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Imports and the Demand for Skilled and Unskilled Labour: The Australian Experience

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Abstract

This paper employs a unit cost function to investigate the impacts of aggregate imports on the demand for skilled and unskilled labour in Australia. Similar to Tombazos (1999b), I use a model that focuses on the displacement effects of the Stolper-Samuelson variety, as well as recognizes the domestic factor-using downstream processes of imports. Contrary to the notion imports hurt unskilled workers, the results of this study suggest that imports overall may stimulate unskilled labour demand. Earnings dispersion between skilled and unskilled labour would have been greater without the occurrence of imports.

JEL Classification: F16; J31; F40

1. Introduction

Since the mid-1970s, there has been considerable growth in real earnings in Australia. However, various studies have suggested that the growth in earnings is not evenly distributed across employees.[1] For example, Norris and Mclean (1999) analyse Australian real weekly earnings using data from the survey of employee earnings and hours (SEEH). They find that real weekly earnings for males in the lowest deciles grew by only 0.5 per cent compared to a 28.5 per cent growth rate in the highest income deciles from 1975 to 1998. The average earnings for females in the lowest and highest deciles have increased by 11.5 per cent and 38 per cent, respectively, between the years from 1975 to 1998 (table 1).

[1] For example, Norris and Mclean (1999), Saunders (1995), Borland and Wilkins (1996), Borland (1999), Harding and Richardson (1998), Gaston (1998), Karunaratne (1999) and De Laine *et al*. (2000).

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Table 1 - Changes in Australian Real Weekly Earnings, 1975 to 1998 (Percentage)

	Lower Deciles	*Lower Quartile*	*Median*	*Upper Qquartile*	*Upper Deciles*
Males	0.5	7.7	17	22.9	28.5
Females	11.5	16.8	25	38.0	38.0

Source: Norris and Mclean (1999).

There has been a considerable interest in whether imports play any role in explaining such labour market outcomes. However, most studies examining this issue in Australia focus primarily on the traditional displacement effects of imports on domestic factors of production.[2] While the traditional displacement effects of imports can be an important channel, Tombazos (1999b) argues that the role of the domestic factor-using downstream processes of imports that potentially stimulate the demand for labour has been overlooked.[3]

This paper extends previous work done in Australia by simultaneously incorporating the displacement effects of Ricardian type of imports and their domestic factor-using downstream processes. Such downstream processing effects, according to Aw and Roberts (1985), as well as Tombazos (1998; 1999a), are expected to be significant. Hence, studies that assume trade only in final goods, and only in the context of the Australian manufacturing, are likely to be too narrow in focus.[4]

2. The Model

In orthodox trade theory, imports are traditionally regarded as final goods, and thus enter directly into consumer's utility function. As noted by Diewert and Morrisson (1988), the implication is that traditional empirical estimation of import demand functions requires that the household sector be modelled.

However, starting from Burgess's (1974a; 1974b) pioneering work, recent empirical research in international economics suggests an alternative approach that explicitly integrates all imports as inputs into the firm's production process. This emerges from the view that most imports are in the form of trade in raw material and intermediate goods. The relevance of trade in intermediate goods is particularly pertinent for Australia as approximately 75 per cent of its trade takes the form of pure intermediate and capital goods (see Wilkinson, 1992). Additionally, as put forward by Kohli (1991, p.2), 'it is hard to imagine a good absorbed by a domestic resident, which does not have any domestic content at all'. As such, all imports, regardless of whether

[2] See Fahrer and Pease (1994), Murtough *et al*. (1998), De Laine *et al*. (2000), Dawkins and Kenyon (2000).

[3] Tombazos (1999a, 1999b, 2003, 2007) uses the term 'downstream processes' to indicate the impact of imports on the demand for primary factors that is generated via domestic factor-using downstream such as transportation, repackaging, marketing and retailing. Such downstream processing activities of imports employ domestic labour.

[4] Tombazos (1999b) is one of the exceptions. He analyses the impact of imports on the demand for labour in Australia using a framework that not only considers trade in final goods but also captures production downstream processes of all imports. However, Tombazos (1999b) does not investigate the issue of labour market inequality in Australia.

the imported goods are so-called final commodities or raw materials require further processing. Such processing employs the services of domestic labour and capital (see Kohli, 1991; Tombazos, 2003).

The advantage of considering all imported goods as inputs in addition to labour and capital in the entire production process is that, it leads to a substantial simplification of the empirical analysis while capturing the true role of imports in domestic labour markets. Specifically, the labour market effects of trade can be derived from modelling the productive sector of the economy (see Diewert and Morrisson, 1988; Kohli, 1991).

Following Kohli (1991, p.22), I consider an aggregate production technology that has *J* inputs, $j \in \{S, U, K, I\}$ and *S, U, K, I* denote skilled labour, unskilled labour, capital and imports, respectively. Denote the quantity of input *j* by *xj* and the quantity of output is represented by *y*. I assume the production possibilities set T (netput vector) to be a closed, nonempty, convex cone that is bounded from above for all nonnegative input quantities that allows for free disposal of inputs. The assumption that T is a cone and convex is required to allow for the production function to exhibit constant returns to scale and decreasing marginal returns. The assumption that T is bounded from above for all nonnegative input quantities guarantees that a given finite amount of inputs cannot produce an unlimited amount of output. And finally, the assumption of free disposal of inputs ensures that more inputs cannot yield less output.

