.7)$$

Summing equation (1.6) over all individuals, we obtain the aggregate expenditure share for commodity i , which can be written as

$$S_i = \alpha_i + \sum_j (\gamma_{ij} \log P_j) + \beta_i \{ \sum_k (E_k \log E_k) / \sum_k E_k - \log P \} + \varepsilon_i \quad (1.8)$$

$$\log P = \alpha_0 + \sum_i (\alpha_i \log P_i) + (1/2) \sum_i \sum_j (\gamma_{ij} \log P_i \log P_j) \quad (1.9)$$

where ε_i is the error term, capturing differences in tastes, random noise and measurement errors. Equation (1.8) shows that aggregate expenditure share depends on prices and on real per-capita income and its distribution through the term $\{ \sum_k (E_k \log E_k) / \sum_k E_k - \log P \}$. If individuals have the same level of income, then

$\{\sum_k (E_k \log E_k) / \sum_k E_k - \log P\} = \log(E/P)$ where E/P is the average real per-capita income.

If individuals have different levels of income, then $\{\sum_k (E_k \log E_k) / \sum_k E_k\}$ is a weighted average of individual incomes, with weights reflecting income distribution.

Parameter β_i captures the income effect on budget shares. A positive (or negative) β_i indicates that commodity i is a luxury (or necessity) good. Homothetic preferences imply that β_i shall not be significantly different from zero for each commodity i .

The parameters in equations (1.8-1.9) shall satisfy the following conditions:

- i) The adding up condition, i.e. the sum of aggregate expenditure shares over all commodities shall add up to one ($\sum_i S_i = 1$). This requires $\sum_i \alpha_i = 1$, $\sum_i \beta_i = 0$, $\sum_j \gamma_{ji} = 0$, $\forall i, j$;
- ii) The homogeneity condition, i.e. the compensated demand function and therefore the expenditure share function is homogenous degree of zero in prices. This requires that $\sum_i \gamma_{ij} = 0$, $\forall i$;
- iii) The symmetry condition, i.e. the substitution (or Slutsky) matrix is symmetric such that $\gamma_{ij} = \gamma_{ji}$ $\forall i, j$;
- iv) The negativity condition, i.e. the substitution matrix is a negative semi-definite.

The negativity cannot be ensured by any restrictions on the parameters, but can be checked afterwards.

In sum, the following parameter restrictions must be satisfied.

$$\gamma_{ij} = \gamma_{ji}, \sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_j \gamma_{ji} = 0 \text{ and } \sum_j \gamma_{ij} = 0 \quad (1.10)$$

2. Empirical implementation

Assume the error term ε_i in equation (1.8) is normally distributed, homoscedastic and non-serial correlated. This could be verified by running a simple cross-country OLS regression of equation (1.8) for each of the eleven commodities. Table 1.3 summarizes the diagnostic tests of the error term ε_i . The Jarque-Bera normality test, Breusch-Pagan heteroscedasticity test and Durbin-Watson autocorrelation test reveal that the assumptions of the error term could not be rejected for each commodity equation.

However, the error term across commodity equations are not independent, since the adding-up restriction requires $\sum_i S_i = I$. The adding-up restriction means that we could drop one commodity in our estimation. Suppose we drop the eleventh commodity. Equations (1.8-1.10) could be rewritten as:

$$S_i = \alpha_i + \sum_j (\gamma_{ij} \log(P_j/P_{11})) + \beta_i \{ \sum_k (E_k \log E_k) / \sum_k E_k - \log P \} + \varepsilon_i \quad (1.11)$$

$$\log P = \alpha_0 + \sum_i (\alpha_i \log P_i) + (1/2) \sum_i \sum_j (\gamma_{ij} \log P_i \log(P_j/P_{11})) \quad (1.12)$$

$$\text{s.t. } \gamma_{ij} = \gamma_{ji} \text{ (Slutsky symmetry)} \quad \forall i, j = 1 \dots 10 \quad (1.13)$$

The above system of equations (1.11-1.13) is estimated by seemingly unrelated regression (SUR). The SUR estimation is efficient because it not only takes into account the cross equation covariance but also the cross equation parameter

restrictions. The null hypothesis of homothetic taste requires β_i for each commodity i equals zero ($H_0: \beta_i = 0, \forall i$).

3. Data

We use expenditure to approximate income. This implicitly assumes zero savings rate. The assumption does not greatly affect our results, because if savings are allowed to be non-zero there will be simply an extra term in the constant. Data for per-capita expenditure, commodity expenditure shares and prices are from Kravis, Heston and Summers (1982)'s 1975 dataset. It contains information for 34 countries on 11 consumption commodities (excluding investment goods and government expenditure). We choose the dataset so as to make our results comparable with Hunter and Markusen (1988).

In equation (1.11), the term $\{\Sigma_k(E_k \log E_k) / \Sigma_k E_k\}$ is a weighted average of per-capita income, with weights being the income share by individual k and thus reflecting the distribution of income. Unfortunately, data on income distribution by individual within each country do not exist. So they have to be constructed from the available income distribution data taken from various issues of World Development Report. The World Development Report contains information on the proportion of income held by five percentile groups of households (i.e. the lowest 20%, 2nd 20%, 3rd 20%, 4th 20% and the highest 20%), with most observations falling between 1970 and

1976. Based on this information, the weighted average per-capita income $\{\sum_k(E_k \log E_k)/\sum_k E_k\}$ is constructed. Appendix 1A provides details on the construction method.

4. Estimation results and hypothesis testing

Results for SUR estimation of equations (1.11-1.13) are presented in Table 1.4. Twenty-one out of fifty-five price coefficients are significantly different from zero. For most commodities, their own prices have significant effect on their budget shares. In Hunter and Markusen (1988)'s study, only 9 out of 121 price coefficients are significant. This could be due to the restrictiveness of the Linear Expenditure System they used.

Eight out of ten β coefficients are significantly different from zero. The deviation of β from zero implies non-homothetic preferences. A positive (or negative) β means that the commodity is a luxury (or necessity) good. The β estimates are significantly positive for rent, fuel, house furnishing, medical care, transport-communication and recreation, while significantly negative for food and education. The β coefficients for beverage-tobacco, and clothing-footwear are negative and positive respectively, but neither is significant. In Hunter and Markusen (1988)'s study, the income elasticity for all commodities is positive, which implies that there are no necessity goods. This is due to the restrictive nature of LES model as we demonstrated earlier.

The test of homothetic preferences is simply a test of whether β_i coefficients for all commodities i equal to zero. We first estimate the unrestricted version as equation (1.11) and then the restricted version where all β_i coefficients were forced to be zero. We then calculate the log-likelihood function in each case and perform the likelihood ratio test. The test indicates that the null hypothesis of all β_i being zero is statistically rejected at 1% significance level (Table 1.5). This means that the level of income and its distribution do affect consumption patterns, and thus sheds doubt on the validity of homothetic preferences commonly assumed in trade models.

The rejection of homothetic taste is the same as in Hunter and Markusen (1988). The result here however should be more convincing, since we use a more flexible demand system that does not impose the equal distribution of income within each country, and a system estimation technique that yields more efficient estimates.

IV. A Counterfactual Volume-of-Trade Experiment

In the last section, the assumption of homothetic preferences is statistically rejected at 1% significance level. This section continues to assess its economic significance using a counter-factual experiment. The experiment is similar to that performed by Hunter and Markusen (1988) and proceeds as follows.

First, assume the world is in free-trade equilibrium: the world market clears and the relative prices of all countries are the same. Suppose that prices in all countries are equal to one. This removes the price term. Equations (1.11-1.13) without price effect can be rewritten as

$$S_i = (\alpha_i - \beta_i \alpha_o) + \beta_i \{ \sum_k (E_k \log E_k) / \sum_k E_k \}. \quad (1.14)$$

Second, with the estimated parameters (α_i, β_i) , we derive the estimated expenditure shares using equation (1.14). The estimated shares eliminate the effects of differences in taste, random noise and measurement errors.

Third, suppose that all thirty-four countries are endowed with the eleven commodities in the same proportion, which neutralizes the possibility of trade due to production-side differences. The procedure of the neutralization is as follows: using fitted expenditure share of country n for commodity i (S_{in}), we get estimated real consumption C_{in} , where $C_{in} = [\text{estimated } S_{in}] [\sum_k (E_{kn} \log E_{kn}) / \sum_k E_{kn}]$ (note $P_i = 1$ for all

i, n). Add C_{in} over n countries to get total world endowment $\sum_n C_{in}$ of commodity i , and total world income $\sum_i \sum_n C_{in}$. Each country is then given a share of the world endowment of commodity i proportional to their share of world income. Let X_{in} be the hypothetical endowment of commodity i for country n . Then the demand-induced trade is the difference between a country's consumption and its hypothetical endowment ($C_{in} - X_{in}$). Table 1.6 gives an example of how to calculate the demand-induced trade for food. Repeat the same procedure for all other ten commodities and then calculate the volume-of-trade statistics as follows:

$$T = \frac{\text{Total value of world inter-industry trade}}{\text{Total value of world income}} = \frac{\sum_i \sum_n |C_{in} - X_{in}| / 2}{\sum_i \sum_n (C_{in})}$$

where: $X_{in} = \theta_n \sum_n C_{in}$ and $\theta_n = \sum_i C_{in} / \sum_i \sum_n C_{in}$ (1.15)

The volume-of-trade statistic calculated is 6.22%. This is the inter-industry trade caused not only by differences in per-capita income but also by differences in income distribution. Note that in calculating the volume-of-trade statistic, we use the net trade flows that do not include intra-industry trade.

We then repeat the above procedure to get the volume-of-trade statistics under the assumption of equal domestic income distribution, i.e. $\sum_k (E_{kn} \log E_{kn}) / \sum_{kn} E_{kn} = \log E_n$ where E_n is country n 's real average per-capita income. The volume of trade statistics

drops to 3.98%. This implies that increasing income discrepancy within each country increases world inter-industry trade by 2.24%.

V. Implications for Trade Puzzles and Paradoxes

This section demonstrates that non-homothetic preferences may explain the puzzles and paradoxes related to the Heckscher-Ohlin-Vanek (HOV) model, in particular the ‘missing trade’ puzzle, the ‘endowment’ paradox and the ‘Leontief’ paradox.

1. The HOV model, puzzles and paradoxes

The HOV model states that a country’s trade embodies a net export of its most abundant factor. In equilibrium, a country’s net factor content of export equals the difference between factors absorbed in production and factors absorbed in consumption. That is:

$$A_n T_n = A_n Q_n - A_n C_n \quad (1.16)$$

where A_n is $F \times J$ matrix of factor input requirements: the amount of factor f required to produce one unit of commodity j . T_n , Q_n and C_n are $J \times 1$ vector of net trade flows, commodity output and commodity consumption for country n .

The HOV model assumes:

- i) equalization of relative commodity prices across countries under free trade;
- ii) incomplete specialization and factor price equalization;
- iii) identical technology: $A_n = A$ for all country n ;

- iv) full employment of factors: $A_n Q_n = V_n$, where V_n is the $F \times 1$ vector of factor endowment for country n ;
- v) identical and homothetic tastes: each country consumes a proportional share of world production for each commodity. That is $C_n = \theta_n Q_w$ and $\theta_n = Y_n/Y_w$, where Q_w is $J \times 1$ vector of world output, θ_n the income share for country n , Y_n is aggregate income for country n , and Y_w is total world income.

With these assumptions, equation (1.16) could be rewritten as:

$$F_n = V_n - \theta_n V_w \quad (1.17)$$

where F_n is a vector of factor content of net exports, V_n is a vector of factor supplies, and $\theta_n V_w$ is a vector of factors absorbed in consumption. Equation (1.17) states that if a country is abundant in factor f (i.e. $V_{fn} - \theta_n V_{fw} > 0$), then its trade embodies a net export of factor f ($F_{fn} > 0$).

The HOV model yields poor predictions in practice, which sheds doubt on its validity (Leontief 1953; Maskus 1985; Bowen *et al.* 1987; Brecher and Choudhri 1988; Staiger 1988; Kohler 1991). Besides the famous Leontief Paradox, Trefler (1995) identifies three more puzzles regarding the HOV model. The first is the ‘missing trade’ puzzle: the actual factor content of trade is much smaller than the HOV prediction (i.e. actual $F_{fn} < \text{HOV's predicted } F_{fn}$). The second is the ‘endowment’ paradox: the correlation between the number of abundant factors and the level of per-capita income is strongly negative (-0.89). This suggests that rich countries tend to be

scarce in most factors, and poor ones tend to be abundant in all factors, which is absurd. The third is the fact that larger economy tends to be inward-oriented.

There have been attempts to explain these puzzles. Recently, Trefler (1993, 1995) and Davis and Weinstein (1998) amend the HOV model by relaxing its many assumptions. Despite their different approaches, both conclude that allowing for international technology differences and demand differences results in strong improvements in HOV's predictive ability.

To capture the demand differences, Trefler (1993, 1995) and Davis and Weinstein (1998) use different approaches. Davis and Weinstein (1998) relax the assumption of costless trade and account for the influence of trade costs on bilateral trade volume. This, in turn, affects the demand for domestically produced goods. Trefler (1995) assumes Armington home-biased consumption, but does not identify the sources of home-biased consumption behaviour. They both, however, amend the demand-side of HOV without relaxing the assumption of identical and homothetic preferences.

The method proposed in this section constitutes a third approach. It amends the demand-side HOV by relaxing the assumption of homothetic preferences. We examine whether non-homotheticity can improve the performance of the HOV model and help explain the puzzles and paradoxes.

2. Modified HOV with non-homothetic preferences

To highlight the effects of non-homothetic preferences, we shall keep all the other HOV assumptions intact. By using the expenditure share equations (1.8-1.10), the modified HOV with non-homothetic preferences could be written as follows (Appendix 1B for derivation):

$$F_n = (V_n - \theta_n V_w) - \varphi \{ \log y_n - \sum_n (\theta_n \log y_n) \} Y_n \quad (1.18)$$

where y_n is weighted average per-capita income and Y_n is country n 's aggregate income. The two terms on the right-hand side of equation (1.18) correspond to two explanations for the factor content of trade. The first is the HOV effect, resulting from cross-country differences in factor endowment. The second is the effect resulting from non-homothetic preferences.

Non-homotheticity affects factor content of trade through FxI parameter vector φ . Parameter φ measures income elasticity of factor absorption. This is so because $\varphi_f = \sum_i (a_{fi} \beta_i)$, with a_{fi} measuring factor-intensity (the amount of factor f required to produce one unit of commodity i) and β_i measuring income elasticity of consumption for good i (positive if it is a luxury good and negative if it is a necessity good). If tastes are homothetic, then $\beta_i = 0$ for all i and $\varphi_f = 0$ for all f . Equation (1.18) is then identical to the unmodified HOV equation (1.17). If non-homothetic tastes are significant (i.e. not all $\beta_i = 0$), it is then possible for $\varphi_f > 0$ or $\varphi_f < 0$ depending on the interaction of income elasticity and factor intensity among different commodities.

For example, if factor f is used intensively in producing luxury goods, then $\varphi_f > 0$ (or $-\varphi_f < 0$)².

Income differences are captured by the term $\{logy_n - \sum_n(\theta_n logy_n)\}$. It measures the difference between country n 's average of per-capita income ($logy_n$) and the world's weighted average per-capita income ($\sum_n(\theta_n logy_n)$) with weights θ_n reflecting world income distribution among nations. If a country has the same average per-capita income as the world average, then $\{logy_n - \sum_n(\theta_n logy_n)\}=0$ and the equation is identical to the unmodified HOV: $F_n = V_n - \theta_n V_w$.

The modified HOV model could help to explain the puzzles and paradoxes if we make the plausible assumption that luxury goods are also capital-intensive. Take a rich country n ($logy_n - \sum_n \theta_n logy_n > 0$) as an example. The HOV model predicts that the capital-abundant rich country's trade will embody a net export of capital (K) and net import of labour (L). That is: $F_{Kn}^{HOV} = (V_{Kn} - \theta_n V_{Kw}) > 0$ and $F_{Ln}^{HOV} = (V_{Ln} - \theta_n V_{Lw}) < 0$. However, under the modified model, if we make the plausible assumption that luxury goods are capital-intensive ($\varphi_K > 0$) and necessity goods ($\varphi_L < 0$) are labour-intensive, we obtain

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² Suppose there are two sectors, then $\varphi_f = a_{f1} \beta_1 + a_{f2} \beta_2 = a_{f1} (\beta_1 + \beta_2) - \beta_2 (a_{f1} + a_{f2})$. If factor f is used intensively in producing luxury goods (i.e. $\beta_2 > 0$ and $a_{f1} - a_{f2} > 0$), then $\varphi_f > 0$ since $(\beta_1 + \beta_2) = 0$.

$$\begin{aligned}
|(F_{Kn})^{Modified}| &= |(V_{Kn} - \theta_n V_{Kw}) - \phi_K \{logy_n - \sum_n (\theta_n logy_n) Y_n\}| \\
&< |(V_{Kn} - \theta_n V_{Kw})| = |(F_{Kn})^{HOV}|
\end{aligned} \tag{1.19}$$

and,

$$\begin{aligned}
|(F_{Ln})^{Modified}| &= |(V_{Ln} - \theta_n V_{Lw}) - \phi_L \{logy_n - \sum_n (\theta_n logy_n) Y_n\}| \\
&< |(V_{Ln} - \theta_n V_{Lw})| = |(F_{Ln})^{HOV}|
\end{aligned} \tag{1.20}$$

Equations (1.19-1.20) show that the modified HOV yields less factor content of trade than HOV predicts. The difference arises since the modified model allows higher absorption of the abundant factor and lower absorption of the scarce factor.

If the factor absorption for the abundant factor is large enough, the direction of the factor content of trade could actually be reversed and result in the Leontief Paradox. For example, for a given ϕ_K and ϕ_L in equations (1.19-1.20), the further away a country's average per-capita income is from the world's average per-capita income (either the very rich, or the very poor), the more likely is the reverse direction of the factor content of trade. This is so because as a country gets rich, so does its demand for luxury goods. Luxury goods are relatively more capital-intensive, so the absorption of the abundant factor capital increases. If the absorption gets large enough, the abundant factor may become scarce and results in 'Leontief' paradox.

Equations (1.19-1.20) also show how the size of an economy may affect the factor content of trade. Y_n is a country's aggregate income, which equals its per-capita

income times its total labour force $Y_n = y_n L_n$. The larger the economy (the larger the L_n), the higher is the absorption of its abundant factor and the less is the factor content of trade. This may explain Treffer's empirical finding that larger economies tend to be inward-oriented.

In sum, non-homothetic preferences and cross-country differences in income among countries could result in different consumption patterns, and hence different absorption of various factors. The problem with the unmodified HOV model lies in its definition of factor abundance or factor scarcity. As Kenen (1968) states: "Scarcity can only be interpreted in the light of demand conditions." A capital-abundant country may have high absorption of capital in its consumption, hence its net export could embody less capital than HOV predicts, and if the absorption dominates its relative abundance in factor supply, the direction of the factor content of trade as predicted by HOV could actually be reversed, resulting in a "Leontief paradox" situation.

3. Empirical findings

Does non-homotheticity improve the prediction of the HOV model? Ideally one should use the estimated β_i directly from section III, then compare both sides of the modified HOV equation (1.18). However there is a problem in mapping consumption

goods into trade goods, so we will use the data and methods in Trefler (1995) and compare our results with his.

The data cover thirty-three countries and nine factors: capital, cropland, pasture, and six categories of labour for the year 1983. As in Trefler (1995), we shall scale all observations in order to ensure that the errors are homoscedasticity assumption. Let D_{fn} be the deviations from the HOV theorem so that $D_{fn} = F_{fn} - (V_{nf} - \theta_n V_{fw})$, and σ_f be the standard error of D_{fn} for a given factor f . All data relating to factor f will be scaled by σ_f to have comparable units across factors. Further, let θ_n be the income share of country n , and all observations relating to country n be scaled by $\theta_n^{1/2}$ to control for country size. Therefore, the scale factor for all observations (f, n) is $\sigma_f \theta_n^{1/2}$. (See Trefler 1995 for further detail.)

We estimate parameter σ_f in equation (1.18) using OLS. First we restrict the constant and the coefficient of $(V_n - \theta_n V_w)$ equal zero and one respectively. Column A of Table 1.7 reports the estimates. Many of the coefficients of $(V_n - \theta_n V_w)$ are significantly negative, which means that most of the factors examined are used intensively in the production of luxury good. When we relax the restrictions, we get expected signs - some negatives and some positives, yet many are insignificant (Table 1.7 column B).

Table 1.8 compares the three models: the unmodified HOV, the modified HOV with non-homothetic preferences and the modified HOV with Trefler's Armington home

bias effect. In particular, we examine which demand-side modification explains better of the ‘endowment’ paradox and the ‘missing trade’ puzzle as identified in Trefler (1995).

The ‘endowment’ paradox is measured by the correlation between per-capita income and the number of times the predicted value of F_{fn} is positive for country n . If the ‘endowment’ paradox is present, there will be a high negative correlation. A high negative correlation suggests that a rich country tends to be scarce in most factors. Our modified model, with or without parameter restrictions, yields a much weaker correlation and outperforms both the unmodified HOV and the Armington model in reducing the ‘endowment’ paradox.

‘Missing trade’ puzzle refers to the observation that the actual factor content of trade is much smaller than the HOV model predicts (i.e. actual $F_{f,n}$ < HOV’s predicted $F_{f,n}$). ‘Missing trade’ is measured by the variance of actual F_{fn} divided by the variance of the predicted F_{fn} . If a model yields better prediction, then the correlation between the actual factor content of trade and the predicted factor content of trade shall increase. Our model increases the correlation than the unmodified HOV, but not as well as the Armington model.

When judged by a likelihood ratio, Schwarz values and goodness of fit statistics, our modified model without parameter restrictions outperforms both the unmodified

HOV model and the Armington home bias model. Once the parameter restrictions are imposed, our model still outperforms the unmodified HOV, but not as well as the Armington model.

In sum, the non-homotheticity modification does improve the performance of the HOV prediction. It outperforms Trefler's Armington home bias model in reducing the 'endowment' paradox, but is not as good in explaining the 'missing trade' puzzle.

VI. Conclusion

This paper examines the effect of income and its distribution on international trade. We first demonstrate analytically how non-homothetic preferences, in particular how cross-country differences in average per-capita income and income distribution, could give rise to demand-induced trade.

We then examine empirically the statistical and economic significance of non-homothetic preferences. Using a flexible Almost Ideal Demand System (AIDS) and the Seemingly Unrelated Regression technique, we test the assumption of homothetic preferences. The assumption is statistically rejected at 1% significance level. A counter-factual experiment is performed to further assess the economic significance of non-homothetic taste. The experiment shows that the demand-induced trade due to differences in income and distribution amount to 3.98% and 2.24% of world expenditure respectively.

The implication of non-homothetic preferences is that it may help us to explain some of the trade puzzles and paradoxes. By modifying the HOV model with non-homothetic preferences, we demonstrate the possibility of lower factor content of trade than HOV predicts, and the possibility for Leontief Paradox to occur if factor absorption dominates its relative abundance. It is shown that the modified model with non-homothetic preferences improves the HOV prediction and could explain the

‘missing trade’ puzzle and the ‘endowment’ paradox as identified. It outperforms Trefler’s Armington home-bias modification in reducing ‘endowment’ paradox, but does not perform as well in explaining the ‘missing trade’ puzzle.

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Figure 1.1**Per-capita income as a basis for trade**

Figure 1.2
Income distribution as a basis for trade

Figure 1.3 Expenditure shares (vertical axes) against real per-capita income (horizontal axes) for thirty-four countries

1. Food	2. Beverages-tobacco	3. Clothing-footwear	4. Gross rent	5. Fuel-power	6. House furnishings
7. Medical care	8. Transport-Communications	9. Recreation	10. Education	11. Other expenditures	
- Data source: Kravis, Heston and Summers (1982)

Table 1.1 Grouping 34 countries into six groups

Groups Real expenditure per capita (valued in US dollar)		Country	% of US	US\$
I	Less than 15% (US=100) 0-750 (US\$)	Malawi (1)	5.53	285.56
		Kenya (2)	7.36	379.53
		India (3)	6.84	352.68
		Pakistan (4)	8.90	459.35
		Sri Lanka (5)	10.32	532.45
		Zambia (6)	8.37	431.98
		Thailand (7)	14.08	726.24
		Philippines (8)	13.97	720.64
II	15-30% (US=100) 900-1500 (US\$)	Korea (9)	20.65	1065.70
		Malaysia (10)	18.90	975.00
		Colombia (11)	25.62	1321.70
		Jamaica (12)	26.85	1385.29
		Syria (13)	26.12	1347.55
		Brazil (14)	24.56	1267.29
		Romania (15)	29.03	1498.08
		Iran (18)	27.05	1395.49
III	30-50% (US=100) 1900-2500 (US\$)	Mexico (16)	37.23	1921.08
		Yugoslavia (17)	38.50	1986.49
		Uruguay (19)	45.03	2323.35
		Ireland (20)	46.40	2394.15
		Hungary (21)	46.73	2410.91
		Poland (22)	43.42	2240.15
IV	50-70% (US=100) 2800-3600 (US\$)	Italy (23)	53.15	2742.32
		Spain (24)	60.52	3122.64
		U.K. (25)	63.91	3297.53
		Japan (26)	58.78	3033.03
		Netherlands (28)	68.42	3530.46
V	70-90% (US=100) 3800-4100 (US\$)	Austria (27)	74.21	3828.98
		Belgium (29)	74.85	3861.73
		France (30)	75.41	3891.01
		Luxembourg(31)	79.20	4086.29
		Denmark (32)	78.34	4041.84
VI	More than 90%	Germany (33)	75.34	3887.29
		US (34)	100.00	5159.62

Data source: Kravis, Heston and Summers (1982) Table 6-1 and Table 6-3 (1st line)

Table 1.2 Average expenditure shares by country group and by commodity

Commodities	Group I <15% (0-750)	Group II 15-30% (900-1500)	Group III 30-50% (1900-2500)	Group IV 50-70% (2800-3600)	Group V 70-90% (3800-4100)	Group VI > 90%
Food	0.50	0.37	0.29	0.23	0.17	0.13
Beverage - Tobacco	0.06	0.06	0.07	0.05	0.05	0.03
Clothing - footwear	0.07	0.09	0.09	0.08	0.08	0.07
Gross rent	0.05	0.07	0.05	0.11	0.11	0.14
Fuel, power	0.03	0.03	0.04	0.03	0.04	0.04
House furnishings	0.05	0.06	0.09	0.07	0.09	0.07
Medical care	0.04	0.05	0.07	0.08	0.09	0.13
Transp - commu	0.06	0.09	0.08	0.10	0.12	0.13
Recreation	0.03	0.04	0.05	0.07	0.06	0.06
Education	0.05	0.06	0.06	0.07	0.07	0.09
Other expenditures	0.05	0.09	0.10	0.11	0.11	0.12
Observation	8	8	6	5	6	1

Data source: Kravis, Heston and Summers (1982) Table 6-1 and Table 6-3 (1st line)

Table 1.3 Diagnostic test of error terms ε_i for each commodity group

$$\text{OLS } S_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \{ \sum_k E_k \log E_k / \sum_k E_k \} - \beta_i \log P + \varepsilon_i \quad (1.8)$$

Commodities	R ²	Goodness of Fit $\rho(S_i, \text{fitted } S_i)$	JB Normality Test	BP Heteroscedacity Test	DW auto- correlation test
Food	0.96	0.98	4.8*	9.94	2.15
Beverages -Tobacco	0.52	0.72	1.03	20.17*	2.03
Clothing - Footwear	0.41	0.64	0.58	15.61	2.59
Gross Rent	0.66	0.82	0.87	9.44	1.81
Fuel - Power	0.46	0.68	0.36	16.55	1.9
House Furnishings	0.75	0.86	3.83	9.47	1.78
Medical Care	0.81	0.90	0.07	9.93	1.74
Transport – Communication	0.66	0.81	0.22	15.79	2.29
Recreation	0.77	0.88	1.73	9.45	2.31
Education	0.77	0.88	1.69	16.22	2.8
Other Expenditures	0.64	0.8	0.93	7.98	1.7

Notes: * 10% significance level

Table 1.4 SUR estimates of the Almost Ideal Demand System (equations 1.11-1.13)

Commodity i	α_i	γ_{i1}	γ_{i2}	γ_{i3}	γ_{i4}	γ_{i5}	γ_{i6}	γ_{i7}	γ_{i8}	γ_{i9}	γ_{i10}	$\hat{u}_i$
Food	0.3049*** (17.32)	0.155*** (6.52)	-0.020 (-1.33)	0.0069 (0.50)	-0.017 (-1.49)	0.005 (0.80)	-0.009 (-0.69)	-0.017** (-2.28)	-0.041*** (-3.28)	0.013* (1.68)	-0.063*** (-7.07)	-0.098*** (-8.80)
Beverages – Tobacco	0.046*** (4.50)		0.034*** (2.88)	-0.0021 (-0.24)	0.006 (0.69)	0.003 (0.58)	-0.019** (-2.16)	-0.011** (-2.03)	0.007 (0.81)	0.014** (1.96)	0.008 (0.93)	-0.0005 (-0.08)
Clothing – Footwear	0.0815*** (10.69)			0.002 (0.11)	-0.021** (-2.53)	-0.007 (-1.29)	0.033*** (3.02)	0.007 (1.18)	-0.012 (-0.74)	-0.020** (-2.27)	-0.009 (-1.29)	0.0037 (0.71)
Gross Rent	0.061*** (6.07)				0.028*** (3.86)	0.002 (0.46)	-0.006 (-0.89)	-0.009* (-1.76)	0.005 (0.66)	0.006 (1.38)	-0.006 (-1.12)	0.031*** (4.97)
Fuel – Power	0.029*** (6.16)					0.005 (1.06)	-0.0005 (-0.14)	0.005* (1.79)	0.004 (0.69)	-0.008** (-2.38)	-0.003 (-0.98)	0.008*** (3.27)
House Furnishings	0.063*** (8.46)						-0.016** (-2.02)	0.001 (0.15)	0.009 (0.89)	0.0003 (0.03)	-0.002 (-0.53)	0.012** (2.19)
Medical Care	0.082*** (14.11)							0.028*** (4.50)	0.003 (0.76)	-0.014** (-2.43)	0.010** (2.23)	0.013*** (3.19)
Transport – Communication	0.081*** (9.81)								0.017 (0.86)	-0.0005 (-0.09)	0.003 (0.45)	0.020*** (3.88)
Recreation	0.028*** (3.31)									-0.010 (-0.81)	-0.007 (-1.36)	0.023*** (5.67)
Education	0.119*** (12.21)										0.039*** (5.25)	-0.023*** (-3.24)
Other Expenditures	0.105	-0.013	-0.0199	0.022	0.012	0	0.0092	0.087	-0.0575	0.0262	0.093	0.0108

Notes: t-values in parentheses, *** 1% significance level, ** 5% significance level, * 10% significance level

Table 1.5 Hypothesis testing of non-homothetic preferences

Commodity <i>i</i>	SSR _{ur} (unrestricted sum of squared residual)	SSR _r (restricted sum of squared residual)	Chi-Square test Likelihood Ratio (LR)
Food	0.04398	0.079872	
Beverages - Tobacco	0.017823	0.01564	
Clothing - Footwear	0.009919	0.010036	
Gross Rent	0.019062	0.020847	
Fuel – Power	0.003578	0.002996	
House Furnishings	0.006839	0.005697	
Medical Care	0.006462	0.007624	
Transport - Communication	0.013402	0.014333	
Recreation	0.005215	0.008091	
Education	0.006968	0.043307	
Log Likelihood Function	-1133.03	-1206.79	147.52 ***

Notes:

Log Likelihood Function (LLF) = $[(-n/2)\ln(2\pi) - (n/2)\ln(n) - n/2] - (n/2)\ln(ssr)$

LR = $-2(LLF_r - LLF_{ur}) = 147.52 > \text{chi-square } (\alpha = 1\%, n=10)$

*** Significant at a 1% level

Table 1.6 An example of a counter-factual experiment

A	B	C	D	E	F	G
Food	Country	Estimated Consumption ($C_{i,n}$)	Income share (θ_n)	Hypothetical endowment ($X_{i,n}$)	Imports	Value of world trade
1	1. Malawi	151.62	0.00	73.28	78.34	2248.20
1	2. Kenya	223.86	0.01	97.39	126.47	
1	3. India	180.73	0.00	90.50	90.24	
1	4. Pakistan	211.17	0.01	117.87	93.30	
1	5. Sri Lanka	231.87	0.01	136.63	95.24	
1	6. Zambia	243.37	0.01	110.85	132.52	
1	7. Thailand	309.63	0.01	186.36	123.28	
1	8. Philippines	319.84	0.01	184.92	134.92	
1	9. Rep. of Korea	387.69	0.01	273.46	114.23	
1	10. Malaysia	408.73	0.01	250.19	158.53	
1	11. Colombia	480.11	0.02	339.16	140.95	
1	12. Jamaica	473.99	0.02	355.47	118.51	
1	13. Syria	480.49	0.02	345.79	134.70	
1	14. Brazil	545.66	0.02	325.19	220.47	
1	15. Romania	466.49	0.02	384.42	82.07	
1	16. Mexico	630.32	0.03	492.96	137.36	
1	17. Yugoslavia	519.39	0.02	457.38	62.01	
1	18. Iran	491.67	0.02	358.83	132.84	
1	19. Uruguay	658.73	0.03	596.18	62.55	
1	20. Ireland	618.16	0.03	614.35	3.80	
1	21. Hungary	605.40	0.03	618.66	-13.25	
1	22. Poland	580.73	0.03	574.84	5.89	
1	23. Italy	675.90	0.04	703.70	-27.80	
1	24. Spain	716.06	0.04	801.29	-85.23	
1	25. U.K.	723.88	0.05	846.17	-122.28	
1	26. Japan	693.02	0.04	778.30	-85.27	
1	27. Austria	781.07	0.05	982.54	-201.47	
1	28. Netherlands	734.44	0.05	905.94	-171.50	
1	29. Belgium	776.04	0.05	990.95	-214.90	
1	30. France	805.32	0.05	998.46	-193.14	
1	31. Luxembourg	802.78	0.06	1048.57	-245.78	
1	32. Denmark	787.06	0.06	1037.16	-250.11	
1	33. Germany	796.72	0.05	997.51	-200.79	
1	34. U.S.A.	887.32	0.07	1323.99	-436.67	

Notes:

- Estimated consumption $C_{in} = \{estimated S_{in}\} / \{\sum_k E_{kn} \log E_{kn} / \sum_k E_{kn}\}$, where S_{in} is expenditure share of commodity i for country and E_{kn} is individual k 's total expenditure. Thus $\{\sum_k E_{kn} \log E_{kn} / \sum_k E_{kn}\}$ is a weighted average per-capita income with weights reflecting income distribution.
- Share of world expenditure $\theta_n = \sum_i C_{i,n} / \sum_i \sum_n C_{i,n}$
- Hypothetical endowment for food per capita $X_{food, n} = (\theta_{food, n})(\sum_n C_{food, n})$
- Imports for food per capita = estimated consumption - hypothetical endowment
- Value of world trade for food = sum of the positive or negative values in column F.
Repeat the above process for the other ten commodities. Then add Column G and get the total value of world trade. Add column C over eleven commodities and get the total world expenditure. Volume-of-trade statistics = the total value of world trade / the total value of world expenditure.

Table 1.7 Estimates of parameter ϕ_f

OLS equation (1.18): $F_n = (V_n - \theta_n V_w) - \phi \{ \log y_n - \sum_n \theta_n \log y_n \} Y_n$

Factors	Restricted modified HOV (Column A) (constant=0, coefficient of ($V_n - \theta_n V_w$)=1)		Unrestricted modified HOV (Column B) (constant $\neq$ 0, coefficient of ($V_n - \theta_n V_w$) $\neq$ 1)	
	ϕ_f	t-statistics	ϕ_f	t-statistics
Capital	-0.957	-6.76 ***	-0.066	-1.5
Labour				
Professional and technical	-0.585E-05	-6.61 ***	0.104E-06	1.21
Clerical	-0.610E-05	-8.89 ***	0.299E-07	0.21
Sales	-0.208E-04	-6.42 ***	0.173E-07	0.69
Service	-0.981E-05	-5.43 ***	0.433E-07	1.00
Agriculture	-0.115E-03	-6.21 ***	-0.52E-06	-2.17 **
Production and transport	-0.402E-04	-8.60 ***	0.101E-05	1.68
Land				
Cropland	-0.929E-09	-5.08 ***	-0.40E-07	-3.94 ***
Pasture	-0.307E-07	-0.93	-0.65E-08	-0.77

Data source: Trebler (1995). Significance level: *** 1%, ** 5%, * 10%

Table 1.8 Model comparison

	Description Parameters k	Likelihood		Mysteries		Goodness-of-fit	
		Ln(L)	Schwarz criterion	Endowment paradox	Missing trade	Weighted sign	$\rho(F, F')$
(i) Unmodified HOV theorem	0	-1007	-1007	-0.89	0.032	0.71	0.28
(ii) Consumption Differences: Armington	24	-439	-507	-0.42	3.057	0.87	0.55
(iii) Consumption differences: Nonhomotheticity (equation 1.18) – restricted	9	-904	-930	-0.36	0.052	0.74	0.41
(iv) Consumption differences: Nonhomotheticity (equation 1.18) – unrestricted	27	-395	-421	-0.40	2.19	0.76	0.67

Notes: Row (i) and (ii) and the following methods of calculation are from Treffer (1995, P1036): k is the number of estimated parameters. $Ln(L)$ is the maximized value of the log-likelihood function, and the Schwarz-model selection criterion is $Ln(L) - k Ln(297)/2$. The 'endowment' paradox is the correlation between per-capita GDP, y_n , and the number of times the predicted value of F_{fn} being positive for country n . The 'missing trade' is the variance of F_{fn} divided by the variance of the predicted F_{fn} . "Weighted sign" is the weighted proportion of observations for which F_{fn} and the predicted F_{fn} have the same sign, with weights being $F_{fn}/\sum_n |F_{fn}|$. And $\rho(F, F')$ is the correlation between F_{fn} and the predicted F_{fn} .

Appendix 1A Construction of income distribution data

We need to calculate a weighted average of per-capita income ($\sum_k (E_k \log E_k) / \sum_k E_k$) with weights being income shares by individual and thus reflecting the distribution of income. Since data on income distribution by individual do not exist, they have to be constructed from available information taken from various issues of World Development Report. The World Development Report contains information on the proportion of income held by 5 percentile groups of households (i.e. the lowest 20%, 2nd 20%, 3rd 20%, 4th 20% and the highest 20%), with most observations falling between 1970 and 1976.

According to Kuznet's hypothesis, income discrepancy increases with per capita income. We divide countries into six groups according to their level of development (Table 1.1). For Syria, Iran and Uruguay where the income distribution data are not available, we take an average of household income distribution from countries 1-15 (group I and group II). For Romania and Poland where there is no available information, we use income distribution data of Yugoslavia and Hungary as proxies respectively, due to their similar systems before reform. For Luxemboug and Austria, we take averages of advanced western countries.

Let S_g and S_k be the proportion of income held by household group g and individual k respectively, E_a be the average per-capita income, E_k be the individual k 's income, and L the total population. Then:

$$\begin{aligned} [\sum_k (E_k \log E_k)] / \sum_k E_k &= \sum_k (S_k \log (S_k E_a L)) \\ &= S_1 \log (S_1 E_a L) + S_2 \log (S_2 E_a L) + \dots + S_L \log (S_L E_a L) \end{aligned}$$

Suppose there are J individuals belonging to the same group, say group 1. Further assume equal distribution of income within each group. Then for group 1 (the lowest 20%)

$$\begin{aligned} S_1 \log (S_1 E_a L) + S_2 \log (S_2 E_a L) + \dots + S_J \log (S_J E_a L) \\ = (S_1 + S_2 + \dots + S_J) \log (S_{g1} E_a L / 20\% L) = S_{g1} \log (S_{g1} E_a / 20\%) \end{aligned}$$

Similarly

$$\text{For group 2 (the 2nd 20\%)} = S_{g2} \log (S_{g2} E_a / 20\%)$$

$$\text{For group 3 (the 3rd 20\%)} = S_{g3} \log (S_{g3} E_a / 20\%)$$

$$\text{For group 4 (the 4th 20\%)} = S_{g4} \log (S_{g4} E_a / 20\%)$$

$$\text{For group 5 (the highest 20\%)} = S_{g5} \log (S_{g5} E_a / 20\%)$$

So we derive

$$\begin{aligned} \sum_k (E_k \log E_k) / \sum_k E_k &= \sum_k (S_k \log (S_k E_a L)) \\ &= S_{g1} \log (S_{g1} E_a / 20\%) + S_{g2} \log (S_{g2} E_a / 20\%) + S_{g3} \log (S_{g3} E_a / 20\%) \\ &\quad + S_{g4} \log (S_{g4} E_a / 20\%) + S_{g5} \log (S_{g5} E_a / 20\%) \\ &= \sum_g (S_g \log S_g) + \log (E_a / 0.2) \end{aligned}$$

Appendix 1B The derivation of the modified HOV model

Let C_{in} , Y_n and B_n be country n 's total consumption of good i , its aggregate income and its current account respectively. Using equations (1.8-1.9) and the fact that prices in all countries are set to one in free-trade equilibrium ($P_j^n = 1, \forall n, j$), we obtain

$$C_{in} = S_{in}(Y_n - B_n)/P_{in} = [(\alpha_i - \beta_i \alpha_0) + \beta_i \log y_n][Y_n - B_n] \quad (1B.1)$$

where $y_n = \sum_k (E_k \log E_k) / \sum_k E_k$. Summing C_{in} over n countries and for simplicity assuming $B_n = 0 \forall n$ (the analytical results are not affected), we get $(\alpha_i - \beta_i \alpha_0) = Q_{iw}/Y_w - \beta_i \sum_n (Y_n \log y_n)/Y_w$. Substituting $(\alpha_i - \beta_i \alpha_0)$ into equation (1B.1), we have

$$C_{in} = \{Q_{iw} - \beta_i \sum_n (Y_n \log y_n) + \beta_i Y_w \log y_n\} (Y_n / Y_w) \quad (1B.2)$$

Multiplying both sides by a_{if} (the amount of factor f required for unit output of good i) and summing over i , we obtain

$$a_f C_n = \sum_i (a_{if} C_{in}) = \theta_n V_{fw} - \phi_f \{ \log y_n - \sum_n (\theta_n \log y_n) \} Y_n \quad (1B.3)$$

where $\theta_n = Y_n / Y_w$, $\phi_f = \sum_i (a_{if} \beta_i)$, and $V_{fw} = \sum_i (a_{if} Q_{iw})$. Substituting equation (1B.3) into equation (1.16), we obtain equation (1.18) in a vector form:

$$F_n = (V_n - \theta_n V_w) - \phi \{ \log y_n - \sum_n (\theta_n \log y_n) \} Y_n \quad (1B.4)$$

Chapter 2

The Impact of Trade and Technology on Skill Upgrading and Production Efficiency -- Evidence from Canadian Manufacturing Industries

I. Introduction

Since the 1980s, there has been an increase in the relative demand for skilled labour, leading to a rise in the wage gap between skilled and unskilled labour in most industrialized countries (Katz and Murphy 1992, Bound and Johnson 1992, Katz and Autor 99 for the United States; Berman et al 1998 for other OECD countries). This has generated considerable debate on the causes of this phenomenon, especially of the roles of trade and technology.