It is assumed that production decisions are made by cost minimizing firms which operate in perfectly competitive markets.[5] As in Tombazos (1999a; 1999b), the Australia production function can be represented by its dual unit cost function. Using the symmetric normalized quadratic flexible functional form proposed by Diewert and Wales (1987, 1992), this cost function that also internalizes technological change *(t)* can be written as:[6]

$$c = \sum_j \alpha_j w_j + \frac{1}{2}\sum_j \sum_k b_{j,k} \frac{w_j w_k}{\sum_j \beta_j w_j} + \sum_j \delta_j w_j t + \frac{1}{2}\left(\sum_j \beta_j w_j\right)\delta_{tt} t^2 \qquad (1)$$

where $b_{j,k} = b_{k,j}$, $\sum_k b_{k,j} = 0$, and $\sum_j \beta_j = 1$; *j* and *k* are index sets for inputs, $j,k \in \{S, U, K, I\}$. *c* is per unit cost of output and w_j represents the price of input *j*. The denominator of the second term on the right hand side of (1), $\Sigma\beta_j w_j$, can be viewed as the fixed-weight input price index.

The function is well defined for positive input prices and all nonnegative output quantities. Given the assumption of the production possibilities set T, *C(.)* is non-decreasing, nonnegative, concave and linearly homogeneous in input prices. For the cost function to be economically meaningful, the curvature condition of the cost

[5] To some extent, the assumption of perfect competition is violated. However, as argued by Truett and Truett (1998) in the case of Korea, the involvement of the government in the economy has resulted in some characteristics of perfect competition as certain prices would appear to be fixed. Similarly in Australia, it is a small open economy where in the labour market, the wage-fixing is centralised and the minimum wage is still high by international standards (Dawkins, 2000). In that sense, the derived demand function is still valid with the assumption of perfect competition.

[6] The advantage of the SNQ flexible functional form employed here is that the enforcement of global curvature does not compromise its flexibility. For further discussion, see Diewert and Wales, 1992.

function, which requires the function to be concave in input prices, must be satisfied. Consider an increase in the price of a factor input. Concavity in input prices means if inputs can be substituted for one another, cost minimising firms will shift away from the expensive resources to the cheaper inputs. The substitution of relatively cheaper inputs should moderate the cost rise or in other words, costs will still increase but at a decreasing rate. Thus, the property of concavity is required in any estimation. This curvature condition will require the substitution matrix of the second derivatives of the cost function to be symmetric negative semi-definite (see Tombazos, 1999a). The sign of the definiteness can be checked by computing the eigenvalues of the relevant sub-Hessian matrix. Concavity requires the Hessian to be negative semi-definite or the calculated eigenvalues of matrix $B \equiv \left[b_{j,k} \right]$ to be non-positive. These conditions need to be verified after estimation and corrected accordingly if need be.

Differentiating equation (1) with respect to factor prices (see Shephard's Lemma, 1953) the following unit input demand functions are obtained:

$$c_j = \frac{x_j}{y} = \alpha_j + \frac{\sum_k b_{j,k} w_k}{\sum_k \beta_k w_k} - \frac{1}{2} \beta_j \frac{\sum_k \sum_m b_{k,m} w_k w_m}{\left(\sum_k \beta_k w_k \right)^2} + \delta_j t + \frac{1}{2} \beta_j \delta_{tt} t^2 \qquad (2)$$

where *j, k, m* are index sets for fixed inputs, precisely skilled labour, unskilled labour, net capital and imports.

Using the estimated coefficients, Allen-Uzawa elasticities of substitution (AUES) can be derived as follows:

$$\sigma_{jk} = \left\{ \frac{b_{j,k}}{\sum_m \beta_m w_m} - \frac{\beta_k \sum_m b_{j,m} w_m}{\left(\sum_m \beta_m w_m \right)^2} - \frac{\beta_j \sum_m b_{k,m} w_m}{\left(\sum_m \beta_m w_m \right)^2} + \frac{\beta_j \beta_k \sum_m \sum_n b_{m,n} w_m w_n}{\left(\sum_m \beta_m w_m \right)^3} \right\} \frac{c}{c_j c_k} \qquad (3)$$

3. Data Construction

Estimating the SNQ cost function discussed in the previous section requires economy-wide data on prices and quantities for labour, capital, imports and aggregate output. The relevant raw data were collected from the Australian Bureau of Statistics (ABS). Annual observations for relevant variables cover the period 1974/1975-2003/2004 when estimating the impact of imports on aggregate labour. However, due to limitation in obtaining the data on skilled and unskilled labour, the data only cover the period 1982/1983-2003/2004 when estimating the impact of imports on skilled and unskilled labour. Representative price and quantity indexes for all the variables were constructed using the Tornqvist aggregation method. The Tornqvist chain price index, normalised for 2002, is calculated by:

$\ln P'_T = \sum_{t=1}\sum_{n=1}\frac{1}{2}\left(s_{n,t} + s_{n,t-1}\right)\times \ln\left(\frac{p_{n,t}}{p_{n,t-1}}\right) \Big/ \ln P_{2002}$ where $s_{n,t} = \frac{p_{n,t}\times q_{n,t}}{\sum_n p_{n,t}\times q_{n,t}}$ is the share of each component to be aggregated at time t. The associated quantity index is obtained by $q'_T = \frac{\sum_n p_{n,t}\times q_{n,t}}{p'_T}$.