The majority of studies conclude that technology, especially computer technology rather than trade with low-wage countries, is the main explanation of the increased demand for skilled labour. Models of international trade, such as the Heckscher-Olin-Venok (HOV) model, predict that a developed country trading with low-skill and low-wage countries would experience a contraction of the low-skill-intensive industries and an expansion of the high-skill-intensive industries. This between-

industry shift increases the relative demand for skilled labour. However, several decomposition analyses (Berman et al 1994 for the United States, and Berman et al 1998 for other OECD countries) find that the vast majority of the shift towards skilled labour is due to within-industry skill upgrading (the increased use of skilled labour within industries) rather than due to between-industry shift (the reallocation of employment from unskill-intensive industries to skill-intensive industries). In addition, they find strong positive correlation between within-industry skill upgrading and investments in R&D and in computers. It is therefore argued that skill-biased technological change rather than trade is the major cause of the increased relative demand for skilled labour.

However, trade may affect within-industry skill upgrading through at least two channels. First, an industry, even at the lowest level of aggregation, is composed of plants producing differentiated products with varying degree of skill-intensity. This heterogeneous nature within industries could lead to within-industry restructuring in response to increased international competition¹. Firms may switch from domestic low-skill intensive producers to foreign suppliers in low-wage countries, leading to a rise in the demand for skilled labour at home.

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¹ A recent study by Baldwin and Caves (1997) demonstrates the effect of international competition on the amount of adjustment within domestic industries. Using a panel of 110 narrowly defined Canadian manufacturing industries over 1973-1992, they find that an industry's turbulence, in the form of firm's entry and exit, the growth and contraction of employment levels among incumbents, and the frequency of changes in control of business units (merger), pervasively increases with trade exposure after controlling for time and industry effects.

Second, firms may also respond to international competition by moving their low-skill-intensive production process to low-wage countries, and import back the processed products either as intermediate inputs or as final consumption goods. By shifting low-skill-intensive production overseas, trade increases the relative demand of skilled labour within domestic industries. This point has been examined in Feenstra and Hanson (1996, 1999). They find that foreign outsourcing - the import of intermediate inputs by domestic firms - can account for 13-23% of skill upgrading in the US manufacturing sector in the 1980s.

These findings suggest that trade might be just as important as technology in explaining the relative demand shift towards more skilled labour within industry. The role of trade on skill upgrading is worth re-examining. The first objective of this chapter is to examine the relative role of trade (in the form of foreign outsourcing) and high technology (computer and other information and communication technology) on skill upgrading in the Canadian manufacturing sector during the period of 1981-1996. So far, there have been limited Canadian studies on the issue. Gera *et al* (2001) examine the effect of technological change on skill upgrading across Canadian industries. They find that technology, measured by the stock of patents and the age of capital stock, are significantly correlated with skill-intensity. This paper will investigate not only the impact of technology but also of trade on skill upgrading for the Canadian manufacturing sector.

Our second objective is to examine the efficiency effect of trade and high technology. Empirical evidence seems to support the hypothesis that adoption of high-tech machinery and equipment has an impact on productivity (Jorgensen and Stiroh 2000 a, b). It is also argued that exposure to increased foreign competition can increase efficiency through several channels: by forcing inefficient firms to exit and remaining firms to increase their scale of operations (Melitz 1999), or by increasing the rate of knowledge spillover across countries (Grossman and Helpman 1991a, b), or by importing more cost and/or technological efficient intermediate inputs from abroad (foreign outsourcing). Empirical research for the trade argument is limited, however; some support is provided from studies on Chile and Mexico (Tybout et al 1991, and Tybout and Westbrook 1995)². This chapter contributes to the empirical literature by examining the efficiency effect of foreign outsourcing.

The framework adopted in the chapter originates from the translog cost function, as used by Berman et al (1994) and Autor et al (1998) in their studies of labour-demand shifts. The standard approach is to estimate a labour demand function derived from the short-run translog cost function. We depart from the standard approach in two ways. First, we allow variable inputs to include not only labour, but also energy, material, and services. Second, instead of estimating one demand function for skilled labour, we derive a system of equations from the translog cost function and estimate

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² John Ries (2000) provides a excellent overview of the theoretical and empirical research in this area.

the system using the Generalized Methods of Moments technique³. The system estimation approach allows us to examine the impact of foreign outsourcing and high technology on skill upgrading and production efficiency simultaneously.

To preview our results, we find that both computers and foreign outsourcing (within the same two digit industries) are strongly biased towards the use of more skilled non-production labour. Both are important in explaining the skill upgrading that occurred during the 80s and 90s. Their relative importance is, however, sensitive to the way by which technology is measured. Our results for the Canadian manufacturing industries are consistent with other U.S studies, despite using different analytical framework and dataset. The finding that trade, in the form of foreign outsourcing, has significant impact on skill upgrading is one of the empirical contributions of the paper.

We also find that the foreign outsourcing (within the same two-digit industry) significantly increases the efficiency of Canadian manufacturing sector. The cost effect of high technology is sensitive to the measurement of technology.

Section II outlines the analytical framework. Section III introduces the data and examines the extent of skill-upgrading, foreign outsourcing, and technology adoption

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³ This is similar to the approach adopted by Morrison and Siegel (2001), who used a generalized Leontief cost function and the 3SLS estimation technique.

that have occurred in Canadian manufacturing industries. Section IV presents empirical results and section V concludes.

II. Analytical Framework

Suppose output is produced by a combination of non-capital and capital inputs. Non-capital inputs include non-production workers, production workers, energy, material, and services. Capital inputs include various assets, such as buildings, machinery and equipments. Capital is assumed to be fixed in the short-run. The amount of output produced for a given level of inputs is also dependent on other exogenous variables that could potentially affect the production process. Such variables include high technology usage and foreign outsourcing. The production function can be characterized by,

$$Y = F(V, K, T) \quad (2.1)$$

where Y is output, V is a vector of non-capital variable inputs, K is quasi-fixed capital inputs, and T is a vector of other exogenous variables.

For a given level of output and capital stock, firms choose non-capital inputs to minimize costs. That is to minimize WV subject to $F(V, K, T) = Y$, where W is a vector of non-capital input prices. The solution to this minimization problem yields the following variable cost function:

$$C = G(W, Y, K, T) \quad (2.2)$$

where C is the variable cost and G is the variable cost function that is twice continuously differentiable, non-decreasing in W and Y , non-increasing in K , concave

and homogeneous degree of one in W . Applying Shephard's Lemma ($V = \partial C / \partial W$), we can retrieve a vector of variable cost shares for non-capital inputs, S ,

$$S = \partial \ln C / \partial \ln W \quad (2.3)$$

To implement equations (2.2) and (2.3) empirically, we need to specify a variable cost function. The often-used functional form in the labour-demand-shift literature is the translog cost function, introduced by Christensen, Jorgenson and Lau (1973). Equation (2.2) in the form of translog cost function can be written as

$$\begin{aligned} \ln C = & \alpha_0 + \sum_i \alpha_i \ln W_i + \alpha_y \ln Y + \alpha_k \ln K + \sum_m \alpha_m T_m \\ & + 0.5 (\sum_i \sum_j \alpha_{ij} \ln W_i \ln W_j + \alpha_{yy} \ln Y \ln Y + \alpha_{kk} \ln K \ln K + \sum_m \sum_n \alpha_{mn} T_m T_n) \\ & + \sum_i \alpha_{iy} \ln W_i \ln Y + \sum_i \alpha_{ik} \ln W_i \ln K + \sum_i \alpha_{im} \ln W_i T_m \\ & + \alpha_{yk} \ln Y \ln K + \sum_m \alpha_{ym} \ln Y T_m + \sum_m \alpha_{km} \ln K T_m \end{aligned} \quad (2.4)$$

The parameters in the above equation must satisfy the following restrictions due to the symmetry and homogeneous conditions:

$$\begin{aligned} \alpha_{ij} &= \alpha_{ji}, \alpha_{mn} = \alpha_{nm} \text{ for all } i, j \text{ and } m, n \\ \sum_i \alpha_i &= 1, \sum_j \alpha_{ij} = 0, \sum_i \alpha_{iy} = 0, \sum_i \alpha_{ik} = 0, \sum_i \alpha_{im} = 0 \end{aligned} \quad (2.5)$$

where i and j are indexes for non-capital inputs, and m and n are indexes for exogenous variables in vector T . By Shephard's Lemma, the variable cost share for non-capital input i is,

$$S_i = \alpha_i + \sum_j \alpha_{ij} \ln W_j + \alpha_{iy} \ln Y + \alpha_{ik} \ln K + \sum_m \alpha_{im} T_m \quad (2.6)$$

where subscript i stands for the five variable inputs: non-production labour, production labour, energy, material and services. The five cost share equations (2.6), along with the cost equation (2.4) and parameter restrictions (2.5), constitute a system of equations to be estimated. The estimated parameters will allow us to evaluate the effects of foreign outsourcing and high technology on skill upgrading and production efficiency simultaneously.

The effect on skill upgrading is captured in the factor-bias parameter α_{im} in equation (2.6). A positive α_{im} indicates that the exogenous variable T_m is relatively input i -using, while a negative α_{im} means that T_m is relatively input i -saving. An insignificant α_{im} implies that T_m is input i -neutral. Suppose there are two types of labour: skilled (L_s) and non-skilled (L_n). If exogenous variable T_m is biased towards the use of more skilled labour, then $(\alpha_{sm} - \alpha_{nm})$ will be positive. Similarly, if variable T_m is more biased towards non-skilled labour, then $(\alpha_{sm} - \alpha_{nm})$ will be negative. The term $(\alpha_{sm} - \alpha_{nm})$ thus measures the marginal impact of variable T_m on the relative use of skilled to non-skilled labour. The total contribution of variable T_m to skill upgrading is simply the product of the marginal impact and total changes in the variable T_m . By comparing the total contribution, we could determine which exogenous variable, foreign outsourcing or high technology, is more important in explaining the skill upgrading during the 80s and 90s.

The efficiency impact is based on the calculation of cost elasticity with respect to the exogenous variables. Cost elasticity, $\varepsilon_{c,m}$, can be obtained by differentiating equation (2.4) with respect to exogenous variable T_m ,

$$\varepsilon_{c,m} = \partial \ln C / \partial \ln T_m = (\alpha_m + \sum_n \alpha_{mn} T_n + \sum_i \alpha_{im} \ln W_i + \alpha_{ym} \ln Y + \alpha_{km} \ln K) T_m \quad (2.7)$$

The cost elasticity measures the percentage change of variable cost for a given percentage change of technology or trade factors. A negative cost elasticity reflects cost reduction, which is an efficiency gain.

The above framework differs slightly from the standard specification used in the literature (Berman *et al* 94, Autor *et al* 1998, Feenstra and Hanson 1999). In the standard model, there are only two variable inputs: skilled and non-skilled labour. Thus only one equation is needed for estimation and for testing any non-neutrality of the exogenous variable T_m ⁴. Typically the estimation equation for each input share is written in the first difference form across time and the wage terms are dropped⁵, with subscript s stands for skilled labour

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⁴ Since the variable cost shares in equation (2.6) sum to unity, one of the equations can be dropped.

⁵ Berman, Bound and Griliches (1994) argue that change changes are unlikely to be exogenous, since they reflect both the mix of different quality of labour and the skill upgrading effect. To address the endogeneity problem, the wage terms are typically dropped from the regression. The argument is that even though there are substantial inter-industry wage differentials for workers with similar measurable skills, the wage changes are more driven by economy wide changes that are common to all sectors rather than to changes that are specific to each sector. It is therefore felt that there is no useful cross-sectional variation in wage changes, and the term is dropped. Of course, the omitted variable could give rise to biased estimates depending on whether the omitted variable is correlated with the independent variables.

$$dS_s = \alpha_s + \alpha_{sy} d\ln Y + \alpha_{sk} d\ln K + \sum_m \alpha_{sm} dT_m \quad (2.8)$$

The approach used in this study is more general and allows us to examine not only the effects of high technology and foreign outsourcing on skill upgrading, but also their effects on production efficiency.

III. Data and Summary Statistics

The data used in the study are drawn from three sources: the KLEMS (Capital, Labour, Energy, Material and Services) Productivity dataset; the Annual Survey of Manufacturing (ASM); and the Input-Output tables from Statistics Canada. Data from the three sources are all matched to 1980 SIC at P-level of aggregation, covering 84 manufacturing industries from 1981 to 1996. Key variables for Canadian manufacturing sector are summarized in Table 2.1. Industry employment shares are used as weights in calculating manufacturing-wide averages.

1. Trends in the relative wages and relative cost shares

Information on prices and quantities of output, capital, and non-capital inputs (labour, energy, materials and services) are obtained from KLEMS dataset. However, the KLEMS dataset has no detailed information on the labour by skill level. ASM, which is maintained by the Micro-Economic Analysis Division, has such information. It includes the number and compensation for production and non-production workers. From ASM we derive the employment and compensation shares for production and non-production workers, and apply them to the total employment and total labour compensation in the KLEMS dataset.

We use non-production and production workers as proxy for more skilled and less skilled workers respectively⁶. The real wages for the less skilled production workers employed in Canadian manufacturing industries have increased from an average annual earning of \$29,628 in 1981 to \$36,723 in 1996, with an average annual increase of \$473 (or 1.6 percent). However, the real wages for the non-production worker have risen at much faster pace with an average annual increase of \$881 (or 2.3 percent), from \$38,012 in 1981 to \$51,227 in 1996. Figure 2.1 plots the relative wages of non-production to production workers, which have been steadily increasing at an annual average rate of 0.75 percent over the period of 1981-1996.

The share of production wages in total variable cost fell from 20.6 percent in 1981 to 19.8 percent in 1989 and to 19.1 percent in 1996. The cost share of non-production wages remains relatively stable over the time period, from 9.2 percent in 1981 to 9.7 percent in 1989 and back to 9.2 percent in 1996. Therefore the cost share of non-production workers relative to the cost share of production workers has increased, at an average of 0.10 percent per year during the period 1981-1996. The increase in the

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⁶ Production workers include all non-supervisory workers engaged in processing, assembling, inspecting, storing, handling and packing, and workers engaged in maintenance, repair, janitorial and watchman services. All others are non-production workers that are engaged in executive, administrative, and sales activities (Statistics Canada 1990). This broad classification of production and non-production workers has its limitations due to their heterogeneity nature of worker skills within each category (Leamer 1994). However, some studies show that the ratio of non-production to production workers are similar to the ratio of white collar to blue collar workers, the latter of which is derived from data with more detailed skill and occupational categories (Berman, Bound and Griliches 1994; Sachs and Shatz 1994).

relative cost shares of non-production wages to production wages is especially large in the 1980s at 0.16 percent per year. In other words, the relative use of skilled labour has increased, especially in the 1980s.

2. Measures of foreign outsourcing

The definition and measurement of foreign outsourcing follow Feenstra and Hanson (1996). Foreign outsourcing is defined as the proportion of imported intermediate inputs in the use of total non-energy intermediate materials. It is constructed here using Canadian input-output tables, which show the intermediate goods purchased by each three- or four-digit manufacturing industry from every other manufacturing industry. Multiplying the value of input purchases from each supplier industry by the import propensity of each supplier industry, and summing over all supplier industries, we derive the total imported intermediate inputs V_i^m for each purchase industry i . That is

$$V_i^m = (\sum_k V_{ki} M_k) \quad (2.9)$$

where V_{ki} is the value of the intermediate input purchase by industry i from supplier industry k , and M_k is the import propensity for supplier industry k . The import propensity for each supplier industry is calculated as the ratio of imports to total consumption (total output + imports – exports). Foreign outsourcing is then simply the ratio of total imported intermediate inputs to the total non-energy material inputs.

Feenstra and Hanson (1996) propose two measures of foreign outsourcing: a broad measure and a narrow measure. A broad measure is obtained when the subscript k in equation (2.9) includes intermediate inputs from every other manufacturing industry, while a narrow measure is obtained when the subscript k includes only intermediate inputs from the same two-digit SIC industry as the purchase industry i . If one defines foreign outsourcing as transferring overseas part of a company's production processes, then the narrow measure of foreign outsourcing seems more appropriate than the broad measure.

Table 2.1 shows that foreign outsourcing has expanded dramatically for Canadian manufacturing industries over the period of 1981-1996. The imported intermediate inputs, under the narrow definition, increased from an average of 14 percent of material purchases in 1981 to 21.7 percent in 1996. The difference between the broad and the narrow measures of foreign outsourcing, which represents the imported intermediate inputs from outside the same two-digit industry, has a similar trend. This variable increased from 16.8 percent in 1981 to 24.8 percent in 1996. Foreign outsourcing is especially prominent during the 1990s. For example, the broad foreign outsourcing expanded at an average annual rate of 1.73 percent in the 1990s as compared to 0.46 percent in the 1980s. Industries also vary in their extent of foreign outsourcing. For example, 'Office Machinery', 'Motor Vehicle', 'Record Player and Radio Television Receiver', 'Communication and Other Electronic Equipment', and 'Aircraft and Aircraft Parts' industries have the highest propensity to import

intermediate inputs from abroad, around 1.7 to 2.4 times more than the manufacturing average for the broad measure and 3.0 to 4.7 times more for the narrow measure during the period of 1981-1996.

3. Indicators of high technology adoption

There are two alternative indicators of high-technology adoption: high-tech investment shares (the fraction of total investment that is devoted to high-technology capital) and high-tech capital service shares (the proportion of capital services that is attributable to high-technology capital). Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1998) use computer investment shares while Feenstra and Hanson (1999) use computer capital service shares. Each indicator has its advantages and limitations. Conceptually high-tech capital service shares are a better indicator than high-tech investment shares. Investment is a flow concept and is subject to the lumpy nature of investment behaviour. On the other hand, capital services are likely to be affected by more measurement errors than investment data⁷. In this study we

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⁷ Capital service is simply the product of capital stock and the user cost of capital. Capital stock is calculated by using perpetual inventory technique, which requires information on investment, asset price and depreciation rate on each asset. Much of the input data is based on imputations. For example, the industry's investment on each asset type is not directly measured. It is derived by allocating the total investment by asset type to industries using industries' employment or output shares as allocating weights, and then is further adjusted to match control totals by industry and by asset type. The user cost of capital is an ex-ante rate of return that excludes capital gains and adjusts for depreciation, interest and taxes on each asset.

use both measures. The investment and capital service data are from the productivity program at Statistics Canada⁸.

We classify information and communication technology (ICT) as our broad measure of high-technology capital⁹. It includes computers and office equipment, communication equipment, software-own account, software-pre-packaged, and software-custom design. The ICT investment share (the ratio of total investment in ICT assets to total investments in all assets) increased from 8.8 percent in 1981 to 15.8 percent in 1996, while the ICT capital service share (the ratio of total capital service from ICT assets to total capital service from all assets) increased from 3.0 percent in 1981 to 5.6 percent in 1996 (Table 2.1).

An alternative is a narrow definition of high technology capital that includes only computers. The average annual change for computer investment shares and computer capital service shares experienced similar increasing trend, but at a slower pace of 0.08 and 0.02 percent respectively, as compared to 0.39 and 0.16 percent for other ICT assets for the period 1981-1996 (Table 2.1).

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⁸ For details on the dataset, see Harchaoui and Tarkhani (2002).

⁹ Feenstra and Hanson (1999), and Berndt and Morrison (1995) define the broad measure of high-technology capital to include the following assets: office, computing, and accounting machinery; communication equipment; science and engineering instruments; and photocopy and related equipment. Feenstra and Hanson also define a narrow measure of high-tech capital to include only office, computing, and accounting machinery.

IV. Empirical Implementation and Results

1. Empirical methodology

Equations (2.4-2.6) constitute the system to be estimated. The sample consists of a panel of cross sectional time series for 84 Canadian manufacturing industries over 1981-1996. To capture time and sector specific effects, we include time dummies and industry dummies in the intercept term in the cost equation (2.4). We also append an additive disturbance term to each equation to account for sampling errors and measurement errors.

The system is estimated by Generalized Methods of Moments (GMM). There are several advantages of using GMM than other methods of system estimation such as the 3SLS or SUR. First, GMM allows for conditional heteroskedasticity and serial correlation of the disturbances. When the disturbance terms are assumed to be identically and normally distributed and serially independent, the GMM estimator coincides with the 3SLS estimator. GMM is more flexible in that it does not need to impose such assumptions (options in GMM could take into account the distribution of the disturbances and allow one to compute the correct weighting matrix for the

orthogonality conditions). The estimates obtained will thus be consistent and asymptotically efficient¹⁰.

Second, GMM, like the 3SLS, is an instrumental estimation method and thus allows us to address the potential endogeneity problem of the independent variables. Berman, Bound and Griliches (1994) argue that the industry-specific relative wages are unlikely to be exogenous, because wages may reflect both the mix of different quality of labour and the skill-upgrading effect. Besides wages, there could also be reversal causality between the dependent and independent variables in the share equation (2.6). For example, some factors could drive skill upgrading, which in turn lead industries to equip workers with high-tech equipment and machinery or to move their low-skill intensive production abroad. To address this potential endogeneity problem, we use lagged values of all the right-hand side variables as instruments.

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¹⁰ A potential problem in time series regression is the stationarity of the error term. A non-stationary error term will introduce “nuisance” parameters in the distribution of OLS estimates and lead to biased estimates of standard errors. The non-stationarity problem is less severe in our regression, since the regression involves relatively short time series (only 15 years). In addition, the correction of serial correlation of the disturbance terms in the GMM procedure also partially solves the potential “spurious correlation” due to the nonstationary of time series.

2. Empirical results

2A. Relative labour demand shift

Table 2.2 compares the relative contribution of high technology and foreign outsourcing to skill upgrading in Canadian manufacturing sector over 1981-1996. The top and lower panels contain results when high-tech investment shares and high-tech capital service shares are used as indicators of high technology adoption in the regression respectively.

Column (1) shows the coefficient estimates of α_{im} in the share equation (2.6). As indicated earlier, it captures the marginal effect of exogenous variable T_m on the demand of variable input i . A positive α_{im} indicates that the exogenous variable T_m is relatively input i -using, while a negative α_{im} means that T_m is relatively input i -saving. And an insignificant α_{im} implies that T_m is input i -neutral. If exogenous variable T_m uses relatively more skilled labour (L_s) than non-skilled labour (L_n), then $(\alpha_{sm} - \alpha_{nm})$ will be positive. Similarly, if variable T_m is relatively more biased towards non-skilled labour, then $(\alpha_{sm} - \alpha_{nm})$ will be negative. The term $(\alpha_{sm} - \alpha_{nm})$ thus measures the marginal impact of variable T_m on the relative use of skilled to non-skilled labour. The estimated average annual impact of the exogenous variable T_m on skill upgrading (column 3) is simply the product of the marginal impact (column 1) and the average annual change in the variable T_m (column 2). Column 4 reports the percentage of skill upgrading that is due to each exogenous variable T_m .

To read the table, take the impact of computer investment share as an example. Column 1 shows that computer technology has a significant positive impact on the cost share of non-production labour (with a coefficient of 0.362, significant at 1% level), while has a negative and insignificant impact on the cost share of production labour. The net marginal effect is a significant bias towards the use of more skilled non-production workers (with a coefficient of 0.414, significant at 1% level). To examine how much computer investment has contributed to the skill upgrading (the increase in the relative cost shares of non-production to production labour), we simply multiply the marginal effect (column 1) by the average annual changes of computer investment shares (column 2) and obtain the amount of skill upgrading due to computer technology (column 3). As Column 3 indicates, computer technology, when measured as computer investment shares, leads to an average skill upgrading of 0.033 percent per year over the period 1981-1996. This compares to the actual average annual skill-upgrading of 0.103 percent. Therefore computer technology contributes to around 32 percent of the actual skill-upgrading. The remainder of the table can be similarly interpreted and the main results are summarized as follows.

Marginal factor bias effect of high technology and foreign outsourcing

First, column 1 of Table 2.2 shows that when high-tech investment shares are used as indicators of high technology adoption, variables such as computers, other ICT technology, and foreign outsourcing (from the same two digit industry) are all biased

towards the use of more skilled non-production workers, significant at 1% level. Foreign outsourcing outside the same two-digit industry does not have significant bias effect on the relative demand of labours. When high-tech capital service shares are used as indicators of high technology adoption, similar results are obtained except that the effects of other ICT technology become statistically insignificant.

One may therefore conclude that computer technology and foreign outsourcing (within the same two digit industries) are statistically significant in favouring the use of skilled workers. The skill-bias effect is independent of the way by which technology is measured. Whether other ICT technology is skill-biased depends on the method by which technology is measured. Foreign outsourcing outside the same two-digit industry has a very weak and statistically insignificant effect on the relative demand of labours.

Contribution of high technology and foreign outsourcing to skill upgrading

Second, we compare the relative contribution of high technology and narrow foreign outsourcing to the skill upgrading that has occurred in Canadian manufacturing sector during the 80s and 90s (column 4).

The contribution of narrow foreign outsourcing is quite robust to different specifications. The narrow foreign outsourcing contributes to approximately 26

percent or 33 percent of skill upgrading for the cases when high-tech investment shares or high-tech capital service shares are used respectively in the regressions.

The contribution of high technology depends on the specification. When high-tech investment shares are used in the regression, computer and other ICT account for 32 percent and 22 percent of the skill upgrading. when high-tech capital service shares are used, the contributions from computer and other ICT are reduced to 8 percent and 5 percent respectively. The sensitivity mainly comes from the degree of changes of the variables themselves over the period. The contribution of each exogenous variable to skill upgrading is obtained by multiplying the regression coefficient by the mean value of change of the variable. As Table 2.2 shows, the coefficient estimates (or marginal effects) of high technology on skill upgrading are quite robust, whether investment shares or capital service shares are used. But the mean values of the annual changes in computer and other ICT investment shares are approximately 4 and 2.4 times higher than the mean values of the annual changes in computer and other ICT capital service shares. And accordingly the total contribution of high-technology to skill-upgrading is also around 4 times higher when using investment shares than when using capital service shares.

As a result, the relative importance of high technology and foreign outsourcing on skill upgrading depends on the way we measure technology. Using high-tech investment shares means that high technology's contribution to skill upgrading is

approximately twice as much as foreign outsourcing, while using high-tech capital service shares means that high technology's contribution is only about half of foreign outsourcing.

Comparison with other studies

The above conclusions are consistent with the U.S. studies. Berman et al (1994) and Autor *et al* (1998) find strong complementary of computer investment and the demand for skilled labour in the U.S manufacturing industries. Feenstra and Hanson (1999) find that foreign outsourcing for the U.S manufacturing sector is associated with increased relative demand for skilled labour. The results in Feenstra and Hanson (1999) also indicate that the magnitude of technology's contribution to skill upgrading is very sensitive to the measurement of technology – computer's contribution to skill upgrading is 1.5-4 times higher when using investment shares than when using capital service shares.

2B. Cost elasticity

Cost elasticity is obtained according to equation (2.7), using estimated parameters and variable values calculated at the sample mean. Table 2.3 shows the estimates of cost elasticity with respect to high technology and foreign outsourcing for Canadian manufacturing sector. The period is 1981 – 1996 and the two sub-periods are 1981-

1989 and 1989-1996. Cost elasticity measures the percentage change of average variable cost for a given percentage change of trade or technology variables. A reduction in cost implies efficiency gain.

We find that the cost elasticity of high technology is very sensitive to the way we measure technology. When high-tech investment shares are used, a one percent increase in computers decreases significantly (at 1% level) the average variable cost of Canadian manufacturing sector by around -0.059, -0.064, and -0.053 percent for the period 1981-1996, 1981-1989 and 1989-1996 respectively. The cost effect of other ICT technology is insignificant. When high-tech capital service shares are used, the cost effect of computers becomes insignificant.

The cost elasticity of foreign outsourcing is quite robust to the measurement of technology. The narrow foreign outsourcing (within the same two-digit industry) induces significant cost reduction in all cases, significant at 5% level. For example, for the entire period of 1981-1996, a one percent increase in narrow foreign outsourcing significantly reduces the average variable cost of Canadian manufacturing sector by around -0.042 when high-tech investment shares are used and -0.05 percent when high-tech capital service shares are used. The cost reduction due to narrow foreign outsourcing also increased over time, from approximately -0.03 percent in the 80s (1981-1989) to -0.06 percent in the 90s (1989-1996). This is a reflection of the large increase in foreign outsourcing during the 90s than the 80s.

Foreign outsourcing from outside the same 2-digit industries is found to have insignificant impact on cost reduction.

We also calculated the cost elasticity for every 2-digit Canadian manufacturing industry (Appendix 2A and 2B). The results are similar to the manufacturing average – i.e. the cost elasticity of high technology is sensitive to how the technology is measured, while the cost elasticity of foreign outsourcing is quite independent of the measurement. In addition, we find there is a wide variation in the cost elasticity of foreign outsourcing across industries. Foreign outsourcing induces relatively large cost reduction for ‘Machinery Industry’, ‘Leather Industry’ and ‘Transportation Equipment Industry’, while relatively small cost reduction for ‘Furniture and Fixture Industry’, ‘Printing and Publishing Industry’ and ‘Beverage Industry’. The cross-industry differences partly reflect the extent of foreign outsourcing that has occurred in these industries. As we noted earlier, cost elasticity is calculated (equation 2.7) using estimated parameters and variable values at the sample mean. Industries with high proportion of intermediate inputs being imported will therefore also have high cost elasticity. For example, around 24%, 27% and 33% of total intermediate inputs are imported for the ‘Machinery Industry’, ‘Leather Industry’ and ‘Transportation Equipment Industry’ respectively. This compares to only 0.03%, 0.03% and 0.06% for the ‘Furniture and Fixture Industry’, ‘Printing and Publishing Industry’ and ‘Beverage Industry’. An alternative interpretation is that industries that benefit less from foreign outsourcing are likely to engage less in foreign outsourcing, while those

that can gain substantial cost reduction are most likely to shift part of their production processes overseas.

V. Conclusion

Our goal here is to examine the effects of high technology (information and communication technology) and trade (foreign outsourcing) on skill upgrading and production efficiency for Canadian manufacturing industries over the period 1981-1996. To achieve this, we extend the conventional cost share regressions to a system of equations, and adopt the system GMM estimation method.

Our empirical results support the idea that both computer technology and foreign outsourcing (within the same two digit industries) are statistically significant in favouring the use of more skilled workers. The skill-bias effect is independent of the way by which technology is measured. Both are important in explaining the skill upgrading that occurred in the Canadian manufacturing sector.

Their relative importance, however, depends on the way by which high technology is measured. Of the total skill upgrading that occurred, around 26 to 33 percent could be explained by narrow foreign outsourcing. The contribution of high technology (computer + other ICT) is, however, more sensitive to the measurement of technology. When high-tech investment shares are used as indicators of high-technology adoption in the regression, computer and other ICT technology account for 32 percent and 22 percent of the skill upgrading respectively. The contributions are reduced to 8 percent and 5 percent respectively when high-tech capital service

shares are used. As a result, the relative importance of high-technology and foreign outsourcing on skill upgrading depends on the way high-technology is measured. Using high-tech investment shares means that high technology's contribution to skill upgrading is approximately twice as much as foreign outsourcing, while using high-tech capital service shares means that high technology's contribution is only about half of foreign outsourcing. The sensitivity to the measurement of high-technology is consistent with the U.S study by Feenstra and Hanson (1999). They find that computer's contribution to skill upgrading is 1.5-4 times higher when using investment shares than when using capital service shares.

For the efficiency effect, we again find that the cost effect of high technology is sensitive to the way it is measured. When high-tech investment shares are used, computers have significant effect on cost reduction for Canadian manufacturing sector, while other ICT has insignificant effect. When high-tech capital service shares are used, the cost effect of computers becomes insignificant. In contrast, the cost impact of foreign outsourcing is relatively independent on how we measure technology in the analysis. In all cases, we find that the narrow foreign outsourcing (within the same two-digit industry) induces significant cost reduction at 5% level for the Canadian manufacturing sector. The efficiency gain due to the narrow foreign outsourcing is higher for heavy industries, such as 'Transportation Equipment Industry' and 'Machinery Industry', but smaller for light industries, such as

‘Furniture and Fixture Industry’, ‘Printing and Publishing Industry’ and ‘Beverage Industry’.

The sensitivity of the effects of high technology points to the importance in the measurement rather than outcome. In future research, it would be worthwhile to explore other measures of high technology adoption. But it is fair to conclude with relative confidence that foreign outsourcing (within the same two-digit industry) contributes significantly to the skill upgrading and the efficiency gain for the Canadian manufacturing sector over the period 1981-1996.

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Figure 2.1 Relative wages of non-production to production workers

Table 2.1 Manufacturing-wide averages 1981-1996

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	Average Annual Changes		
Real average annual wages (in thousand)																			
non-production worker	38.012 (6.359)	39.557 (7.757)	40.176 (7.919)	41.026 (8.229)	42.183 (8.593)	42.415 (8.486)	42.095 (8.189)	42.922 (7.974)	43.020 (8.167)	44.018 (8.164)	46.280 (9.089)	48.330 (9.253)	49.565 (9.894)	50.653 (10.462)	51.077 (10.889)	51.227 (11.012)	0.8810	0.6260	1.1725
production worker	29.628 (7.131)	30.544 (8.129)	31.359 (8.730)	31.897 (9.183)	32.507 (9.635)	32.547 (9.569)	32.072 (9.526)	32.393 (9.641)	32.295 (9.596)	33.092 (9.507)	34.644 (10.215)	36.270 (10.810)	36.853 (11.485)	37.130 (11.993)	36.746 (11.907)	36.723 (11.863)	0.4730	0.3334	0.6325
relative wages	1.283	1.295	1.281	1.286	1.298	1.303	1.313	1.325	1.332	1.330	1.336	1.333	1.345	1.364	1.390	1.395	0.0075	0.0061	0.0090
variable cost share																			
non-production worker	0.092 (0.045)	0.101 (0.048)	0.100 (0.051)	0.095 (0.049)	0.096 (0.049)	0.095 (0.049)	0.095 (0.048)	0.096 (0.049)	0.097 (0.051)	0.104 (0.054)	0.109 (0.057)	0.108 (0.057)	0.104 (0.058)	0.097 (0.056)	0.092 (0.052)	0.092 (0.053)	0.0000	0.0006	-0.0007
production worker	0.206 (0.071)	0.211 (0.072)	0.211 (0.070)	0.204 (0.067)	0.202 (0.065)	0.201 (0.063)	0.200 (0.061)	0.198 (0.062)	0.198 (0.062)	0.204 (0.065)	0.208 (0.065)	0.209 (0.065)	0.203 (0.065)	0.195 (0.064)	0.189 (0.064)	0.191 (0.065)	-0.0010	-0.0010	-0.0011
difference	-0.114	-0.110	-0.110	-0.109	-0.107	-0.106	-0.105	-0.103	-0.101	-0.100	-0.099	-0.101	-0.099	-0.098	-0.097	-0.098	0.0010	0.0016	0.0004
Investment Shares																			
inform. & commu. tech (ICT)	0.088 (0.088)	0.118 (0.105)	0.136 (0.110)	0.133 (0.110)	0.126 (0.115)	0.123 (0.117)	0.122 (0.109)	0.127 (0.120)	0.123 (0.119)	0.137 (0.120)	0.148 (0.132)	0.170 (0.142)	0.177 (0.132)	0.151 (0.123)	0.167 (0.146)	0.158 (0.132)	0.0047	0.0043	0.0051
computer technology	0.035 (0.026)	0.047 (0.032)	0.053 (0.038)	0.053 (0.036)	0.051 (0.039)	0.043 (0.033)	0.044 (0.032)	0.040 (0.031)	0.038 (0.030)	0.038 (0.027)	0.041 (0.032)	0.050 (0.041)	0.048 (0.035)	0.040 (0.032)	0.049 (0.044)	0.046 (0.039)	0.0008	0.0003	0.0012
difference (other ICT)	0.053 (0.083)	0.071 (0.102)	0.083 (0.109)	0.080 (0.109)	0.075 (0.108)	0.080 (0.113)	0.079 (0.106)	0.087 (0.117)	0.085 (0.115)	0.099 (0.118)	0.107 (0.126)	0.120 (0.134)	0.129 (0.125)	0.110 (0.115)	0.118 (0.128)	0.112 (0.119)	0.0039	0.0040	0.0039
Capital service shares																			
inform. & commu. tech (ICT)	0.030 (0.026)	0.039 (0.036)	0.040 (0.052)	0.039 (0.054)	0.044 (0.065)	0.050 (0.081)	0.048 (0.076)	0.052 (0.078)	0.050 (0.082)	0.054 (0.091)	0.065 (0.099)	0.065 (0.094)	0.064 (0.095)	0.061 (0.092)	0.056 (0.089)	0.056 (0.093)	0.0018	0.0025	0.0009
computer technology	0.013 (0.007)	0.019 (0.012)	0.016 (0.013)	0.015 (0.011)	0.016 (0.013)	0.017 (0.018)	0.016 (0.016)	0.016 (0.016)	0.015 (0.011)	0.015 (0.012)	0.018 (0.018)	0.019 (0.017)	0.018 (0.015)	0.017 (0.025)	0.016 (0.016)	0.015 (0.016)	0.0002	0.0002	0.0001
difference (other ICT)	0.017 (0.025)	0.020 (0.035)	0.024 (0.050)	0.024 (0.054)	0.028 (0.063)	0.032 (0.077)	0.032 (0.073)	0.036 (0.077)	0.035 (0.081)	0.038 (0.090)	0.048 (0.096)	0.046 (0.092)	0.046 (0.093)	0.044 (0.086)	0.040 (0.086)	0.041 (0.090)	0.0016	0.0023	0.0008
Foreign outsourcing																			
broad outsourcing	0.307 (0.140)	0.299 (0.146)	0.301 (0.152)	0.325 (0.154)	0.330 (0.155)	0.346 (0.164)	0.333 (0.156)	0.340 (0.145)	0.344 (0.145)	0.368 (0.153)	0.390 (0.159)	0.415 (0.165)	0.440 (0.174)	0.457 (0.179)	0.463 (0.180)	0.465 (0.179)	0.0105	0.0046	0.0173
narrow outsourcing	0.140 (0.139)	0.141 (0.148)	0.144 (0.152)	0.155 (0.159)	0.159 (0.161)	0.173 (0.176)	0.165 (0.167)	0.164 (0.157)	0.165 (0.158)	0.176 (0.170)	0.185 (0.181)	0.197 (0.185)	0.207 (0.193)	0.215 (0.199)	0.216 (0.199)	0.217 (0.200)	0.0051	0.0032	0.0073
difference	0.168 (0.091)	0.157 (0.086)	0.157 (0.086)	0.169 (0.093)	0.171 (0.092)	0.173 (0.095)	0.168 (0.094)	0.176 (0.097)	0.178 (0.098)	0.192 (0.106)	0.205 (0.113)	0.219 (0.124)	0.233 (0.135)	0.242 (0.141)	0.247 (0.147)	0.248 (0.142)	0.0054	0.0014	0.0100

Note: all averages are manufacturing-wide averages, weighted by industry's employment share. Standard deviations are in parentheses. Average annual changes are calculated as the difference between the first and the last year of a decade divided by the number of years.

Table 2.2 Factor bias and relative labour demand shift (1981-1996)

Actual average annual skill-upgrading:		0.00103				
		Column 1		Column 2	Column 3	Column 4
Dependent variables of equation (2.6)				Average Annual Change	Estimated skill upgrading	Contribution
	non-production worker wage share	production worker wage share	marginal bias effect			
Using high-tech investment shares as indicators of high technology adoption						
computer	0.362 (5.281) **	-0.053 (-0.551)	0.414 (4.832) **	0.0008	0.00033	0.32
other ICT technologies	0.032 (2.470)**	-0.027 (-1.454)	0.059 (3.406) **	0.0039	0.00023	0.22
narrow outsourcing	-0.013 (-0.878)	-0.066 (-3.865) **	0.053 (3.410) **	0.0051	0.00027	0.26
other outsourcing	0.073 (4.073) **	0.125 (4.202) **	-0.052 (-1.809)	0.0054	-0.00028	
Using high-tech capital service shares as indicators of high technology adoption						
computer	0.171 (1.461)	-0.239 (-1.460)	0.409 (2.768) **	0.0002	0.00008	0.08
other ICT technologies	0.017 (1.242)	-0.016 (-0.875)	0.034 (1.796)	0.0016	0.00005	0.05
narrow outsourcing	-0.006 (-0.356)	-0.072 (-4.03) **	0.066 (4.04) **	0.0051	0.00034	0.33
other outsourcing	0.099 (5.560) **	0.116 (4.234) **	-0.017 (-0.637)	0.0054	-0.00009	

Note: Column 1 estimates are obtained from GMM estimation of equations (2.4-2.5) and five share equations (2.6). Newey-West heteroskedasticity- and autocorrelation-consistent t-statistics are shown in parentheses. The regressions include industry and time dummies to allow for fixed industry and time effects), with one-lag of all independent variables as instrumental variables. The average annual changes in Column 2 are from Table 2.1. Column 3 is obtained by multiplying the marginal bias effect from Column 1 by the average annual changes in Column 2. The contribution of each exogenous variable to the skill upgrading in Column 4 is calculated as the ratio of the estimated skill upgrading to the actual average annual skill upgrading of 0.103 percent. Two asterisks (**) indicate statistically significant at the 5% level or better.

Table 2.3
Estimates of average cost elasticity for Canadian manufacturing sector

	1981-1996	1981-1989	1989-1996
Using high-tech investment shares as indicators of high technology adoption			
computer	-0.059 (-3.784) **	-0.064 (-4.212) **	-0.053 (-3.282) **
other ICT technologies	0.006 (0.353)	0.005 (0.342)	0.009 (0.420)
narrow outsourcing	-0.042 (-2.252) **	-0.028 (-2.077) **	-0.060 (-3.087) **
other outsourcing	-0.018 (-0.682)	-0.004 (-0.160)	-0.037 (-1.379)
Using high-tech capital service shares as indicators of high technology adoption			
computer	0.009 (1.555)	0.010 (1.657)	0.008 (1.345)
other ICT technologies	-0.017 (-1.844)	-0.013 (-1.741)	-0.022 (-1.950)
narrow outsourcing	-0.050 (-3.099) **	-0.040 (-2.648) **	-0.061 (-3.538) **
other outsourcing	-0.034 (-1.413)	-0.031 (-1.333)	-0.035 (-1.431)

Note: cost elasticities are calculated according to equation (2.7), using parameter estimates and average values. The t-statistics in parentheses are calculated using "delta" method (Gallant and Jorgenson, 1979, and Gallant and Holly 1980) which combines the standard error of various estimates. Two asterisks (**) indicate statistically significant at the 5% level or better.