The construction of current dollar output involves aggregating two categories of consumption, eight categories of investment, exports, and three categories of changes in durable and non-durable business inventories as identified in the ABS. Since imports can be regarded as inputs to domestic production, output is considered to represent the sum of the private and public consumption, investment and exports. The aggregate value of end-year net capital stock is defined as the sum of seven categories of assets, which are machinery and equipment, non-dwelling construction, dwellings, computer software, mineral and petroleum exploration, livestock and artistic originals. Capital expenditure can be estimated to be equal to output net of the wage bill and import purchases. The rental rate of capital is calculated by dividing capital expenditures by the associated capital stock. Import data were obtained from the ABS and is classified according to the Standard of International Trade Classification (SITC). Representative imports prices and quantities were also derived using Tornqvist aggregation.

Aggregate data on employment by skill level is not available and must be constructed. Consequently, there is a need to construct a relevant proxy. In this vein, I follow Tombazos (1999a, p.511) who notes: ‘an important guideline in choosing a particular approach for the construction of ‘proxies’ of the needed variable is that the resulting disaggregation of the labour force captures directly the impact of imports on the demand for skilled and unskilled labour’. To construct the data utilised in the empirical analysis, seventeen 1-digits industries identified by the Australian and New Zealand Standard Industrial Classification (ANZSIC) were divided in two categories on the basis of their skill intensity.[7]

Similar to Ray (1981) and Tombazos (2003), I define the first four occupational groups of the Australian Standard Classification of Occupations 1 (ASCO1) as skilled labour: managers and administrators, professionals, para-professionals and clerical.[8] The remaining occupations are defined as lower skill or ‘unskilled’ workers. On the basis of these definitions, and following Tombazos (2003), the ratio of skilled workers relative to total employment in each of the seventeen ANZSIC industries was calculated. An industry is considered skill intensive if it employs on average a higher percentage of skilled labour than the average of all industries under examination. I then proceed to calculate representative wages and employment for skilled and unskilled intensive industries via Tornqvist aggregation.

[7] As the data on employment and earning by occupation/skill level is not available, it was constructed based on industry-skill intensity. Data on employment and weekly earning by industries is only available at 1-digit level.

[8] There are eight major groups of occupations in ASCO 1st edition: (1) Managers and Administrators; (2) Professionals; (3) Para-Professionals; (4) Tradepersons; (5) Clerks; (6) Salespersons and Personal Service Workers; (7) Plant, Machine Operators and Drivers; (8) Labourers and Related Workers.

4. Econometric Estimation

Two models are estimated: the first investigates the impact of imports and other factors on *aggregate* demand for labour (model A). It consists of a system of three equations: two primary input demand functions (capital and labour), and a demand function for imports.[9]

The second model estimates the impact of imports and other factors on the demand for *skilled* and *unskilled* labour (model B). This model consists of a system of four equations: the demand functions for skilled labour, unskilled labour, capital, and imports.

The two models (A and B) are estimated simultaneously using Zellner's seemingly unrelated regression (SUR) method in SHAZAM. The parameters derived from the SUR method are equivalent to those of the maximum likelihood estimator (see Berndt 1991, p.463). A cost function treats factor prices and output quantity as exogenous. However, it is likely that factor prices and the quantity of output are also determined endogenously. In an effort to account for such endogeneity, all models are also estimated using a non-linear three stage least square (3SLS) technique.[10]

Initial estimations indicated that the SUR models revealed serial autocorrelation. The models were therefore re-estimated using the Cochrane and Orcutt (1949) method for autocorrelation. Autocorrelation also appears in the 3SLS specification. Given that there is no econometric method that corrects for both autocorrelation and endogenous explanatory variables in a system of simultaneous equations, most empiricists either choose to correct one of the two problems, or to correct for both simultaneously in a three stage least squares framework using an autocorrelation coefficient generated by the SUR technique.[11] As noted by Tombazos (2003, p.50), it is unclear which method is better. As such, both models A and B are estimated using three different econometric methods: an autocorrelation-adjusted SUR method, a 3SLS technique and an autocorrelation-adjusted 3SLS (A3SLS). This approach results in six different specifications: three specifications of model A with aggregate labour (A-SUR, A-3SLS, A-A3SLS), and three specifications of the model B with disaggregated labour (B-SUR, B-3SLS, B-A3SLS).

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[9] As noted by Kohli (1994), since $c = \sum_j (Q_j / Q_Y).w_j$, there appears to be some non-linear dependency between the demand functions and the cost function. The derived input demands should not be estimated jointly with the cost function before dropping one of these equations. Following Kohli (1994) and Tombazos (1999a), I choose to opt for the symmetric treatment of the demand functions and drop the cost function from the simultaneous estimation.

[10] Similar to Kohli (1991) and Tombazos (1999a), the instrumental variables used are: excise taxes and sales taxes and domestic savings have been selected as instruments as they are able to account for the domestic demand and supply and the demand for imports in Australia. The budget deficit is also included as the government sector affects household behavior and imports. Investment levels also have significant effects on the demand and supply of output, labour, capital and imports. Finally, the GDP deflator, the producer price index, the population of Australia's major trading partners (China, Japan, U.S., U.K., Germany and Singapore), and the quantity of imports are included in order to account for foreign demand and supply conditions and the possible endogenous determination of import demand.

[11] For example, Kohli (1993) corrects for endogenous problem but not autocorrelation. In a 1994 article, he corrects for autocorrelation but not endogenous variables. Aw and Roberts (1985), Goss (1990) or Tombazos (1998, 2003) correct for both autocorrelation and endogenous variables.