Appendix 2A Estimates of average cost elasticity (two-digit Canadian manufacturing industries)

Using investment shares

Industry	10	11	12	15	16	17	18	19	24	25	26	27	28	29	30	31	32	33	35	36	37	39
81-96																						
computer	-0.06 (-3.81)	-0.05 (-3.34)	-0.07 (-3.38)	-0.03 (-1.66)	-0.02 (-1.12)	-0.11 (-3.10)	-0.03 (-3.37)	-0.03 (-2.97)	0.06 (1.01)	-0.03 (-4.45)	-0.08 (-3.76)	-0.03 (-3.91)	-0.05 (-1.06)	-0.04 (-3.21)	-0.05 (-3.52)	-0.06 (-2.18)	-0.02 (-1.52)	0.08 (1.11)	-0.03 (-4.01)	-0.02 (-0.88)	-0.05 (-3.13)	-0.14 (-2.82)
other ICT technologies	0.01 (1.47)	0.002 (0.14)	0.002 (0.30)	0.03 (1.62)	0.02 (2.08)	-0.11 (-1.72)	-0.02 (-0.66)	0.04 (1.26)	0.02 (1.20)	0.02 (0.94)	0.01 (0.55)	0.02 (1.43)	0.02 (0.87)	-0.01 (-0.22)	0.01 (0.78)	-0.05 (-1.64)	0.01 (0.71)	-0.05 (-1.87)	0.0005 (0.02)	0.02 (2.56)	0.004 (0.32)	-0.12 (-0.86)
narrow outsourcing	-0.02 (-1.13)	-0.02 (-2.15)	-0.01 (-0.85)	-0.03 (-4.75)	-0.03 (-4.38)	-0.06 (-1.56)	0.00 (-0.09)	-0.03 (-3.95)	-0.03 (-3.02)	-0.02 (-1.15)	-0.01 (-2.07)	-0.03 (-1.82)	-0.01 (-2.12)	-0.02 (-0.69)	-0.03 (-2.70)	-0.06 (-2.66)	-0.11 (-3.54)	0.04 (0.91)	-0.02 (-1.49)	-0.05 (-3.78)	-0.03 (-0.93)	-0.08 (-2.48)
other outsourcing	0.03 (1.21)	-0.02 (-0.64)	0.04 (1.86)	-0.08 (-2.26)	-0.10 (-2.13)	-0.05 (-1.25)	-0.04 (-1.94)	-0.22 (-4.58)	-0.04 (-0.60)	0.01 (0.38)	-0.03 (-0.67)	0.01 (0.40)	0.06 (1.056)	-0.01 (-0.53)	-0.05 (-1.51)	-0.06 (-1.99)	-0.10 (-3.26)	-0.03 (-0.78)	-0.02 (-0.79)	0.05 (1.35)	0.003 (0.19)	-0.07 (-1.18)
81-89																						
computer	-0.06 (-4.11)	-0.05 (-3.56)	-0.06 (-3.93)	-0.04 (-2.13)	-0.04 (-2.05)	-0.12 (-3.30)	-0.04 (-3.78)	-0.03 (-3.48)	0.03 (0.60)	-0.03 (-4.53)	-0.08 (-4.10)	-0.02 (-4.20)	-0.08 (-1.83)	-0.03 (-3.48)	-0.06 (-3.97)	-0.04 (-1.03)	-0.03 (-1.64)	0.05 (0.83)	-0.04 (-4.28)	-0.03 (-1.19)	-0.05 (-3.58)	-0.15 (-3.01)
other ICT technologies	0.01 (1.50)	0.002 (0.33)	0.004 (0.98)	0.02 (1.43)	0.01 (1.94)	-0.06 (-1.48)	-0.02 (-0.88)	0.03 (1.25)	0.01 (1.32)	0.01 (0.82)	0.01 (0.55)	0.02 (1.41)	0.02 (1.20)	-0.001 (-0.05)	0.01 (0.50)	-0.07 (-2.04)	0.01 (0.54)	-0.03 (-1.69)	0.001 (0.09)	0.01 (2.64)	0.01 (0.52)	-0.13 (-0.94)
narrow outsourcing	-0.02 (-0.83)	-0.01 (-1.78)	-0.01 (-1.07)	-0.02 (-3.89)	-0.02 (-3.46)	-0.04 (-1.21)	0.01 (0.31)	-0.02 (-3.45)	-0.02 (-2.64)	-0.01 (-0.89)	0.00 (-1.56)	-0.02 (-1.41)	-0.01 (-1.81)	-0.02 (-0.56)	-0.02 (-1.95)	-0.03 (-1.13)	-0.08 (-2.92)	0.06 (1.43)	-0.01 (-1.01)	-0.03 (-3.53)	-0.02 (-0.79)	-0.06 (-1.88)
other outsourcing	0.02 (1.25)	-0.01 (-0.27)	0.03 (1.69)	-0.04 (-1.09)	-0.04 (-0.86)	-0.01 (-0.28)	-0.02 (-1.06)	-0.15 (-3.30)	0.01 (0.09)	0.01 (0.57)	-0.01 (-0.26)	0.01 (0.59)	0.06 (1.20)	-0.005 (-0.34)	-0.02 (-0.52)	-0.02 (-0.53)	-0.07 (-2.81)	-0.02 (-0.57)	-0.01 (-0.26)	0.04 (1.19)	0.01 (0.40)	-0.03 (-0.44)
89-96																						
computer	-0.06 (-3.41)	-0.05 (-2.95)	-0.06 (-2.09)	-0.02 (-1.22)	-0.01 (-0.42)	-0.09 (-2.87)	-0.03 (-2.85)	-0.02 (-2.47)	0.10 (1.42)	-0.03 (-4.29)	-0.08 (-3.35)	-0.02 (-3.51)	-0.02 (-0.37)	-0.04 (-2.93)	-0.04 (-2.98)	-0.04 (-2.59)	-0.02 (-1.43)	0.10 (1.32)	-0.03 (-3.69)	-0.02 (-0.49)	-0.05 (-2.60)	-0.12 (-2.60)
other ICT technologies	0.01 (1.45)	-0.001 (-0.06)	-0.01 (-0.59)	0.04 (1.83)	0.03 (2.23)	-0.17 (-1.74)	-0.02 (-0.51)	0.05 (1.28)	0.02 (1.08)	0.02 (1.07)	0.01 (0.56)	0.02 (1.45)	0.01 (0.68)	-0.01 (-0.36)	0.02 (1.06)	-0.02 (-0.80)	0.02 (0.91)	-0.08 (-1.96)	0.000 (0.02)	0.03 (2.46)	0.002 (0.13)	-0.12 (-0.75)
narrow outsourcing	-0.03 (-1.56)	-0.03 (-2.57)	-0.01 (-0.51)	-0.06 (-5.45)	-0.04 (-5.05)	-0.10 (-1.78)	-0.02 (-0.65)	-0.05 (-4.30)	-0.04 (-3.33)	-0.02 (-1.47)	-0.01 (-2.55)	-0.04 (-2.35)	-0.02 (-2.49)	-0.03 (-0.87)	-0.05 (-3.40)	-0.10 (-3.95)	-0.15 (-4.07)	0.02 (0.29)	-0.03 (-2.03)	-0.06 (-4.13)	-0.03 (-1.11)	-0.10 (-3.08)
other outsourcing	0.03 (1.14)	-0.04 (-1.22)	0.05 (2.05)	-0.15 (-3.61)	-0.18 (-3.29)	-0.10 (-2.14)	-0.07 (-2.88)	-0.31 (-5.31)	-0.09 (-1.35)	0.004 (0.15)	-0.05 (-1.15)	0.003 (0.14)	0.04 (0.78)	-0.01 (-0.71)	-0.10 (-2.73)	-0.11 (-3.80)	-0.12 (-3.46)	-0.04 (-0.97)	-0.04 (-1.47)	0.05 (1.49)	-0.001 (-0.05)	-0.15 (-2.09)

Note: cost elasticities are calculated according to equation (2.7), using parameter estimates and average values. The t-statistics in parentheses are calculated using delta method (Gallant and Jorgenson, 1979, and Gallant and Holly 1980) which combines the standard error of various estimates. For the description of the 2-digit industries, see Appendix 2B.

Appendix 2A Estimates of average cost elasticity (two-digit Canadian manufacturing industries) - continued

Using capital service shares

Industry	10	11	12	15	16	17	18	19	24	25	26	27	28	29	30	31	32	33	35	36	37	39
81-96																						
computer	0.01 (1.95)	0.003 (0.56)	0.005 (1.12)	-0.002 (-0.15)	0.003 (0.44)	0.01 (1.49)	0.004 (1.22)	0.003 (1.07)	0.01 (1.88)	0.01 (2.51)	0.01 (2.50)	0.004 (1.03)	0.04 (2.42)	0.01 (0.97)	0.01 (1.83)	0.01 (1.02)	0.003 (0.45)	0.03 (1.92)	0.003 (0.92)	-0.02 (-0.66)	0.005 (0.71)	0.01 (0.70)
other ICT technologies	-0.004 (-1.65)	-0.002 (-0.85)	-0.003 (-1.65)	-0.01 (-0.82)	-0.002 (-0.55)	-0.06 (-3.04)	-0.02 (-3.08)	0.01 (0.83)	-0.0005 (-0.27)	-0.01 (-1.09)	0.003 (0.68)	-0.02 (-1.76)	0.002 (0.28)	-0.05 (-3.91)	-0.001 (-0.37)	-0.02 (-2.19)	-0.02 (-3.17)	-0.02 (-3.48)	-0.01 (-1.19)	-0.01 (-2.09)	-0.02 (-3.18)	0.01 (0.47)
narrow outsourcing	-0.03 (-1.66)	-0.02 (-2.95)	-0.03 (-2.26)	-0.03 (-3.86)	-0.02 (-2.65)	-0.10 (-4.08)	-0.02 (-0.79)	-0.02 (-2.57)	-0.02 (-2.20)	-0.02 (-2.18)	-0.01 (-1.95)	-0.03 (-2.61)	-0.01 (-2.17)	-0.07 (-2.53)	-0.03 (-2.39)	-0.07 (-3.91)	-0.07 (-2.53)	-0.06 (-1.86)	-0.03 (-2.84)	-0.04 (-3.18)	-0.05 (-2.19)	-0.10 (-4.21)
other outsourcing	0.003 (0.16)	-0.06 (-2.13)	0.004 (0.24)	-0.07 (-2.21)	-0.06 (-1.71)	-0.05 (-1.82)	-0.04 (-2.11)	-0.16 (-4.19)	-0.08 (-1.83)	-0.02 (-0.71)	-0.10 (-2.79)	-0.002 (-0.09)	-0.04 (-0.99)	-0.01 (-0.38)	-0.07 (-2.51)	-0.08 (-3.12)	-0.04 (-1.37)	-0.08 (-2.68)	-0.05 (-1.84)	0.05 (1.55)	-0.01 (-0.39)	-0.04 (-1.11)
81-89																						
computer	0.01 (1.96)	0.002 (0.57)	0.004 (0.97)	0.004 (0.21)	0.01 (1.11)	0.02 (2.29)	0.01 (1.75)	0.003 (1.65)	0.01 (1.44)	0.01 (1.95)	0.01 (2.50)	0.01 (1.28)	0.03 (2.62)	0.01 (0.99)	0.01 (1.98)	0.01 (1.34)	0.01 (0.75)	0.03 (1.62)	0.004 (1.09)	-0.01 (-0.65)	0.01 (0.87)	0.02 (1.27)
other ICT technologies	-0.003 (-1.61)	-0.001 (-0.89)	-0.001 (-1.53)	-0.01 (-0.88)	-0.002 (-0.61)	-0.03 (-2.11)	-0.01 (-2.74)	0.01 (0.58)	-0.0004 (-0.39)	-0.01 (-1.08)	0.001 (0.47)	-0.02 (-1.59)	0.002 (0.32)	-0.04 (-3.47)	-0.002 (-0.52)	-0.02 (-2.52)	-0.01 (-3.15)	-0.01 (-3.41)	-0.01 (-1.24)	-0.01 (-2.05)	-0.01 (-2.79)	-0.0001 (-0.003)
narrow outsourcing	-0.03 (-1.46)	-0.01 (-2.68)	-0.01 (-2.20)	-0.02 (-3.65)	-0.01 (-2.40)	-0.06 (-3.02)	-0.02 (-0.69)	-0.02 (-2.46)	-0.01 (-2.06)	-0.02 (-1.94)	-0.01 (-1.78)	-0.03 (-2.26)	-0.01 (-1.82)	-0.06 (-2.29)	-0.02 (-2.32)	-0.07 (-3.73)	-0.06 (-2.68)	-0.04 (-1.41)	-0.02 (-2.44)	-0.02 (-2.89)	-0.04 (-2.07)	-0.08 (-3.97)
other outsourcing	0.002 (0.13)	-0.05 (-1.78)	0.004 (0.25)	-0.07 (-1.93)	-0.05 (-1.40)	-0.04 (-1.79)	-0.03 (-1.93)	-0.13 (-3.64)	-0.05 (-1.24)	-0.01 (-0.77)	-0.08 (-2.40)	-0.003 (-0.17)	-0.03 (-0.61)	-0.01 (-0.56)	-0.06 (-2.19)	-0.07 (-2.88)	-0.04 (-1.62)	-0.07 (-2.99)	-0.04 (-1.63)	0.04 (1.40)	-0.01 (-0.49)	-0.04 (-1.28)
89-96																						
computer	0.01 (1.90)	0.003 (0.54)	0.01 (1.32)	-0.01 (-0.55)	-0.002 (-0.28)	0.01 (0.68)	0.004 (1.15)	0.002 (0.75)	0.01 (0.58)	0.01 (1.76)	0.01 (2.44)	0.003 (0.63)	0.03 (2.04)	0.01 (0.94)	0.01 (1.59)	0.004 (0.66)	0.001 (0.20)	0.04 (2.26)	0.002 (0.69)	-0.02 (-0.68)	0.003 (0.50)	0.01 (0.28)
other ICT technologies	-0.01 (-1.67)	-0.003 (-0.79)	-0.004 (-1.76)	-0.01 (-0.76)	-0.002 (-0.51)	-0.09 (-4.29)	-0.02 (-3.41)	0.02 (1.11)	-0.0004 (-0.15)	-0.01 (-1.11)	0.01 (0.89)	-0.03 (-1.97)	0.002 (0.19)	-0.06 (-4.29)	-0.001 (-0.21)	-0.02 (-1.79)	-0.02 (-3.12)	-0.03 (-3.10)	-0.01 (-1.19)	-0.02 (-2.14)	-0.02 (-3.56)	0.03 (1.01)
narrow outsourcing	-0.04 (-1.90)	-0.03 (-3.17)	-0.04 (-2.29)	-0.04 (-4.00)	-0.02 (-2.80)	-0.15 (-4.26)	-0.02 (-0.85)	-0.02 (-2.61)	-0.02 (-2.31)	-0.03 (-2.43)	-0.01 (-2.08)	-0.04 (-3.03)	-0.02 (-2.50)	-0.08 (-2.72)	-0.03 (-2.39)	-0.08 (-3.78)	-0.07 (-2.32)	-0.10 (-2.13)	-0.04 (-3.29)	-0.05 (-3.52)	-0.06 (-2.24)	-0.13 (-4.30)
other outsourcing	0.004 (0.20)	-0.07 (-2.59)	0.005 (0.26)	-0.07 (-2.37)	-0.07 (-1.84)	-0.05 (-1.66)	-0.05 (-2.24)	-0.19 (-4.33)	-0.10 (-2.46)	-0.01 (-0.58)	-0.12 (-3.20)	0.0003 (0.01)	-0.06 (-1.40)	-0.002 (-0.17)	-0.08 (-2.76)	-0.08 (-3.15)	-0.03 (-0.96)	-0.08 (-2.21)	-0.05 (-2.03)	0.05 (1.71)	-0.04 (-0.24)	-0.03 (-0.69)

Note: cost elasticities are calculated according to equation (2.7), using parameter estimates and average values. The t-statistics in parentheses are calculated using delta method (Gallant and Jorgenson, 1979, and Gallant and Holly 1980) which combines the standard error of various estimates. For the description of the 2-digit industries, see Appendix 2B.

Appendix 2B

Industrial classification - 84 Canadian manufacturing industries (P level aggregation)

P_ code	P_NAME	2-digit industry code	2-digit industry name
14	Poultry, meat and meat prod. ind.	10	Food inds
15	Fish products industry	10	Food inds
16	Fruit and vegetable industries	10	Food inds
17	Dairy products industries	10	Food inds
18	Feed industry, Cane and beet sugar industry, Miscellaneous food product industries	10	Food inds
19	Vegetable oil mills (except corn oil)	10	Food inds
20	Biscuit industry, Bread and other bakery products ind	10	Food inds
21	Soft drink industry	11	Beverage inds
22	Distillery products industry	11	Beverage inds
23	Brewery products industry	11	Beverage inds
24	Wine industry	11	Beverage inds
25	Tobacco products industries	12	Tobacco inds
26	Rubber products industries	15	Rubber inds
27	Plastic products industries	16	Plastic inds
28	Leather tanneries, Footwear industry, Misc. leather and allied products ind.	17	Leather inds
29	Man-made fibre yarn and woven cloth ind.,Wool yarn and woven cloth industry	18	Primary textile inds
30	Broad knitted fabric industry	18	Primary textile inds
31	Miscellaneous textile products industries	19	Textile products inds
32	Carpet, mat and rug industry	19	Textile products inds
33	Clothing, hosiery industries	24	Clothing inds
34	Sawmill, planing mill and shingle mill prod. ind.	25	Wood inds
35	Veneer and plywood industries	25	Wood inds
36	Sash, door and other millwork industries	25	Wood inds
37	Wooden box and coffin industries	25	Wood inds
38	Other wood industries	25	Wood inds
39	Household furniture industries	26	Furniture and Fixture inds
40	Office furniture industries	26	Furniture and Fixture inds
41	Other furniture and fixture industries	26	Furniture and Fixture inds
42	Pulp and paper industries	27	Paper & Allied prods inds
43	Asphalt roofing industry	27	Paper & Allied prods inds
44	Paper box and bag industries	27	Paper & Allied prods inds
45	Other converted paper products industries	27	Paper & Allied prods inds
46	Printing and publishing industries	28	Printing, publishing inds
47	Platemaking, typesetting and bindery ind.	28	Printing,publishing inds
48	Primary steel industries	29	Primary metal inds
49	Steel pipe and tube industry	29	Primary metal inds
50	Iron foundries	29	Primary metal inds
51	Non-ferrous metal smelting and refining ind.	29	Primary metal inds

52	Aluminum rolling, casting and extruding ind.	29	Primary metal inds
53	Copper and alloy roll., cast. and extr. ind.	29	Primary metal inds
54	Oth. Roll., cast & extr. non-ferr. met. prod. ind.	29	Primary metal inds
55	Power boiler and structural metal industries	30	Fabricated metal prods inds
56	Ornamental and architectural metal prod. ind.	30	Fabricated metal prods inds
57	Stamped, pressed and coated metal prod. ind.	30	Fabricated metal prods inds
58	Wire and wire products industries	30	Fabricated metal prods inds
59	Hardware, tool and cutlery industries	30	Fabricated metal prods inds
60	Heating equipment industry	30	Fabricated metal prods inds
61	Machine shop industry	30	Fabricated metal prods inds
62	Other metal fabricating industries	30	Fabricated metal prods inds
63	Agricultural implement industry	31	Machinery inds
64	Commercial refriger. and air cond. equip. ind.	31	Machinery inds
65	Other machinery and equipment industries	31	Machinery inds
66	Aircraft and aircraft parts industry	32	Transportation equip inds
67	Motor vehicle industry	32	Transportation equip inds
68	Truck and bus body and trailer industries	32	Transportation equip inds
69	Motor vehicle parts and accessories ind.	32	Transportation equip inds
70	Railroad rolling stock industry	32	Transportation equip inds
71	Shipbuilding and repair industry	32	Transportation equip inds
72	Misc. transportation equipment ind.	32	Transportation equip inds
73	Small electrical appliance industry	33	Electrical & Electronic prods. Inds
74	Major appl. ind. (electric and non-electric)	33	Electrical & Electronic prods. Inds
75	Other electrical and electronic product ind., Battery ind	33	Electrical & Electronic prods. Inds
76	Record player, radio and television receiver ind.	33	Electrical & Electronic prods. Inds
77	Communic. & other electronic equip. ind.	33	Electrical & Electronic prods. Inds
78	Office, store and business machine ind.	33	Electrical & Electronic prods. Inds
79	Communic. and energy wire and cable ind.	33	Electrical & Electronic prods. Inds
80	Clay products industries	35	Non-metallic mineral prods. Inds
81	Hydraulic cement industry	35	Non-metallic mineral prods. Inds
82	Concrete products industries	35	Non-metallic mineral prods. Inds
83	Ready-mix concrete industry	35	Non-metallic mineral prods. Inds
84	Glass and glass products industries	35	Non-metallic mineral prods. Inds
85	Misc. non-metallic mineral prod. ind.	35	Non-metallic mineral prods. Inds
86	Refined petroleum and coal products ind.	36	Refined petroleum & Coal prod.inds
87	Industrial chemicals industries n.e.c.	37	Chemical & chemical prods.inds
88	Chemical products industries n.e.c.	37	Chemical & chemical prods.inds
89	Plastic and synthetic resin industry	37	Chemical & chemical prods.inds
90	Pharmaceutical and medicine industry	37	Chemical & chemical prods.inds
91	Paint and varnish industry	37	Chemical & chemical prods.inds
92	Soap and cleaning compounds industry	37	Chemical & chemical prods.inds
93	Toilet preparations industry	37	Chemical & chemical prods.inds
94	Floor tile, linoleum and coated fabric ind., Other manufacturing industries	39	Other mnfg
95	Jewellery and precious metal industries	39	Other mnfg
96	Sporting goods and toy industries	39	Other mnfg
97	Sign and display industry	39	Other mnfg

Chapter 3

Trade, Technology and Wage Inequality in Canada

I. Introduction

As we have shown in chapter 2, there has been a widening wage gap between the skilled and unskilled labour in Canada since the 1980s. The real wages for the less skilled production workers employed in Canadian manufacturing industries have increased at an annual average rate of 1.6 percent. This compares to an annual average rate of 2.3 percent for the more skilled non-production worker (Table 2.1). Similar trends are apparent in many other industrialized countries. Two hypotheses have been offered to explain this phenomenon: globalisation and skilled-biased technological change. This chapter examines the relative role of globalisation and technology in the rising wage gaps in Canada.