After correcting for autocorrelation, it is revealed that the specification B-SUR fails to satisfy the curvature conditions. Table 2 reports eigenvalues of the matrix B for both models A and B. The violation of the curvature conditions is not surprising since, as noted by Diewert and Wales (1987) and Kohli (1991; 1994), the failure of the curvature condition is common when estimating flexible functional forms. The need to enforce concavity therefore arises for model B-SUR.[12] I employ the approach suggested by Tombazos (1999a), Kohli (1994) and Greenwood *et al*. (1996) in global enforcement of the concavity condition. Their technique is based on the work of Wiley *et al*. (1973), who prove that a sufficient condition for the matrix to be negative semi-definite is if it can be expressed as:

$$\Psi = -\,\Gamma \times \Gamma' \tag{4}$$

where $\Gamma \equiv \left[z_{j,k}\right]$ is a lower triangular matrix. Since the econometric specification is comprised of four fixed inputs: skilled labour, unskilled labour, capital and imports, then, matrix B is a 4x4 matrix. Matrix Γ can be written as follows:

$$\Gamma = \begin{bmatrix} Z_{1,1} & 0 & 0 & 0 \\ Z_{2,1} & Z_{2,2} & 0 & 0 \\ Z_{3,1} & Z_{3,2} & Z_{3,3} & 0 \\ Z_{4,1} & Z_{4,2} & Z_{4,3} & Z_{4,4} \end{bmatrix} \tag{5}$$

And the negative product of this lower triangular matrix with its transpose yields:

$$\Psi = \begin{bmatrix} -Z^2_{1,1} & -Z_{1,1}.Z_{2,1} & -Z_{1,1}.Z_{3,1} & -Z_{1,1}.Z_{4,1} \\ -Z_{1,1}.Z_{2,1} & -Z^2_{1,2} - Z^2_{2,2} & -Z_{2,1}.Z_{1,3} - Z_{2,2}.Z_{3,2} & -Z_{2,1}.Z_{4,1} - Z_{2,2}.Z_{4,2} \\ -Z_{1,1}.Z_{3,1} & -Z_{2,1}.Z_{1,3} - Z_{2,2}.Z_{3,2} & -Z^2_{1,3} - Z^2_{2,3} - Z^2_{3,3} & -Z_{3,1}.Z_{4,1} - Z_{3,2}.Z_{4,2} - Z_{3,3}.Z_{4,3} \\ -Z_{1,1}.Z_{4,1} & -Z_{2,1}.Z_{4,1} - Z_{2,2}.Z_{4,2} & -Z_{3,1}.Z_{4,1} - Z_{3,2}.Z_{4,2} - Z_{3,3}.Z_{4,3} & -Z^2_{1,4} - Z^2_{2,4} - Z^2_{3,4} - Z^2_{4,4} \end{bmatrix} \tag{6}$$

Enforcing the curvature condition requires replacing the elements of matrix B with the corresponding elements of matrix Ψ.[13]

Table 2 - Eigenvalues

	Matrix B			
Model A – SUR	-0.1226	-0.0942	0	
Model A – 3SLS	-0.2707	-0.0393	0	
Model A – A3SLS	-0.1647	-0.1127	0	
Model B – SUR	-0.1329	-0.0479	**0.0017**	0
Model B – 3SLS	-0.1715	-0.0838	-0.0250	0
Model B – A3SLS	-0.1388	-0.0569	-0.0021	0

[12] Kohli (1991, p.113) notes that 'while the finding that estimates of flexible function forms with more than three or four components seem to violate curvature conditions more often than not is disturbing, one has little choice but to impose these conditions. That is, one must be willing to sacrifice goodness of fit for economic plausibility if one wishes to be able to use those estimates for analytical purposes'.

[13] See Tombazos (1999a) for further discussion on curvature condition enforcing reparameterisation.

5. Results

Tables 3 and 4 report estimated parameters and associated *t*-values, Berndt's generalized $\widetilde{R}^2$ for models A and B. As can be seen from all tables, most of the coefficients are significant at the one per cent level and Berndt's $\widetilde{R}^2$ is quite high. The *Wald* statistics, *W*, also suggest autocorrelation is rejected at the five per cent level for all input demand equations.[14] Consequently, the estimated cost function is now consistent with all the properties implied by economic theory and good econometric practice.

Table 3 - Estimated Symmetric Normalized Quadratic Cost Function Parameters: Import and Aggregate Labour (MODEL A)

Parameters	*SUR*	*3SLS*	*A3SLS*
a_L	0.6344***	0.6589***	0.6366***
	(55.986)	(66.390)	(54.249)
a_K	0.6219***	0.5071***	0.6228***
	(17.060)	(34.812)	(18.180)
a_I	0.1154***	0.1086***	0.1148***
	(14.799)	(10.261)	(14.631)
$b_{L,L}$	-0.0784***	-0.0343	-0.0998***
	(-3.8590)	(-0.87369)	(-4.8400)
$b_{L,K}$	0.0329	0.0471	0.0635***
	(1.5612)	(1.0232)	(2.8012)
$b_{K,K}$	-0.0629***	-0.1677***	-0.1023***
	(-2.8865)	(-2.6393)	(-3.7746)
δ_L	-0.2644***	-0.2366***	-0.2681***
	(-10.565)	(-13.404)	(-10.711)
δ_K	-0.1854***	-0.0032	-0.1885***
	(-3.6479)	(-0.14914)	(-3.9698)
δ_I	0.0372	0.0581***	-0.0047
	(0.2029)	(3.7099)	(-0.26653)
δ_{tt}	0.1900*	-0.1739*	0.20064*
	(1.8688)	(-2.3946)	(2.0581)
N	29	29	29
$\widetilde{R}^2$	0.9929	0.9912	0.9920
W_L	0.7497	-	-
W_K	0.6826	-	-
W_I	-1.2793	-	-
W	1.0730	-	-

t-statistic in parentheses. *** Significant at 1 per cent level with a two tailed test. * Significant at 10 per cent level with a two tailed test. Subscript I, K, L, t represents imports, capital, labour and technological change respectively.

[14] According to White (1992), the Wald statistic is given by: $n^{1/2} \times \rho$ where n corresponds to the number of observations and ρ represents the autocorrelation of coefficient. Autocorrelation is rejected using a one-tailed test at five per cent level if the absolute value of the statistic is smaller than 1.645.

Table 4 - Estimated Symmetric Normalized Quadratic Cost Function Parameters: Imports and Skilled and Unskilled Labour (MODEL B)

SUR			3SLS			A3SLS		
Parameters			*Parameters*			*Parameters*		
a_s	0.2614	(23.123***)	a_s	0.2514	(34.881***)	a_s	0.2627	(21.342***)
a_u	0.3518	(33.977***)	a_u	0.3199	(57.875***)	a_u	0.3505	(36.388***)
a_k	0.5610	(23.682***)	a_k	0.5602	(60.885***)	a_k	0.5631	(24.11***)
a_i	0.1169	(10.803***)	a_i	0.1072	(10.245***)	a_i	0.1179	(11.171***)
$Z_{1,1}$	-0.1682	(-3.422***)	$b_{s,s}$	-0.0024	(-1.524)	$b_{s,s}$	-0.0030	(-1.523)
$Z_{1,2}$	0.1671	(1.882*)	$b_{s,u}$	0.0021	(1.443)	$b_{s,u}$	0.0031	(1.472)
$Z_{1,3}$	-0.1772	(-4.142***)	$b_{s,k}$	-0.0014	(-1.014)	$b_{s,k}$	-0.0031	(-2.524**)
$Z_{2,2}$	-0.1182	(-2.711***)	$b_{u.u}$	-0.0092	(-4.379***)	$b_{u.u}$	-0.0051	(-1.675*)
$Z_{2,3}$	-0.0084	(-1.142)	$b_{u.k}$	0.0065	(4.145***)	$b_{u.k}$	0.0025	(1.896*)
$Z_{3,3}$	-2.30E-08	(-3.42E-08)	$b_{k,k}$	-0.0099	(-4.224***)	$b_{k,k}$	-0.0043	(-2.553**)
δ_s	-0.0080	(-2.904***)	δ_s	-0.0039	(-2.611***)	δ_s	-0.0083	(-3.171***)
δ_u	-0.1837	(-6.706***)	δ_u	-0.1205	(-9.378***)	δ_u	-0.184	(-7.784***)
δ_k	-0.1166	(-2.956***)	δ_k	-0.0088	(-5.569***)	δ_k	-0.1206	(-3.347***)
δ_i	4.60E-03	(0.186)	δ_i	0.0043	(2.689***)	δ_i	0.0002	(0.008)
δ_{tt}	0.1801	(1.181)	δ_{tt}	-0.0068	(-0.845)	δ_{tt}	0.1948	(1.505)
N	21			21			21	
$\tilde{R}^2$	0.9949			0.9975			0.9949	
W_S	1.4194			-			-	
W_U	-0.0286			-			-	
W_K	1.7074			-			-	
W_I	-1.8011			-			-	
W	0.3953			-			-	

t-statistic in parentheses.*** Significant at 1 per cent level with 2-tailed test. ** Significant at 2 per cent level. * Significant at 10 per cent level. Subscript I, S, U, K, t represents imports, skilled labour, unskilled labour, capital and technological change respectively.

Using the estimated parameters, substitution possibilities between any two combinations of inputs *j* and *k* can be evaluated using the Allen-Uzawa elasticities of substitution (AUES). The AUES for selected years together with their average estimates for models A and B are reported in tables 5 and 6 respectively. The own price elasticity of demand for each input is negative as expected. The elasticity of substitution between skilled and unskilled labour suggests skilled and unskilled workers are substitutes (table 6).

Examination of the import-labour elasticities ($\sigma_{L,I}$) undermines the quantitative content. Thus, to facilitate the quantitative measure, I also calculate the cross price elasticities and report the findings in table 7. Price elasticities can be calculated from the estimated parameters: L,I) in table 5 reveals that imports and aggregate labour are substitutes with the average values ranging from 1.048 (A3SLS) to 1.299 (SUR).

Table 5 - Selected and Average Price Elasticities of Demand (ε) and Allen-Uzawa Partial Elasticities of Substitution (σ). SNQ Cost Function: Imports and Aggregate Labour – Model A