Canadian studies on this issue are limited ¹. Davis (1992), Burbidge *et al* (1997), Richardson (1995), Wolfson and Murphy (1999) have examined the trends of

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¹ There is a vast literature on U.S wage inequality. The results are mixed. Some conclude that trade with low-wage countries is the main suspect for the relative decline of low-skilled wages in the United States in the 1980s, while some maintain that it is technology. Surveys with differing points of view are provided in Freeman (1995), Richardson (1995), Wood (1995), and Slaughter (1999).

Canadian wage or earnings inequality. Baldwin and Rafiquzzaman (1998) and Zakhilwal (2000) are the few papers that have examined why such trends have occurred. Baldwin and Rafiquzzaman (1998) hypothesize that the relative wages between the non-production and production workers are a function of a number of industry characteristics, such as capital intensities, type of technology use, trade intensity, etc. They find that both trade intensity and the usage of labour-saving technologies have significant positive effect on increasing Canadian wage differentials. Zakhilwal (2000) studies wages of the more and the less educated workers in the 1990s. By regressing the real wages on a set of variables, including the measurement of openness to trade, technology usage, unemployment, tenure, union, sex, etc, he finds that international trade has significant impact on the wages of both the more and the less educated, with the impact on the more educated being four times stronger. Technological change has roughly the same magnitude of impact on the relative wages of the more and the less educated workers in his study.

We address the issue using a different analytical framework. The approach we adopt is the two-stage “mandated wage regression”, which is based on a set of zero profit conditions underlying the Stolper-Samuelson (SS) theorem. The basic idea of SS theorem is that differential growth of product price and productivity alters the relative profitability of sectors. This shifts the relative demand of various production inputs. Input prices change accordingly, to restore the zero profit equilibrium. The theory implies a regression of the changes in industry prices and productivity on the

input cost shares. The coefficients reflect the economy-wide input price changes that are “mandated” by the differential movements in product prices and productivity across sectors. This technique has been used by trade economists, such as Leamer (1998), Baldwin and Cain (1997), and Krueger (1997). To address the endogeneity issue of the product price changes and productivity growth, Feenstra and Hanson (1999) and Haskel and Slaughter (2001) further propose a two-stage mandated wage regression method. In the first stage, product price changes and productivity growth are attributed to a set of exogenous variables. In the second stage, the wage impacts of these exogenous variables are estimated through their induced product price changes and productivity growth.

This study follows the spirit of Feenstra and Hanson (1999) and Haskel and Slaughter (2001), with one improvement. In their models, the determination process of product price changes and productivity growth is rather ad-hoc. Here we derive explicitly the first-stage equations that are based on an oligopoly model with differentiated products. This is a methodological contribution to the literature.

Several interesting results emerge. In the first stage, we find some support for the notion that the competitiveness of a market (measured by concentration ratio) and the adoption of computer technology increase productivity. We also find some evidence of the “pro-competitive” effect of trade on domestic product market. Both import price competition and foreign outsourcing (within the same two-digit industries) are

significant in increasing productivity and reducing product prices. The empirical finding of the pro-competitive effect of trade is an empirical contribution to the literature. In his survey on the relationship between trade and productivity, Ries (2000) notes that “by in large, this literature fails to consistently find that openness to trade or the volume of trade is associated with greater productivity growth within countries. Evidence on the effect of trade liberalization on industry-level productivity is also inclusive”.

In the second stage, foreign outsourcing is found to have increased wage inequality (significance unknown for both 80s and 90s), while import price competition is found to have reduced wage inequality (insignificant in the 80s and significance unknown in the 90s). The impact of computer technology, however, depends on how we measure it. Using investment shares leads to significant impact of computers on rising wage gap, while using capital service shares leads to insignificant wage effect. Other information and communication technology, whether measured as investment shares or capital service shares, have insignificant effect on the rising wage gap in both decades. The net effect of foreign factors (import price competition and foreign outsourcing) on wage inequality is very small, only about one-tenth or less of the magnitude of ICT (computers and other ICT). One should be aware, however, that the comparison is based on the imprecise point estimates with large (or unknown) standard errors.

Section II provides a critical review of the “mandated wage regression” literature. Section III outlines the two-stage analytical framework used in the paper. Section IV introduces data source and provides summary statistics. Section V reports empirical results. Section VI offers conclusions.

II. Critical Literature Review

The ‘mandated wage regression’ technique was first used by Leamer (1998), Baldwin and Cain (1997) and Krueger (1997), and later by Feenstra and Hanson (1999) and Haskel and Slaughter (2001) in their investigation of wage inequality in the U.S and the U.K. This section first briefly overviews the earlier literature on ‘mandated wage regression’. This is followed by a discussion of the problems associated with the earlier approach.

1. An overview of earlier ‘mandated wage’ regression

The ‘mandated wage regression’ is derived from total differentiating a set of zero profit conditions. Suppose there are i industries in the economy, each of which requires M primary and N intermediate inputs. Then zero profit condition requires

$$P_i Q_i = \sum_{f \in M} W_{if} Q_{if} + \sum_{f \in N} W_{if} Q_{if} \quad (3.1)$$

where P_i and Q_i are the price and quantity of industry i 's output, and W_{if} and Q_{if} are the price and quantity of inputs f used in industry i . In our study, the M primary inputs include non-production workers, production workers and capital stock. The N intermediate inputs include energy, material and services. Total differentiating equation (3.1) and expressing the resulting infinitesimal changes in first-differences, we obtain the basic “mandated wage” equation

$$\Delta \ln P_i^V + \Delta \ln TFP_i = \sum_{f \in M} \theta_{if} \Delta \ln W_{if} \quad i = 1 \dots I \quad (3.2)$$

where $\Delta \ln P_i^V = \Delta \ln P_i - \sum_{f \in N} \theta_{if} \Delta \ln W_{if}$, is the percentage change in value added prices, $\Delta \ln TFP_i = \Delta \ln Q_i - \sum_{f \in (M+N)} \theta_{if} \Delta \ln Q_{if}$, is the primal measure of total factor productivity growth, θ_{if} is cost share of factor f in industry i , and $\Delta \ln(W_{if})$ is the change in input price for industry i . As Feenstra and Hanson (1999) note, equation (3.2) is an identity if total factor productivity is measured as dual Tornqvist index of TFP - the difference between output price growth and cost-share weighted average of input price growth.

Typically in the literature it is assumed that the primary production factors (such as labour) are homogeneous and that factors are perfectly mobile in the long run so that factor prices are equalized across industries. Equation (3.2) could then be rewritten as

$$\Delta \ln P_i^V + \Delta \ln TFP_i = \sum_{f \in M} \theta_{if} \Delta \ln W_f \quad i = 1 \dots I \quad (3.3)$$

where $\Delta \ln W_f$ is not indexed by industry i , and it measures economy-wide input price changes. Equation (3.3) is the basic equation used in the ‘mandated wage regression’ literature. It links product price changes and productivity growth with the input factor price changes. It shows, for given changes in product prices and productivity across sectors, how much economy-wide changes in factor prices are required in order to restore zero-profit conditions in all sectors. It is consistent with the long run Stolper-Samuelson Theorem. Suppose the economy starts at equilibrium, so that all sectors satisfy the zero profit condition and thus equation (3.3) holds for each industry. However, any differential changes in product prices ($\Delta \ln P_i^V$) or productivity ($\Delta \ln TFP_i$) will make some industries more profitable than others at given initial

factor prices. This attracts and shifts economy's resources towards the more profitable sectors. The relative demand for the factor used intensively in the expanding sector will increase. Accordingly the price for that factor will rise. The input price $\Delta \ln W_f$ will adjust until a new equilibrium is reached. Thus Equation (3.3) tells us how much input price changes are needed to restore the zero profit conditions for a given change in product prices and/or productivity.

To evaluate the relative impact of trade and technology on wages, earlier studies typically assume that product price changes and productivity growth are exogenous. The assumption has several implications, the limitation of which will be discussed later. First, the exogenous changes in product prices are taken as characteristics of a small open economy, where product prices are entirely determined by international market. Therefore prices' effect on wages is regarded as the effect of trade. Second, productivity growth is exogenous, and its effect on wages is regarded as the effect of technology. Third, since product price changes and productivity growth are exogenous, it is argued that there is no interaction or feedback effect between the two variables. Any productivity gain has zero pass-through to consumers in the form of lower product prices. Therefore the exogeneity assumption allows earlier researchers to find the proportion of wage changes due to trade and technology by simply running the following two equations.

Trade effect on wages:

$$\Delta \ln P_i^V = \sum_f \theta_{if} \Delta \ln W_{f,p} + \varepsilon_i \quad (3.4)$$

Technological effect on wages:

$$\Delta \ln TFP_i = \sum_f \theta_{if} \Delta \ln W_{f,t} + \zeta_i \quad (3.5)$$

where $(\Delta \ln W_{f,p})$ and $(\Delta \ln W_{f,t})$ are interpreted as wage changes due to trade and technology respectively. A positive $\Delta \ln W_{fp}$, for example, means that the product price changes are larger in sectors that employ input f relatively more intensively (a higher θ_{if}). This earlier approach in examining the relative role of trade and technology has its drawbacks and limitations, which will be discussed below.

2. Problems with the earlier approach

There are two major problems with the earlier ‘mandated wage’ approach: the mis-specification of equation (3.3) and the exogeneity assumption of product price changes and productivity growth.

Mis-specification of equation (3.3)

As Feenstra and Hanson (1999) note, equation (3.3) could be mis-specified. In equation (3.3) factor prices are assumed to be equal across industries. The existence

of inter-industry wage differentials, however, could make equation (3.3) misspecified. To demonstrate, Feenstra and Hanson (1999) rewrite equation (3.2) as

$$\Delta \ln P_i^V + \Delta \ln TFP_i = \sum_{f \in M} \theta_{if} \Delta \ln W_f + e_i \quad (3.6)$$

$$e_i \equiv \sum_{f \in M} \theta_{if} (\Delta \ln W_{if} - \Delta \ln W_f) \quad (3.7)$$

where e_i measures industry-specific factor-price changes relative to the manufacturing wide average factor price changes. Under the assumption that production factors are homogeneous in quality and perfectly mobile in the long run, factor prices are equalized across industries. In this case, the inter-industry factor price differentials (e_i) disappears and equation (3.6) coincides with equation (3.3). However, differences in factor quality or imperfect mobility of production factors will generate inter-industry factor price differentials. Since we measure long run factor price changes in our model, where factors can reasonably assumed to be mobile, the differentials can be interpreted as a reflection of quality differences. Thus the manufacturing wide average wage, W_f , is the effective wage paid by industries after controlling for quality differences. The conventional price regression (3.3) typically omits the term e_i and implicitly includes it in the error term. The omitted term e_i could be highly correlated with the independent variables θ_{if} , and the estimated parameters could therefore be biased. Feenstra and Hanson (1999) demonstrate that the wage estimates in the conventional ‘mandated wage’ regression omitting the term e_i are very sensitive to specifications and do not match actual wage changes.

To deal with this problem, Feenstra and Hanson (1999) propose the following specification. Define quality-adjusted total factor productivity (TFP) as effective total factor productivity (ETFP). That is

$$\Delta \ln ETFP_i \equiv \Delta \ln TFP_i - e_i \quad (3.8)$$

Combining equations (3.8) and (3.6), we obtain

$$\Delta \ln P_i^V + \Delta \ln ETFP_i = \sum_{f \in M} \theta_{if} \Delta \ln W_f \quad i = 1 \dots I \quad (3.9)$$

Note equation (3.9), as equation (3.2), is an identity if TFP growth is defined as the Tornqvist index – the difference between output price growth and cost share weighted input price growth. An identity may be manipulated so that for given changes in product prices and productivity growth ($\Delta \ln P_i^V + \Delta \ln ETFP_i$) and for given information on factor cost shares (θ_{if}), one could estimate the economy-wide wage changes ($\Delta \ln W_f$) that are required to maintain the zero-profit condition of equation (3.9). The estimated wage changes (in nominal dollars) should match closely the actual wage changes².

This is indeed the case. Table 3.1 presents the estimation results for equation (3.9). For the 1980s, the changes in product prices and productivity mandated an average annual wage increase of 6.1 and 5.5 percent for the non-production and production workers respectively. This is very close to the actual average annual increase of 6.0

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² Because of sampling errors, measurement errors and the primal measure of TFP growth (the difference between output growth and the cost share weighted input growth), equation (3.9) will not hold exactly but with error.

and 5.4 percent. Similarly, for the 1990s, the estimated wage changes are 4.5 and 3.1 percent for the non-production and production workers respectively, as compared to the actual annual wage increases of 4.2 and 3.5 percent. The F-test shows a significant increase in the relative wages of non-production to production workers in both decades. We adopt Feenstra and Hanson's modified specification in our analysis.

Exogeneity assumption of product price changes and productivity growth

Another major problem of the earlier 'mandated wage' regression approach is the exogeneity assumption on product price changes and productivity growth and the assumption of no-interaction between product price changes and productivity growth.

Product price changes are assumed to be exogenous and to be determined entirely by international forces. The assumption means that the country is a small open economy, technical progress is country-specific, and products are homogeneous and traded in a perfectly competitive world economy. To the extent that the assumptions do not hold, it becomes possible for factors other than international forces, to affect domestic product prices. For example, in a large open economy the productivity gain of an industry will increase the supply of the industry's product. The increase in the relative supply will in turn decrease the product price, the magnitude of which

depends on the price elasticity of demand³. But this needs not to be the only case. Even when a country is a small open economy, its product prices could still be endogenously determined. This could happen in Krugman (2000)'s integrated world where there is a simultaneous technological change in the world as a whole, though the rate of technical progress needs not to be identical across countries (Xu 2001). This could also happen in a world where products are highly differentiated. As micro studies on purchasing power parity (Isard 1977, Giovannini 1988, Richardson 1978, Bordo and Choudhri 1977, Engel and Rogers 1996, 1998) indicate, price equalization between domestic and foreign prices depends on the degree of product differentiation and tradability. Various country studies⁴ also find that the relative importance of domestic and international factors in the determination of domestic prices depends on the degree of product differentiation, tradability and market structure.

Productivity growth is also likely to be endogenously determined by factors such as international competition and the adoption of new and advanced technology.

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³ The magnitude depends on the price elasticity of demand. When consumption preference is Cobb-Douglas (the elasticity of demand equals one), a relative higher productivity gain in one sector will increase the relative supply of its output, which will lead to a proportionate reduction in its relative output prices. In this case, the productivity gain is 100% passed on to consumers in the form of lower product prices. If elasticity of demand is elastic (>1), the pass through of product prices will be less than 100%. And when the elasticity is inelastic (<1), productivity growth will lead to more than proportionate price reduction. Leamer (1998) in his study recognized the possible pass-through effect of productivity gain to product prices. He experimented with different pass-through rates. In general, the results are sensitive to which pass-through rates are used.

⁴ Examples of studies on industrial pricing behaviour include Feinberg (1989) for the U.S; Feinberg (1986) for Germany; Bloch and Olive (1996, 1999) for Australia; Hazledine (1980), Kardasz and Stollery (1998) for Canada.

Empirical evidence seems to support the hypothesis that the adoption of high-tech machinery and equipment could have impact on productivity (Jorgensen and Stiroh 2000 a, b). International competition may also induce productivity growth through several channels: the market disciplinary effect, or the increasing rate of knowledge spill-over across countries (Ethier 1982, Grossman and Helpman 1991a,b), or the increasing scale of industry-level production by forcing inefficient firms out of the market (Melitz 1999). The empirical evidence of trade's effect on productivity is limited and inconclusive. Ries (2000) provides an excellent overview on the theoretical and empirical research in this area.

With the different forces that could affect product price changes and productivity growth, we cannot conclude that relative wage changes induced by product price changes are entirely due to international trade as in equation (3.4), and that wage changes induced by productivity growth are entirely due to technical progress as in equation (3.5).

To address the endogeneity issue, we adopt a two-stage regression technique. It has been used by Feenstra and Hanson (1999) and Haskel and Slaughter (2001) for the U.S and U.K study respectively. The first stage examines how changes in exogenous variables such as foreign outsourcing and high-tech capital contribute to product price changes and productivity growth. In the first stage, changes in prices and productivity are regressed on a set of exogenous variables. The second stage examine

how changes in prices and productivity implied by each exogenous variable influence wages. That is, in the second stage, the component of changes in price and productivity due to each exogenous variable are regressed on factor cost shares, and the coefficients obtained are interpreted as predicted wage changes due to that exogenous variable. This paper follows their spirit with one improvement. In their models, the determination process of product price changes and productivity growth is rather ad-hoc. Here we derive explicitly the first-stage equations that are based on an oligopoly model with differentiated products. The model helps us to understand the mechanism and the magnitude of the impact of trade and technology on product price changes, productivity growth and relative wage movements between the more and the less skilled workers.

III. Analytical Framework

This section outlines the two-stage mandated wage regression framework used in the study. In the first stage, we endogenize product price changes and productivity growth, using an oligopoly model with differentiated products. This allows us to decompose changes in product price and productivity to a set of underlying exogenous variables, such as high-technology adoption and international competition. In the second stage, we regress on cost shares the decomposed changes in product price and productivity induced by each exogenous variable. The cost share coefficients give the wage changes that are required to maintain the zero-profit conditions.

1. First-stage: modelling product price changes and productivity growth

We consider a simple oligopoly model with differentiated products (Kamien and Schwartz 1983, Feenstra 1989, Varian 1992). The model assumes many industries, each one composed of H home producers and F importers. Each firm supplies some variant of a product that is a close but not perfect substitute to satisfy market demand. Assume the differentiated product is weakly separable from other goods in the consumer's utility function. We could then write the demand for a home variety as $X(P_H, P_F, E)$, where P_H and P_F are the price vector of domestic and imported foreign varieties, and E is the total expenditure on all varieties of the product. Further assume

the cost of production C for a home variety depends on a vector of input prices W , the level of output X , and a vector of other exogenous variables T that could potentially affect the production process. The cost function could then be expressed as $C=C(W, X, T)$. The T vector, in our model, includes such variables as foreign outsourcing and high-technology adoption.

The home producer of a variety i maximizes its profits, treating other prices and total expenditure on the product as exogenous. The maximization problem can be stated as

$$\text{Max (w.r.t } P_i) \pi_i = P_i X_i(P_H, P_F, E) - C(W_i, X_i(P_H, P_F, E), T_i) \quad (3.10)$$

The first-order condition for (3.10) (see Appendix 3A for derivation) is:

$$P_i = C'(W_i, P_H, P_F, E, T_i) / (1 + 1/\eta_i) \quad \text{where} \quad (3.11)$$

$$\eta_i = \varepsilon_{ii} + \sum_{h \neq i} \varepsilon_{ih} \theta_{hi} + \sum_f \varepsilon_{if} \theta_{fi} \quad (3.12)$$

where C' is the marginal cost of producing a unit of the i th firm's variety, and η_i is the perceived price elasticity of demand that depends on own price elasticity of demand ($\varepsilon_{ii} = d\ln X_i / d\ln P_i$), cross price elasticity of demand with rival home varieties ($\varepsilon_{ih} = d\ln X_i / d\ln P_h$), cross price elasticity of demand with rival foreign varieties ($\varepsilon_{if} = d\ln X_i / d\ln P_f$), and firm i 's perceived responsiveness of rival home producers ($\theta_{hi} = d\ln P_h / d\ln P_i$) and rival importers ($\theta_{fi} = d\ln P_f / d\ln P_i$) to its own price changes. We shall restrict our attention to a 'symmetric' equilibrium in which home producers are identical and all importers are also identical. That is, in equilibrium, all home producers, as well as all importers must have the same product prices and face the same factor prices and demand functions, so that $P_i = P_h$, $P_f = P_m$, $W_i = W$, $X_i = X$, $\varepsilon_{ih} =$

$\varepsilon_{dd}, \varepsilon_{if} = \varepsilon_{dm}, \theta_{hi}=1, \theta_{fi} = \theta_{md}$, for $i, h= 1, \dots, H, f=1, \dots, F$. From equation (3.11-3.12)

we obtain the implicit pricing equation

$$P_d = f(P_m, W, \eta, E, T) \text{ where} \quad (3.13)$$

$$\eta = H \varepsilon_{dd} + F \varepsilon_{dm} \theta_{md} \quad (3.14)$$

Equations (3.13) and (3.14) state that domestic product price P_d is determined by import price P_m , input prices W , the perceived elasticity of demand η , the total expenditure on product E and other exogenous variables T . The perceived elasticity of demand η in turn reflects home producer's own price elasticity of demand ε_{dd} , cross price elasticity of demand with rival import varieties ε_{dm} , home producer's perceived responsiveness of importers to its price changes θ_{md} , and the relative number of home producers and importers (H, F). In general, the perceived elasticity of demand reflects the underlying demand functions, product differentiation, and market structure.

Total differentiating equation (3.13) and replacing the instantaneous changes with discrete changes, we obtain

$$\begin{aligned} \Delta \ln P^v &= (\varepsilon_{pd,pm} \Delta \ln P_m + \varepsilon_{pd,\eta} \Delta \ln \eta + \varepsilon_{pd,E} \Delta \ln E + \sum_j \varepsilon_{pd,Tj} \Delta \ln T_j) + \sum_{f \in M} \theta_f \Delta \ln W_f \\ &= f(Z_p) \end{aligned} \quad (3.15)$$

where $\Delta \ln P^v = \Delta \ln P_d - \sum_{f \in N} \theta_f \Delta \ln W_f$. Equation (3.15) indicates that the value-added product price changes ($\Delta \ln P^v$) depend on a vector of underlying variables Z_p , which includes changes in import prices $\Delta \ln P_m$, perceived elasticity of demand $\Delta \ln \eta$,

expenditure $\Delta \ln E$, other exogenous variables $\Delta \ln T_j$, and cost share weighted primary input price changes $\sum_{f \in M} \theta_f \Delta \ln W_f$. The parameters $\varepsilon_{pd,pm}$, $\varepsilon_{pd,\eta}$, $\varepsilon_{pd,E}$ and $\varepsilon_{pd,Tj}$ measure elasticity of product price changes to changes in import price, perceived elasticity of demand, total expenditure on the product, and exogenous variable T_k , respectively.