	SUR					*3SLS*					*A3SLS*				
	1976	*1995*	*2004*	*Average*	*p-value*	*1976*	*1995*	*2004*	*Average*	*p-value*	*1976*	*1995*	*2004*	*Average*	*p-value*
$\sigma_{L,I}$	2.310	1.149	0.605	1.299	0.000***	-0.276	-0.205	-0.225	-0.217	0.677	1.853	0.925	0.488	1.048	0.002***
$\sigma_{L,K}$	0.218	0.172	0.202	0.173	0.186	0.350	0.252	0.280	0.254	0.367	0.492	0.355	0.369	0.358	0.010***
$\varepsilon_{L,L}$	-0.121	-0.167	-0.206	-0.154	0.000***	-0.046	-0.068	-0.098	-0.061	0.393	-1.147	-0.209	-0.267	-0.193	0.000***
$\varepsilon_{K,K}$	-0.123	-0.125	-0.139	-0.122	0.003***	-0.341	-0.340	-0.359	-0.334	0.006***	-0.194	-0.200	-0.229	-0.196	0.000***
$\varepsilon_{I,I}$	-0.799	-0.617	-0.407	-0.672	0.000***	-1.196	-0.900	-0.565	-0.985	0.000***	-0.803	-0.618	-0.404	-0.672	0.000***
$\sigma_{L,T}$	-0.418	-0.461	-0.522	-0.447	0.000***	-0.372	-0.593	-0.789	-0.519	0.000***	-0.407	-0.463	-0.522	-0.451	0.000***

*** Significant at 1 per cent level with two tailed test. ** Significant at 2 per cent level with two tailed test.
Note: Because of the limited space in the table, I do not present the elasticity value in every year of the study period. For the purpose of projecting the value of elasticity throughout the study period, I present the elasticity value for only three years.

Table 6 - Selected and Average Allen-Uzawa Partial Elasticities of Substitution of SNQ Cost Function: Imports and Skilled and Unskilled Labour – Model B

	SUR					*3SLS*					*A3SLS*				
	1984	*1995*	*2004*	*Average*	*p-value*	*1984*	*1995*	*2004*	*Average*	*p-value*	*1984*	*1995*	*2004*	*Average*	*p-value*
$\sigma_{s,i}$	3.126	1.647	0.727	1.651	0.003***	1.995	0.969	0.377	0.986	0.116	3.099	1.631	0.714	1.634	0.004***
$\sigma_{s,k}$	-0.625	-0.407	-0.288	-0.397	0.000***	-0.300	-0.192	-0.135	-0.185	0.284	-0.643	-0.421	-0.302	-0.410	0.008***
$\sigma_{s,t}$	-0.306	-0.221	-0.157	-0.239	0.000***	-0.156	-0.218	-0.298	-0.214	0.000***	-0.317	-0.224	-0.152	-0.237	0.000***
$\sigma_{u,i}$	-0.026	-0.161	-0.228	-0.177	0.562	0.731	0.364	0.135	0.338	0.393	0.043	-0.110	-0.194	-0.128	0.704
$\sigma_{u,k}$	0.215	0.210	0.236	0.203	0.198	0.884	0.742	0.745	0.712	0.000***	0.282	0.270	0.294	0.260	0.078*
$\sigma_{u,t}$	-0.564	-0.634	-0.735	-0.635	0.000***	-0.386	-0.541	-0.764	-0.515	0.000***	-0.564	-0.626	-0.715	-0.619	0.000***
$\sigma_{s,s}$	-1.263	-0.833	-0.654	-0.825	0.072*	-1.038	-0.683	-0.558	-0.689	0.121	-1.323	-0.877	-0.698	-0.870	0.113
$\sigma_{u,u}$	-0.951	-1.026	-1.156	-0.955	0.226	-2.246	-2.294	-2.461	-2.130	0.000***	-1.181	-1.264	-1.411	-1.176	0.097*
$\sigma_{k,k}$	-0.364	-0.239	-0.159	-0.229	0.006***	-0.791	-0.575	-0.440	-0.561	0.000***	-0.396	-0.263	-0.179	-0.252	0.007***

*** Significant at 1 per cent level with two tailed test. * Significant at 10 per cent level with two tailed test.
Note: Because of the limited space in the table, I do not present the elasticity value in every year of the study period. For the purpose of projecting the value of elasticity throughout the study period, I present the elasticity value for only three years.

However, it is important to note that the Allen-Uzawa elasticity of substitution has no meaning as a quantitative measure. As pointed out by Blackorby and Russell (1975; 1989), the sign of the Allen-Uzawa is meaningful, but to calculate the Allen-Uzawa elasticity, the share of input is divided in the elasticity calculation $(c(.)/(c_i c_j))$ that undermines the quantitative content. Thus, to facilitate the quantitative measure, I also calculate the cross price elasticities and report in table 7. Price elasticities can be calculated from the estimated parameters:

$$\varepsilon_{jk} = \left\{ \frac{b_{j,k}}{\sum_m \beta_m w_m} - \frac{\beta_k \sum_m b_{j,m} w_m}{\left(\sum_m \beta_m w_m\right)^2} - \frac{\beta_j \sum_m b_{k,m} w_m}{\left(\sum_m \beta_m w_m\right)^2} + \frac{\beta_j \beta_k \sum_m \sum_n b_{m,n} w_m w_n}{\left(\sum_m \beta_m w_m\right)^3} \right\} \tag{7}$$

Table 7 - Cross-Price Elasticities – Model B

	SUR	*p-value*	*3SLS*	*p-value*	*A3SLS*	*p-value*
Labour-Imports	0.100	0.000***	-0.016	0.677	0.081	0.002***
Labour-Capital	0.054	0.186	0.078*	0.367	0.111	0.010*
Skilled-Imports	0.140	0.003***	0.089	0.116	0.152	0.004***
Unskilled-Imports	-0.197	0.473	0.030	0.393	-0.012	0.704
Skilled-Capital	-0.126	0.000***	-0.065	0.284	-0.146	0.008***
Unskilled-Capital	0.055	0.313	0.250	0.000***	0.093	0.078*

*** Significant at 1% level with two tailed test. * Significant at 10% level with two tailed test.

The cross price elasticity of labour and imports suggests that for one per cent decrease in the price of imports, the demand for labour would decrease by approximately 0.08 per cent (A3SLS). While the significance of any positive downstream production related effect on the demand for aggregate labour cannot be assessed in this case, it is clear that the displacement effect, which arises from domestic output substitution, is of a greater magnitude. Nevertheless, the cross price elasticity suggested that imports and labour are weak substitutes.