Since the dual Tornquist index of total factor productivity (TFP) growth is defined as the difference between output price growth and cost-share weighted average of input price growth, from equation (3.15) we could further derive equation for productivity growth:

$$\begin{aligned}
 \Delta \ln TFP &= (\Delta \ln P^v - \sum_{f \in M} \theta_f \Delta \ln W_f) \\
 &= (\varepsilon_{pd,pm} \Delta \ln P_m + \varepsilon_{pd,\eta} \Delta \ln \eta + \varepsilon_{pd,E} \Delta \ln E + \sum_j \varepsilon_{pd,Tj} \Delta \ln T_j) \\
 &= g(Z_t)
 \end{aligned} \tag{3.16}$$

Equation (3.16) indicates that total factor productivity growth is a function of a vector of variables Z_t which includes changes in import prices $\Delta \ln P_m$, perceived elasticity of demand $\Delta \ln \eta$, expenditure $\Delta \ln E$, and other exogenous variable $\Delta \ln T_j$.

Equations (3.15) and (3.16) will be the two basic equations in our first-stage regression. The aim is to decompose product price changes and productivity growth into various components that are due to the underlying exogenous variables Z_p and Z_t . The regression models could be written as

$$\begin{aligned}
(\Delta \ln P^v)_i &= \alpha_0 + \alpha_1(\Delta \ln P_m)_i + \alpha_2(\Delta \ln \eta)_i + \alpha_3(\Delta \ln E)_i + \sum_k \alpha_{4,k}(\Delta \ln T_k)_i \\
&+ \alpha_5(\sum_{f \in M} \theta_f \Delta \ln W_f)_i + u_i
\end{aligned} \tag{3.17}$$

and

$$\begin{aligned}
(\Delta \ln ETFP)_i &= \beta_0 + \beta_1(\Delta \ln P_m)_i + \beta_2(\Delta \ln \eta)_i + \beta_3(\Delta \ln E)_i + \sum_k \beta_{4,k}(\Delta \ln T_k)_i + v_i
\end{aligned} \tag{3.18}$$

where α and β are coefficients, and u_i and v_i are *i.i.d* disturbance terms that are assumed to be orthogonal to the exogenous variables Z_p and Z_t . Summing (3.17) and (3.18), we obtain:

$$\begin{aligned}
\Delta \ln P_i^v + \Delta \ln ETFP_i &= \gamma_0 + \gamma_1(\Delta \ln P_m)_i + \gamma_2(\Delta \ln \eta)_i + \gamma_3(\Delta \ln E)_i + \sum_k \gamma_{4,k}(\Delta \ln T_k)_i \\
&+ \alpha_5(\sum_{f \in M} \theta_f \Delta \ln W_f)_i + \varepsilon_i
\end{aligned} \tag{3.19}$$

where $\varepsilon_i = u_i + v_i$ and $\gamma_s = \alpha_s + \beta_s$ ($s=0-4$). Parameter γ measures the net impact of exogenous variables on product price changes and effective productivity growth. From the first stage estimation of (3.19), one could decompose the changes of product prices and productivity into components that are due to the various exogenous variables. For example, the contribution of exogenous variable T_k to product price changes and effective TFP growth is $\gamma_{4,k} \Delta \ln T_k$. The decomposed component will be used to estimate the wage effect of variable T_k in our second-stage regression.

2. Second-stage: estimates of wage changes due to exogenous variables

In the second stage, we regress the decomposed product price changes and productivity growth ($\Delta \ln P_i^V + \Delta \ln ETFP_i$) on factor cost shares. The share coefficients are the estimated factor price changes. For example, the second stage regression for exogenous variable T_k is

$$(\gamma_{4,k} \Delta \ln T_k)_i = \sum_f \Delta \ln W_f \theta_{if} + \zeta_i \quad (3.20)$$

with ζ_i being the error terms. The coefficients, $\Delta \ln W_f$, are the estimated factor price changes that are due to exogenous variable T_k . If changes in product prices and productivity induced by T_k are strongly biased towards skill-intensive industries, then there will be an increase in the wage in favour of the more skilled workers relative to the less skilled workers.

3. Sector-bias or factor-bias

There has been some debate in the literature on the relevance of sector-bias and factor-bias in determining wage changes. Leamer (1998) argues that only sector-bias of technical change matters for relative wages, while Krugman (2000) demonstrates a case where only factor-bias matters. Xu (2001) demonstrates that each argument is valid, but only under special assumptions. The pure sector-bias argument is valid only when the technical progress is local and in a small open economy, or when the elasticity of substitution of demand is infinite. The pure factor-bias argument is valid

only when technical progress is global and identical across countries and when preferences are in Cobb-Douglas functional form. To the extent that these restrictive assumptions are unlikely to hold, both factor and sector bias could have an impact on wages. So the question is: how are the sector and factor biases represented in our two-stage model?

In the first-stage regression (3.18), we allow both factor-neutral and factor-biased shocks to have a potential impact upon productivity growth. Equation (3.18) reflects the net impact. It does not distinguish the form in which exogenous variables affect productivity growth.

In the second stage, it is the sector bias that determines the wage changes. In other words, the wage impact of exogenous variable (T_k) depends on whether its induced changes in product prices and productivity (e.g. $\gamma_{4,k} \Delta \ln T_k$) is sector-biased.

IV. Data and Summary Statistics

The data used in the study are drawn from three sources: the KLEMS Productivity dataset, the Annual Survey of Manufacturing (ASM), and the Input-Output Tables from Statistics Canada. Data from the three sources are all matched to 1980 SIC at PL level of aggregation, covering 84 manufacturing industries from 1981 to 1996. Further we divide the period into two sub-periods: 1981-1989 for the 1980s and 1989-1996 for the 1990s. The dividing point corresponds approximately to the business cycles.

The summary statistics for some key variables are provided in Table 3.2. It calculates the average annual changes for the 80s and 90s. Average annual changes for variables, such as product prices, effective TFP, import prices, product expenditure, are measured as the log difference between the last year and the first year of a decade divided by the number of years. Cost shares are averages of the first and the last year of a decade.

1. Product price change, productivity growth, wage changes and cost shares

Information regarding product price changes, productivity growth, wage changes and average cost shares are derived from KLEMS and ASM. The KLEMS dataset contains information on TFP, and prices and quantities of output, capital, labour,

energy, materials and services, but has no information on the number of production and non-production workers and their compensation. ASM, which is maintained by Micro-Economic Analysis Division, has such information. From ASM we derive the share of the number of production and non-production workers and the share of their compensations, and apply them to the total employment and total labour compensation in the KLEMS dataset. We define production and non-production workers as non-skilled and skilled workers respectively.

Table 3.2 provides summary statistics of the key variables. Average annual changes of product prices are 3.6% and 2.1% for the 80s and 90s respectively while average annual TFP growth is 0.5% for both decades. Wage inequality has been rising in both decades. The wages of non-production workers increased at an annual average rate of 6.0% in the 80s and 4.2% in the 90s, while the wages of production workers increased at 5.4% and 3.5% per year for the 80s and 90s respectively.⁵ Thus the wages of non-production relative to production workers rose at an annual average rate of 0.6% in the 80s and 0.7% in the 90s.

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⁵ The percentage increases in factor prices are measured in nominal dollars. Given GDP inflation were 4.4% and 1.8% per year for the 80s and the 90s respectively, the real annual average wage increase for non-production workers are 1.6% in the 80s and 2.4% in the 90s, while the real annual average wage increase for the production workers are 1.0% and 1.7% for the 80s and 90s respectively.

2. Exogenous variables

First we shall briefly discuss the variables that are included in the vector T . As we defined earlier, vector T includes factors that could potentially affect production process and cost. In our model, such factors include foreign outsourcing and high-technology adoption. There are several reasons for choosing these two variables. First, choosing these two variables make our results more comparable to the U.S study by Feenstra and Hanson (1999). Second, besides the rationale given by Feenstra and Hanson, the two variables are also of relevance to Canada. Baldwin *et al* (1997) find that wages are higher in plants that adopt advanced technologies. So far there has been no study in Canada to examine the extent of foreign outsourcing and its impact on productivity, product prices and wages. Our study fills this gap.

We use the same measurement of high-technology adoption and foreign outsourcing as chapter 2. For the detailed information on the construction and the summary statistics of the two variables, please consult pages 66 – 69.

Other exogenous variables are measured as follows. Import prices are the implicit import price indexes derived from the Input-Output tables; they are the c.i.f price (cost+insurance+freight) plus duties. These are the effective prices that compete directly with domestic producers, and represent the pressure from international competition. Total expenditure on the industry product is calculated as the total

industry output, plus imports and minus exports. As we demonstrated in section III, the perceived elasticity of demand depends on the underlying demand functions, product differentiation, and market structure. Here we use changes in the market structure (measured by the concentration ratio) as a proxy for the changes in elasticity of demand. The concentration ratio is calculated as the employment share of four largest plants, using firm level data from ASM.

V. Empirical Results

1. First-stage regression

Table 3.3 reports the first-stage estimation of equations (3.17 – 3.19) by pooling data of 84 industries over two decades 1981-1989 and 1989-1996. Columns 1-3 of the table show the results when high technology is measured as annual average investment shares (the averages of the first and last years of a decade).

Column (1) contains results for the price equation (3.17). The main findings regarding the determinants of domestic product price changes are summarized as follows:

- (i) Both changes in import price and domestic cost of production have significant positive effect on domestic value-added product price changes. It means that a fall in import price or a fall in the cost of production reduces domestic product price.
- (ii) Narrow foreign outsourcing has negative effect on product price changes, significant at 1% level. It implies a significant non-zero pass-through of efficiency gain from foreign outsourcing to product prices.
- (iii) Other variables, such as investment in computers and other ICT technology, have no significant impact on product price changes.

Column (2) reports results for the productivity equation (3.18). The main findings regarding the determinants of productivity growth are summarized as follows:

- (i) Import price increase has negative effect on productivity growth, weakly significant at 10% level. In other words, a reduction in a trade barrier, as captured by a reduction in import prices, increases productivity growth.
- (ii) An increase in the market concentration ratio has negative effect on productivity growth, but only weakly significant at 10% level. The negative sign indicates that a decrease in market concentration (i.e an increase in competition) increases productivity growth.
- (iii) Computers and other ICT increases productivity growth, significant at 10% and 1% level respectively;
- (iv) The narrowly defined foreign outsourcing (within the same two-digit industries) has significant (at 1% level) positive effect on productivity growth.
- (v) By importing cheaper and more efficient intermediate inputs, foreign outsourcing is likely to increase efficiency and reduces cost of production.

Column (3) reports the net effect of exogenous variables on changes in product price and productivity from equation (3.19). We find that the use of computers and other ICT technology have significant positive effect on the total changes in product prices and productivity. Other variables, such as import prices, market concentration ratio, and outsourcing, have insignificant effects. This is likely due to the fact that the productivity effect of these variables offset their price effects, yielding the net effect

insignificant. The estimated coefficients from equation (3.19) will be used in the second-stage regression.

Columns 4-6 show the results when high technology is measured as annual average changes in capital services (the difference between the last year and the first year of a decade divided by the number of years). We find that:

- (i) The results from the product price regression (column 4) are similar to those in column 2.
- (ii) In the productivity regression (column 4), the effects of import prices, market concentration ratio, computers and narrow foreign outsourcing on productivity growth are similar to those in column (1). The effects of market concentration and computers become more statistically significant from 10% to 5% level, and the effect of other ICT technology become insignificant.
- (iii) Unlike in column 3, the net impact of computer and other ICT technology (column 6) become insignificant.

Due to the possible endogeneity of import price changes, we repeat the above regression using changes in tariff rate instead of import prices. We obtain similar results except that tariff changes are not found to have significant impact upon product price changes and/or effective TFP growth (Table 3.4).

In sum, the first stage regression reveals several interesting results:

- (1) Import price increases have a negative effect on productivity growth and a positive effect on domestic prices, statistically significant at 10% and 5% level respectively. It means that a reduction in trade barriers, as captured by the reduction in import prices, increases productivity growth and reduces domestic product prices. This is consistent with the hypothesis that trade or openness has “pro-competitive” effect on domestic product market.
- (2) Foreign outsourcing (within the same two-digit industries) significantly (at 1% level) increases productivity and reduces product prices. This is consistent with the expectation that importing cheaper and more efficient intermediate inputs increases efficiency and reduces costs of production. The cost reduction and productivity gain are further passed on to consumers in the form of lower product prices.
- (3) Besides foreign outsourcing and import price competition, we find that Canadian product prices are also influenced by domestic cost of production, statistically significantly at 5% level. Thus it seems that both international and domestic forces are important in determining product prices in Canada.
- (4) We find some support for the notion that the competitiveness of a market (measured by concentration ratio) and the adoption of computer technology increase productivity growth; the significant level ranges from 5% to 10% depending on how we measure high technology.

2. Second-stage regression

To understand the influence of these exogenous variables on wages, we need to estimate the second stage regression of equation (3.20). The dependent variable in (3.20) is the fitted value, i.e. the estimated contribution of each exogenous variable to the net changes in product prices and productivity (using the coefficient estimates from column 3 and 6 in Table 3.3). We regress the fitted value on cost shares. The coefficients of the cost shares are then the estimated wage changes due to each exogenous variable. Since the dependent variables are fitted rather than true values, the variance/covariance matrix of the errors in the second-stage regression is a combination of errors from the true regression and the first-stage regression. Thus the standard errors of the coefficients need to be adjusted. The adjustment procedures (Feenstra and Hanson 1999) could yield negative values for the estimated variance, in which case we could not calculate the adjusted t-statistics.

All regressions are run using OLS. To account for possible industry size effect on wages, we weigh all the regressions with industry's average employment level (averages of the first and the last year of a decade). The estimated coefficients are therefore weighted averages of annual growth rate of earnings. To see if the results are sensitive to the regression weights, we also repeat all the regressions without employment weights. The results are similar to those reported herein.

Tables 3.5 and 3.6 contain the second-stage results, using average annual investment shares and average annual changes in the capital service shares as measures of technology respectively.

To read the tables, consider column (1) of Table 3.5 as an example. It shows the impact on wage of import price changes. The import price change, through its effect on changes in product prices and productivity, is estimated to have increased insignificantly both the non-production wage (0.05 percent annually), and the production wage (0.12 percent annually) over the period of 1981-1989. The difference between the wage estimates for the non-production and production workers gives the estimated wage inequality changes. As we see, import price competition yielded only an insignificant drop in wage inequality of 0.07 percent per year. The rest of the Table reads similarly for each exogenous variable.

The findings of Table 3.5 (when high technology is measured by average annual investment shares) can be summarized as follows:

- (1) *The effect of high technology.* For the 1980s, computers mandated a statistically significant (at 1% level) increase of wage inequality at 1.1 percent annually. Other ICT technology also mandated a rise in the relative wages of the non-production worker, but insignificantly. Similar results are obtained for the 1990s, when computers led to a significant increase of wage inequality of 1.7

percent annually, while the adoption of other ICT technology raised the relative wages only by an insignificant amount.

- (2) *The effect of international competition.* For the 1980s, foreign outsourcing within the same two-digit industries mandated a decrease of wage inequality at 0.01 percent annually. The significant level is unknown due to the negative values of the estimated variance, though it is more likely to be insignificant since it induces insignificant net changes in product price and productivity (column 3 of Table 3.4). Foreign outsourcing outside the same two-digit industries mandated an insignificant rise in wage inequality (0.23 percent per year). Import price competition mandated an insignificant fall in wage inequality (0.07 percent annually). The total effect of trade variables on wage inequality is very small, only about one tenth of the magnitude of high technology (computer + other ICT). Similar results are obtained for the 1990s.

The main message from Table 3.5 is that computer investment has a significant impact on rising wage gaps in the 1980s and 1990s. Other ICT technology raises wage inequality, but only insignificantly. The net effect of foreign factors on wage inequality is very small, only about one-tenth of the magnitude of high technology (computer + other ICT).

Table 3.6 reports the estimates when high technology is measured as capital service shares. The results are qualitatively similar to those in Table 3.5, except that computers' impact becomes insignificant.

The results for the second-stage regression could be summarized as follows. When we use high-tech investment share as a measure of high technology adoption, computers have a significant effect on rising wage gaps for both the 80s and 90s (significant at 10% level or better), while other ICT technology has an insignificant effect. Foreign outsourcing is found to have increased wage inequality (significance unknown for both 80s and 90s), while import price competition is found to have reduced wage inequality (insignificant in the 80s and significance unknown in the 90s). When we use high-tech capital service share as a measure of high technology, we obtain similar results, except that computers mandated only an insignificant rise in wage inequality. In either case, the total effect of foreign factors (import price competition and foreign outsourcing) on wage inequality is very small, only about one-tenth or less of the magnitude of high technology. One should be aware, however, that the comparison is based on imprecise point estimators with large (or unknown) standard errors.

3. Discussion of empirical results

There are some notable similarities and differences between our Canadian findings and the other two papers that used the two-stage regression technique - Haskel and Slaughter (2001) for the U.K and Feenstra and Hanson (1999) for the U.S.

In Haskel and Slaughter (2001)'s first-stage regression, they find a significant positive effect of OECD and NIC (newly industrialized countries) import price changes on UK domestic product prices, and a significant negative effect of NIC import prices on total factor productivity growth. This is consistent with our findings for Canada.

As to the wage effect of computer technology and foreign outsourcing, Feenstra and Hanson (1999) find that both played a role in the increasing wage inequality in the U.S during the 1980s (1979-1990). But the relative importance of computer technology is sensitive to how it is measured. The adoption of computer technology has an impact that is twice as large as foreign outsourcing when it is measured as capital services using ex-post rental prices. By contrast, when capital services are estimated using ex-ante rental prices, the use of computer technology has a smaller impact on wage inequality than foreign outsourcing. Further, when investment shares are used, the use of computer technology has the largest impact, with outsourcing having minimal role for increasing wage inequality.

Our results are consistent with Feenstra and Hanson (1999)'s findings in that we find the impact of computer to be sensitive to the measurement – it significantly increases wage inequality in both decades when investment shares are used, but it has an insignificant effect when capital service (ex-ante rental prices) shares are used. On the other hand, we only find weak evidence (either insignificant or significant level unknown) of foreign outsourcing on rising wage gap in Canada. For the U.S., Feenstra and Hanson (1999) find that in general narrow foreign outsourcing increases wage gaps, significant when capital services are used, but insignificant when investments are used. To make our results more directly comparable to theirs, we re-run equations (3.17)-(3.20) with only high technology and foreign outsourcing as the exogenous variables for the 1980s (1981-1989). The results are reported in Table 3.7. They are qualitatively similar to those already discussed in the paper. Thus the difference in our results cannot be attributed to the different specifications.

VI. Conclusion

This chapter examines the relative role of trade and technology in explaining the rising wage inequality in Canada during the 80s and 90s. Based on zero-profit conditions, it adopts the two-stage mandated wage regression technique in its investigation.

In the first stage, we endogenize product price changes and productivity growth. Using a simple oligopoly model with differentiated products, we derive the structural equations for product price changes and productivity growth. This is a methodological contribution to the literature. Several interesting results emerge from the first stage analysis.

First, import price competition increases productivity growth and reduces domestic product prices, significant at 10% and 5% level respectively. This is consistent with the hypothesis that trade or openness has “pro-competitive” effect on domestic product market.

Second, foreign outsourcing (within the same two-digit industries) significantly (at 1% level) increases productivity and reduces product prices. This is consistent with our expectation that importing cheaper and more efficient intermediate inputs

increases efficiency and reduces costs of production. The reduction of cost is further passed on to consumers in the form of lower product prices.

Third, besides foreign outsourcing and import price competition, we find that Canadian product prices are also significantly (at 5% level) influenced by domestic cost of production. Thus both international and domestic forces are important in determining product prices in Canada.

Fourth, we find some support for the expectation that the competitiveness of a market (measured by concentration ratio) and the adoption of computer technology increase productivity growth; the significant level ranges from 5% to 10% depending on how we measure high technology.

In the second stage, we estimate the wage impact of these exogenous variables through their induced changes in product prices and productivity. Foreign outsourcing (within and outside the same two-digit industries) is found to have increased wage inequality (significance unknown for both 80s and 90s), while import price competition is found to have reduced wage inequality (insignificant in the 80s and significance unknown in the 90s). The impact of computer technology depends on how we measure it. Using computer investment shares lead to significant impact of computers in rising wage inequality, while using computer capital service shares lead to insignificant effect on wages. Other ICT technology, whether measured as

investment shares or capital service shares, have insignificant effect on the increasing wage inequality in both decades. In general, the net effect of foreign factors (import price competition and foreign outsourcing) is very small, only about one-tenth or less of the magnitude of high technology (computer + other ICT). One should be aware, however, that the comparison is based on the imprecise point estimators with large (or unknown) standard errors.

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Table 3.1 Identity regression

Identity regression of equation (3.9): $\Delta \ln P_i^V + \Delta \ln ETFP_i = \sum_{f \in M} \theta_{if} \Delta \ln W_f + \varepsilon_i$

	1981-1989	1989-1996
Average cost share of non-production worker	0.061 (5.75) ***	0.045 (4.46) ***
Average cost share of production worker	0.055 (12.28) ***	0.031 (5.93) ***
Average cost share of capital	0.079 (12.51) ***	0.023 (4.07) ***
R-squared	0.99	0.93
N	84	84

Note: regressions are weighted by industry's average employment share. Averages are calculated as the averages of the first and last years of a decade. t - statistics are in parentheses. Three asterisks (***) indicate statistically significant at the 1% level or better.

Table 3.2 Summary statistics

	1981-1989		1989-1996	
	average annual change	std. dev.	average annual change	std. dev.
Average factor cost shares				
Capital	0.123	0.053	0.141	0.055
Non-production worker	0.082	0.039	0.080	0.042
Production worker	0.177	0.058	0.167	0.054
Energy	0.022	0.027	0.019	0.023
Material	0.468	0.121	0.457	0.122
Service	0.128	0.034	0.136	0.038
Changes in log factor prices				
Capital	0.070	0.086	0.041	0.078
Non-production worker	0.060	0.009	0.042	0.013
Production worker	0.054	0.012	0.035	0.010
Energy	0.040	0.010	0.023	0.008
Material	0.027	0.017	0.017	0.017
Service	0.043	0.008	0.022	0.011
Changes in log product price and TFP				
Nproduct price	0.036	0.020	0.021	0.018
TFP	0.005	0.015	0.005	0.012
Changes in capital service shares				
Inf. & com. technolgoy (ICT)	0.003	0.007	0.001	0.006
Computer	0.000	0.001	0.000	0.002
Difference (other ICT)	0.002	0.007	0.001	0.005
Average investment shares				
Inf. & com. technolgoy (ICT)	0.106	0.099	0.142	0.121
Computer	0.036	0.026	0.042	0.033
Difference (other ICT)	0.070	0.096	0.099	0.114
Changes in outsourcing				
Broad outsourcing	0.004	0.005	0.018	0.008
Narrow outsourcing	0.003	0.006	0.007	0.010
Difference	0.001	0.005	0.011	0.008
Changes in other exogenous variables				
Tariff	-0.003	0.006	-0.003	0.004
Logged import prices	0.024	0.033	0.028	0.022
4-firm concentration ratio	-0.002	0.006	0.000	0.006
Logged GDP price index	0.044	0.000	0.018	0.000

Note: averages are computed over the first and last year of a decade, while changes are measured as the difference between the last and the first year of a decade divided by the number of years. Both averages and changes are weighted by the industry share of total manufacturing employment. For variable definitions and measurement, see text for detail.

Table 3.3 First-stage regression (using import prices)

Equations (3.17 – 3.19)   Dependent Variables: $\Delta \ln P_i^V$, $\Delta \ln ETFP_i$, $\Delta \ln P_i^V + \Delta \ln ETFP_i$

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta \ln P_i^V$	$\Delta \ln ETFP_i$	$\Delta \ln P_i^V + \Delta \ln ETFP_i$	$\Delta \ln P_i^V$	$\Delta \ln ETFP_i$	$\Delta \ln P_i^V + \Delta \ln ETFP_i$
change of log import prices	0.115 (2.068)**	-0.099 (-1.781)*	0.026 (1.440)	0.108 (2.142)**	-0.083 (-1.851)*	0.027 (1.452)
change of concentration ratio	0.197 (1.360)	-0.269 (-1.675)*	-0.008 (-0.096)	0.259 (1.535)	-0.370 (-2.132)**	-0.042 (-0.586)
change of log total expenditure	-0.015 (-0.523)	-0.029 (-1.014)	-0.014 (-0.649)	-0.009 (-0.338)	-0.024 (-0.948)	-0.016 (-0.770)
average investment share in computer	-0.007 (-0.174)	0.068 (1.783)*	0.043 (1.895)*			
average investment share in other ICT tech (ICT other than computer)	0.002 (0.311)	0.013 (2.707)**	0.010 (2.479)**			
change of capital service share in computer				-0.906 (-0.965)	2.007 (2.617)***	0.548 (1.019)
change of capital service share in other ICT				0.110 (0.923)	0.056 (0.669)	0.110 (1.033)
change in narrow outsourcing (within the same 2-digit mnfg industries)	-0.331 (-2.697)***	0.305 (2.629)***	-0.016 (-0.209)	-0.343 (-2.819)***	0.365 (3.575)***	0.020 (0.236)
change in other outsourcing (outside the same 2-digit mnfg industries)	-0.177 (-1.358)	-0.001 (-0.008)	-0.131 (-1.484)	-0.195 (-1.518)	0.135 (1.178)	-0.057 (-0.716)
change in the cost of production	0.360 (5.363)***		0.104 (1.922)*	0.312 (3.693)***		0.141 (2.801)***
constant	0.008 (3.178)***	0.007 (3.060)***	0.019 (9.098)***	0.009 (3.347)***	0.008 (4.881)***	0.020 (9.288)***
decade dummy	-0.005 (-1.821)*	-0.005 (-1.987)**	-0.011 (-6.016)***	-0.004 (-1.633)	-0.006 (-2.263)***	-0.011 (-5.759)***
R	0.44	0.27	0.51	0.45	0.34	0.50
N	168	168	168	168	168	168

Note: Pooled regressions using 84 industry's data over two decade (1981-1989 and 1989-1996), with heteroscedastic-robust t-statistics (in parentheses). Averages are measured as the averages between the first and the last year of a decade, while changes are the difference between the last and the first year of a decade divided by the number of years. One, two and three asterisks (*, **, ***) indicate statistically significant at the 1%, 5% and 10% level respectively.

Table 3.4 First-stage regression (using tariff rate) Estimates of equations (3.17)-(3.19)   Dependent variables: $\ln P_V$, $\ln ETFP$, $\ln P_V + \ln ETFP$

	(1)		(2)		(3)		(4)		(5)		(6)	
	$\ln P_V$	$\ln ETFP$	$\ln P_V$	$\ln ETFP$	$\ln P_V + \ln ETFP$	$\ln P_V + \ln ETFP$	$\ln P_V$	$\ln ETFP$	$\ln P_V$	$\ln ETFP$	$\ln P_V + \ln ETFP$	$\ln P_V + \ln ETFP$
change of tariff rate	-0.093 (-0.737)	-0.064 (-0.494)			-0.149 (-1.489)		-0.112 (-0.918)	-0.062 (-0.589)			-0.167 (-1.551)	
change of concentration ratio	0.241 (1.302)	-0.337 (-1.656)*			-0.017 (-0.209)		0.323 (1.496)	-0.444 (-2.074)**			-0.047 (-0.679)	
change of log total expenditure	-0.011 (-0.346)	-0.037 (-1.359)			-0.013 (-0.602)		-0.003 (-0.127)	-0.029 (-1.188)			-0.014 (-0.714)	
average investment share in computer	-0.037 (-0.699)	0.094 (1.942)*			0.035 (1.343)							
average investment share in other ICT tech (ICT other than computer)	0.003 (0.416)	0.013 (2.591)***			0.011 (2.552)**							
change of capital service share in computer							-1.418 (-1.115)	2.415 (2.362)**			0.405 (0.688)	
change of capital service share in other ICT							0.155 (1.326)	0.033 (0.387)			0.129 (1.226)	
change in narrow outsourcing (within the same 2-digit mnfg industries)	-0.337 (-2.728)***	0.329 (2.907)***			-0.001 (-0.009)		-0.364 (-2.843)***	0.400 (3.874)***			0.032 (0.364)	
change in other outsourcing (outside the same 2-digit mnfg industries)	-0.157 (-1.200)	-0.001 (-0.005)			-0.104 (-1.166)		-0.199 (-1.499)	0.161 (1.337)			-0.036 (-0.454)	
change in the cost of production	0.403 (5.112)***				0.115 (2.088)**		0.326 (3.615)***				0.146 (2.950)***	
constant	0.010 (3.551)***	0.004 (1.484)			0.019 (8.361)***		0.011 (3.499)***	0.006 (3.655)***			0.020 (8.652)***	
time dummy	-0.004 (-1.496)	-0.006 (-2.353)**			-0.011 (-6.002)***		-0.004 (-1.289)	-0.006 (-2.670)***			-0.011 (-5.722)***	
R	0.34	0.17			0.51		0.37	0.27			0.50	
N	168	168			168		168	168			168	

Note: Pooled regressions using 84 industry's data over two decade (1981-1989 and 1989-1996), with heteroscedastic-robust t-statistics (in parentheses). Averages are measured as the averages between the first and the last year of a decade, while changes are the difference between the last and the first year of a decade divided by the number of years.

Table 3.5 Second-stage regression when high technology is measured as investment shares

Equation (3.20)   Dependent variables: predicted $\Delta \ln P^v + \Delta \ln \text{ETFP}$ due to each exogenous Variable

	1981 - 1989						1989 - 1996					
	import price	concentration	industry	computer	other ICT	narrow outsourcing	import price	concentration	industry	computer	other ICT	narrow outsourcing
	ratio	ratio	expenditure		technologies	(within the same 2-digit industry)		ratio	expenditure		technologies	(within the same 2-digit industry)
average cost share of non-production worker	0.00052 (0.0043)	0.00010 (0.0042)	-0.00297 (0.0076)	0.01315 (0.0052)**	0.00548 (0.0066)	-0.00007 (-)	0.00150 (-)	-0.00016 (-)	-0.00013 (0.0014)	0.01705 (0.0089)*	0.00864 (0.0084)	0.00016 (-)
average cost share of production worker	0.00118 (0.0016)	0.00001 (-)	-0.00228 (-)	0.00205 (0.0009)**	0.00194 (0.0019)	0.00004 (-)	0.00253 (0.0017)	0.00004 (-)	0.00011 (-)	0.00030 (0.0013)	0.00260 (0.0025)	-0.00016 (-)
average cost share of capital	0.00306 (0.0041)	0.00003 (0.0005)	-0.00211 (-)	0.00089 (0.0016)	-0.00066 (0.0019)	-0.00043 (0.0018)	0.00150 (0.0013)	0.00006 (0.0015)	-0.00218 (0.0013)	0.00233 (0.0015)	-0.00083 (0.0017)	-0.00065 (0.0012)
wage inequality	-0.00066 (0.0056)	0.00008 (0.0046)	-0.00069 (0.0020)	0.01110 (0.0048)**	0.00354 (0.0073)	-0.00011 (-)	-0.00103 (-)	-0.00020 (-)	-0.00024 (0.0017)	0.01675 (0.0097)*	0.00604 (0.0091)	0.00032 (-)
R-squared	0.05 84	0.02 84	0.13 84	0.19 84	0.05 84	0.13 84	0.20 84	0.01 84	0.01 84	0.17 84	0.09 84	0.00 84
N	84	84	84	84	84	84	84	84	84	84	84	84
average cost share of non-production worker	0.00150 (-)	-0.00016 (-)	-0.00013 (0.0014)	0.01705 (0.0089)*	0.00864 (0.0084)	0.00016 (-)	0.00150 (-)	-0.00016 (-)	-0.00013 (0.0014)	0.01705 (0.0089)*	0.00864 (0.0084)	-0.00016 (-)
average cost share of production worker	0.00253 (0.0017)	0.00004 (-)	0.00011 (-)	0.00030 (0.0013)	0.00260 (0.0025)	-0.00016 (-)	0.00253 (0.0017)	0.00004 (-)	0.00011 (-)	0.00030 (0.0013)	0.00260 (0.0025)	-0.00016 (-)
average cost share of capital	0.00150 (0.0013)	0.00006 (0.0015)	-0.00218 (0.0013)	0.00233 (0.0015)	-0.00083 (0.0017)	-0.00065 (0.0012)	0.00150 (0.0013)	0.00006 (0.0015)	-0.00218 (0.0013)	0.00233 (0.0015)	-0.00083 (0.0017)	-0.00065 (0.0012)
wage inequality	-0.00103 (-)	-0.00020 (-)	-0.00024 (0.0017)	0.01675 (0.0097)*	0.00604 (0.0091)	0.00032 (-)	-0.00103 (-)	-0.00020 (-)	-0.00024 (0.0017)	0.01675 (0.0097)*	0.00604 (0.0091)	0.00032 (-)
R-squared	0.20 84	0.01 84	0.01 84	0.17 84	0.09 84	0.00 84	0.20 84	0.01 84	0.01 84	0.17 84	0.09 84	0.00 84
N	84	84	84	84	84	84	84	84	84	84	84	84

Note: each column reports estimation results for equation (3.20) using a different exogenous variable multiplied by its coefficient estimates from the first stage regression (Table 3.5). Numbers in parentheses are corrected standard errors due to the using of estimated dependent variables. If the correction procedure yields negative value for the estimated variance, then (-) is reported. All regressions are weighted by the average industry share of manufacturing employment. Changes are annual average changes, measured as the difference between the last and the first year of a decade divided by the number of years. Averages are the annual averages of the first and the last year of a decade. One, two and three asterisks (*, **, ***) indicate statistically significant at the 1%, 5% and 10% level respectively

Table 3.6 Second-stage regression when high technology is measured as capital service shares

Equation (3.20) Dependent variables: predicted $\Delta \ln P^V + \Delta \ln ETFP$ due to each exogenous Variable

	1981 - 1989						
	import price	concentration	industry	computer	other ICT	narrow outsourcing	other outsourcing
		ratio	expenditure		technologies	(within the same 2-digit industry)	(outside the same 2-digit industry)
average cost share of non-production worker	0.00053 (0.0043)	0.00053 (0.0039)	-0.00339 (0.0074)	0.00286 (0.0071)	0.00280 (0.0081)	0.00009 (-)	0.00060 (-)
average cost share of production worker	0.00120 (0.0016)	0.00008 (-)	-0.00260 (-)	0.00164 (-)	0.00051 (-)	-0.00005 (-)	-0.00041 (-)
average cost share of capital	0.00309 (0.0041)	0.00018 (0.0007)	-0.00240 (-)	-0.00358 (0.0034)	-0.00056 (0.0013)	0.00054 (0.0020)	-0.00009 (0.00087)
wage inequality	-0.00067 (0.0057)	0.00045 (0.0045)	-0.00079 (0.0024)	0.00122 (0.0071)	0.00229 (0.0083)	0.00014 (-)	0.00100 (-)
R-squared	0.05	0.02	0.13	0.06	0.02	0.13	0.00
N	84	84	84	84	84	84	84
1989 - 1996							
average cost share of non-production worker	0.00152 (-)	-0.00090 (-)	-0.00015 (0.0019)	0.01244 (0.0140)	0.00202 (0.0024)	-0.00021 (0.0003)	-0.00142 (-)
average cost share of production worker	0.00256 (0.0017)	0.00021 (-)	0.00012 (-)	-0.00383 (0.0035)	0.00003 (0.0010)	0.00020 (-)	-0.00279 0.00234
average cost share of capital	0.00152 (0.0013)	0.00031 (0.0013)	-0.00248 (0.0013)	-0.00230 (0.0021)	-0.00050 (0.0009)	0.00082 (0.0014)	-0.00017 (-)
wage inequality	-0.00104 (-)	-0.00112 (-)	-0.00028 (0.0023)	0.01628 (0.0176)	0.00199 (0.0015)	-0.00041 (-)	0.00137 (-)
R-squared	0.20	0.01	0.01	0.18	0.02	0.004	0.18
N	84	84	84	84	84	84	84

Note: each column reports estimation results for equation (3.20) using a different exogenous variable multiplied by its coefficient estimates from the first stage regression (Table 3.5). Numbers in parentheses are corrected standard errors due to the using of estimated dependent variables. If the correction procedure yields negative value for the estimated variance, then (-) is reported. All regressions are weighted by the average industry share of manufacturing employment. Changes are annual average changes, measured as the difference between the last and the first year of a decade divided by the number of years. Averages are the Annual averages of the first and the last year of a decade.

Table 3.7 Second-stage regression
– comparison with Feenstra and Hanson (1999)

Equation (3.20)

Dependent variables: predicted $\Delta \ln P_v + \Delta \ln E_{TFP}$ due to each exogenous variable

Comparison with Feenstra and Hanson's results (1999) using only computer, other ICT, narrow foreign outsourcing (within the same 2-digit industries) and other foreign outsourcing (outside the same 2-digit industries) as exogenous variables in the 1st and 2nd stage regression

1981-1989

using average investment shares for technology				
	computer	other ICT	narrow outsourcing	other outsourcing
average cost share of non-production worker	0.02696 (0.0089)**	0.00468 (0.0080)	0.00051 (-)	0.00336 (0.0064)
average cost share of production worker	0.00420 (0.0027)	0.00166 (0.0009)*	-0.00025 (-)	-0.00228 (0.0025)
average cost share of capital	0.00183 (0.0032)	-0.00057 (0.0006)	0.00297 (0.0032)	-0.00048 (0.0036)
wage inequality	0.02276 (0.0100)**	0.00302 (0.0071)	0.00076 (-)	0.00564 (0.0084)
R-squared	0.19	0.05	0.13	0.001
N	84	84	84	84
using changes of capital services for technology				
	computer	other ICT	narrow outsourcing	other outsourcing
average cost share of non-production worker	0.00021 (0.0088)	0.00243 (0.010)	0.00118 (0.0051)	0.00288 (0.0055)
average cost share of production worker	0.00012 (-)	0.00044 (-)	-0.00059 (0.0021)	-0.00196 (0.0021)
average cost share of capital	-0.00026 (0.0043)	-0.00048 (0.0004)	0.00687 (0.0038)*	-0.00041 (0.0031)
wage inequality	0.00009 (0.0081)	0.00199 (0.0096)	0.00176 (0.0068)	0.00485 (0.0072)
R-squared	0.06	0.02	0.13	0.00
N	84	84	84	84

Note 1: each column reports estimation results for equation (20) using a different exogenous variable multiplied by its coefficient estimates from the first stage regression (Table 3.3). Numbers in parentheses are corrected standard errors due to the using of estimated dependent variables. If the correction procedure yields negative value for the estimated variance, then (-) is reported. All regressions are weighted by the average industry share of manufacturing employment. Changes are annual average changes, measured as the difference between the last and the first year of a decade divided by the number of years. Averages are the annual averages of the first and the last year of a decade. One, two and three asterisks (*, **, ***) indicate statistically significant at the 1%, 5% and 10% level respectively

Table 3.7 Second-stage regression
– comparison with Feenstra and Hanson (1999)

Equation (3.20)

Dependent variables: predicted $\Delta \ln P_v + \Delta \ln E T F P$ due to each exogenous variable

Comparison with Feenstra and Hanson's results (1999) using only computer, other ICT, narrow foreign outsourcing (within the same 2-digit industries) and other foreign outsourcing (outside the same 2-digit industries) as exogenous variables in the 1st and 2nd stage regression

1981-1989

using average investment shares for technology				
	computer	other ICT	narrow outsourcing	other outsourcing
average cost share of non-production worker	0.02696 (0.0089)**	0.00468 (0.0080)	0.00051 (-)	0.00336 (0.0064)
average cost share of production worker	0.00420 (0.0027)	0.00166 (0.0009)*	-0.00025 (-)	-0.00228 (0.0025)
average cost share of capital	0.00183 (0.0032)	-0.00057 (0.0006)	0.00297 (0.0032)	-0.00048 (0.0036)
wage inequality	0.02276 (0.0100)**	0.00302 (0.0071)	0.00076 (-)	0.00564 (0.0084)
R-squared	0.19	0.05	0.13	0.001
N	84	84	84	84
using changes of capital services for technology				
	computer	other ICT	narrow outsourcing	other outsourcing
average cost share of non-production worker	0.00021 (0.0088)	0.00243 (0.010)	0.00118 (0.0051)	0.00288 (0.0055)
average cost share of production worker	0.00012 (-)	0.00044 (-)	-0.00059 (0.0021)	-0.00196 (0.0021)
average cost share of capital	-0.00026 (0.0043)	-0.00048 (0.0004)	0.00687 (0.0038)*	-0.00041 (0.0031)
wage inequality	0.00009 (0.0081)	0.00199 (0.0096)	0.00176 (0.0068)	0.00485 (0.0072)
R-squared	0.06	0.02	0.13	0.00
N	84	84	84	84

Note 1: each column reports estimation results for equation (20) using a different exogenous variable multiplied by its coefficient estimates from the first stage regression (Table 3.3). Numbers in parentheses are corrected standard errors due to the using of estimated dependent variables. If the correction procedure yields negative value for the estimated variance, then (-) is reported. All regressions are weighted by the average industry share of manufacturing employment. Changes are annual average changes, measured as the difference between the last and the first year of a decade divided by the number of years. Averages are the annual averages of the first and the last year of a decade. One, two and three asterisks (*, **, ***) indicate statistically significant at the 1%, 5% and 10% level respectively

Appendix 3A Derivation of Equations (3.11-3.12)

Each firm maximizes profits.

$$\text{Max (w.r.t } P_i) \pi_i = P_i X_i(P_H, P_F, E) - C_i(W_i, X_i(P_H, P_F, E), T_i)$$

The first order condition of the profit maximization is:

$$\begin{aligned} X_i + [dX_i/dP_i + \sum_h (dX_i/dP_h)(dP_h/dP_i) + \sum_f (dX_i/dP_f)(dP_f/dP_i)] \\ - dC_i/dX_i [dX_i/dP_i + \sum_h (dX_i/dP_h)(dP_h/dP_i) + \sum_f (dX_i/dP_f)(dP_f/dP_i)] = 0 \end{aligned} \quad (3A.1)$$

Multiplying both sides of equation (A1) by P_i/X_i and combining terms, we obtain equation (3.11)

$$P_i = C'(W_i, P_H, P_F, E, T_i) / (1 + 1/\eta_i) \quad (3A.2)$$

where

$$\eta_i = \varepsilon_{ii} + \sum_{h \neq i} \varepsilon_{ih} \theta_{hi} + \sum_f \varepsilon_{if} \theta_{fi}$$

$$\varepsilon_{ii} = d \ln X_i / d \ln P_i$$

$$\varepsilon_{ih} = d \ln X_i / d \ln P_h$$

$$\varepsilon_{if} = d \ln X_i / d \ln P_f$$

$$\theta_{hi} = d \ln P_h / d \ln P_i$$

$$\theta_{fi} = d \ln P_f / d \ln P_i$$