Turning attention to the labour-import elasticities for skilled and unskilled labour reported in table 6, I find that the elasticities of imports and unskilled labour $(\sigma_{U,I})$ often exhibit sign reversals and are statistically insignificant. As such, the nature of the relationship between imports and unskilled labour is not completely clear. However, in most cases, the results suggest a weakly complementary relationship between imports and unskilled labour demand.

Contrary to the case of unskilled labour, I also find the somewhat surprising result that aggregate imports substitute for skilled labour. The relevant Allen-Uzawa elasticities $(\sigma_{S,I})$ are remarkably stable over time, statistically significant (except in the case of 3SLS). Results in table 7 suggest that for a one per cent *decrease* in the price of imported goods, the demand for skilled labour would *decrease* by 0.15 per cent (A3SLS). This suggests that imports alone probably compress, rather than augment, the widening gap in demand between skilled and unskilled workers in Australia. In other words, earnings dispersion would have been greater without the occurrence of imports.

One possible explanation for this is the fact that Australia has imported more intermediate goods and capital. Imports of machinery and transport equipment, manufactured goods and articles, as well as chemical products account for about 70 per cent of all imports in Australia.[15] On the one hand, imports of capital goods, which are more likely to contain a higher final content, are more likely to be substituted for skilled labour and complemented by unskilled labour. On the other hand, imported intermediate goods that have lower final content will exhibit complementarity with all types of labour. Hence, other things being equal, when considering the downstream processing effects, imported intermediate goods and capital may result in higher demand for unskilled workers, and lower demand for skilled workers.[16] In terms of the magnitude, in percentage terms, the displacement effect of imports targeted by the pool of skilled workers outweighed the positive stimuli that imports have induced upon the demand for unskilled workers. This result supports my earlier findings that an increase in imports will generate a decrease in aggregate employment.

Examination of the labour-capital elasticities ($\sigma_{L,K}$) in table 5 suggests capital accumulation substitutes for aggregate labour. The average value of the AUES is approximately 0.36 and is statistically significant under the A3SLS specification. Cross price elasticity of labour-capital as in table 7 suggests that for an exogenous one per cent *decrease* in the relative rental rate of capital, total demand for labour would *decrease* by 0.11 per cent (A3SLS).

Contrary to imports, capital accumulation over time has contributed to the increasing demand gap between skilled and unskilled labour in Australia. The results from table 7 suggest that on average, an exogenous one per cent *decrease* in the relative rental rate of capital would *decrease* the demand for unskilled workers by 0.09 (A3SLS) to 0.25 per cent (3SLS). On the other hand, if an exogenous one per cent *decrease* in the rental rate of capital occurred, the demand for skilled workers would have *increased* by 0.14 per cent (A3SLS). Most relevant elasticities are statistically significant across specifications and they are also relatively stable.

Similar to Tombazos (2003), I calculate the capital elasticity of the skilled and unskilled 'labour premium'. This is done by subtracting the average value of $\varepsilon_{S,K}$ from $\varepsilon_{U,K}$ (ε is the cross price elasticity). The 'labour premium' approximates the extent to which an increase in net capital stock affects the employment of skilled relative to unskilled workers. Under the A3SLS specification, the 'labour premium' is 0.093 – (–0.146) = 0.239.[17] Hence, for a one per cent increase in the net capital stock, the skilled-unskilled labour premium increases by 0.24 per cent. In Australia, the net capital stock increased by approximately 77 per cent between 1982/1983 and 2003/2004.[18] This suggests that since the mid-1980s, capital accumulation has contributed to the skilled-unskilled earnings premium by 18.5 per cent, *ceteris paribus*.

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[15] Author's calculation from ABS data.

[16] The same result can be found in Tombazos (2007) where he investigates the effect of observed trends in the prices of ordinary intermediate and semi-final imports on the expanding wage inequality in the U.S. Tombazos (2007, p.13) suggests that: 'other things equal, imports with a high intermediate (final) content are more likely to exhibit complementarity (substitutability) with domestic labour'. In this paper, I am unable to disaggregate imports into intermediate and semi-final imports due to unavailability of the data.

[17] A3SLS is preferred in this case because both the elasticities of skilled and unskilled labour with respect to capital are statistically significant. In other specifications, not all elasticities are statistically significant.

[18] Author's calculation from ABS data.

Robustness

In this section, as a robustness check on the previous findings, I also estimate equation (2) using an alternative narrower index of skill which defines skilled workers to include only professionals, para-professionals and clerical workers. Compared to the previous index of skill, I choose not to classify 'managers' as highly skilled since the classification of 'managers' in the agricultural sector as skilled workers is a matter of debate (Elias and Bynner, 1997). In particular, Elias and Bynner (1997) chose not to classify 'managers' as highly skilled but intermediate skills. The disaggregation of skilled and unskilled labour-intensive industries on the basis of labour input requirements on the basis of each skill index are reported in table 8.

Table 8 - Disaggregation of Skilled and Unskilled Labour-Intensive Industries on the Basis of Labour Input Requirements

	Skill Index = Skilled Workers / Total Employment			
ANZSIC	*Original Index*	*Classification*	*Alternative Index*	*Classification*
Education	0.9177	S	0.8790	S
Government Administration and Defence	0.7470	S	0.6631	S
Property and Business Services	0.7455	S	0.6753	S
Finance and Insurance	0.7375	S	0.6125	S
Cultural and Recreational Services	0.6954	S	0.5550	S
Agriculture, Forestry and Fishing	0.6769	S	0.0432	U
Health and Community Services	0.6748	S	0.6436	S
Communication Services	0.6041	S	0.5436	S
Personal and Other Services	0.5061	U	0.4461	S
Electricity, Gas and Water Supply	0.4622	U	0.4335	S
Wholesale Trade	0.4595	U	0.2785	U
Accommodation, Cafes and Restaurants	0.3835	U	0.1141	U
Retail Trade	0.3101	U	0.109	U
Mining	0.3021	U	0.2568	U
Transport and Storage	0.2859	U	0.2239	U
Manufacturing	0.2695	U	0.1868	U
Construction	0.1902	U	0.1100	U
Average	0.5275		0.3985	

Source: Table is derived from ABS Data Cube Catalogue Number 6291.055 Table E09. "S" and "U" refers to skilled intensive industry and unskilled intensive industry respectively.

The model was estimated again (Model C) using three different econometric methods: an autocorrelation-adjusted SUR, a 3SLS technique and an autocorrelation-adjusted 3SLS (A3SLS). Using the estimated parameters, Allen-Uzawa elasticities of substitutions and prices elasticities were also estimated again. Tables 9, 10 and 11 report estimated parameters, Allen-Uzawa elasticities of substitutions and prices elasticities, respectively. Results from tables 9, 10 and 11 suggested that the main findings are robust. Most coefficient signs are preserved and remained statistically significant across the two skill indices.

Table 9 - Estimated Symmetric Normalised Quadratic Cost Function Parameters: Imports and Skilled and Unskilled Employment – Alternative Skill Index (MODEL C)

	SUR		*3SLS*		*A3SLS*	
	Coef.	*T-stat*	*Coef.*	*T-stat*	*Coef.*	*T-stat*
a_s	0.2961	(19.73***)	0.2629	(35.839***)	0.2978	(20.752***)
a_u	0.3323	(38.899***)	0.3056	(48.847***)	0.3315	(37.997***)
a_k	0.5645	(22.729***)	0.5617	(62.749***)	0.5678	(23.551***)
a_i	0.1289	(12.307***)	0.1084	(10.44***)	0.1264	(13.049***)
b_{ss}	-0.0061	(-4.311***)	-0.0034	(-2.254*)	-0.0059	(-4.048***)
b_{su}	0.0059	(4.285***)	0.0003	(0.207)	0.0058	(3.685***)
b_{sk}	-0.0036	(-2.949***)	0.0007	(0.459)	-0.0032	(-2.7***)
b_{uu}	-0.0078	(-3.222***)	-0.0045	(-1.635)	-0.0079	(-2.948***)
b_{uk}	0.0024	(1.703*)	0.0040	(2.006*)	0.0026	(1.78*)
b_{kk}	-0.0047	(-2.452**)	-0.0093	(-3.902***)	-0.0049	(-2.77***)
δ_s	-0.1206	(-4.049***)	-0.0039	(-2.562**)	-0.1226	(-4.315***)
δ_u	-0.1921	(-8.209***)	-0.1169	(-8.645***)	-0.1914	(-8.432***)
δ_k	-0.1366	(-3.569***)	-0.0089	(-5.628***)	-0.1405	(-3.809***)
δ_i	-0.0024	(-1.087)	0.0042	(2.592***)	-0.0022	(-1.0216)
δ_{tt}	0.317	(2.332**)	-0.0070	(-0.842)	0.3192	(2.450**)
N	21		21		21	
	0.9949		0.9978		0.9975	
W_S	1.4194		-		-	
W_U	-0.0286		-		-	
W_K	1.7074		-		-	
W_I	-1.8011		-		-	
W	0.3953		-		-	

t-statistic in parentheses.*** Significant at 1% level with 2-tailed test. ** Significant at 2% level. * Significant at 10% level. Subscript I, S, U, K, t represents imports, skilled labour, unskilled labour, capital and technological change respectively.

Table 10 - Selected and Average Allen-Uzawa Partial Elasticities of Substitution of SNQ Cost Function: Imports and Skilled and Unskilled Employment – Alternative Skill Index (MODEL C)

	SUR					*3SLS*					*A3SLS*				
	1984	*1995*	*2004*	*Average*	*p-value*	*1984*	*1995*	*2004*	*Average*	*p-value*	*1984*	*1995*	*2004*	*Average*	*p-value*
$\sigma_{s,i}$	3.521	1.950	0.853	1.936	0.000***	2.590	1.281	0.562	1.299	0.032*	3.186	1.771	0.770	1.757	0.000***
$\sigma_{s,k}$	-0.696	-0.456	-0.325	-0.443	0.002***	0.050	0.054	0.081	0.058	0.736	-0.622	-0.406	-0.289	-0.394	0.004***
$\sigma_{s,t}$	-0.420	-0.284	-0.162	-0.302	0.000***	-0.148	-0.205	-0.281	-0.200	0.000***	-0.427	-0.291	-0.169	-0.309	0.000***
$\sigma_{u,i}$	0.136	-0.142	-0.244	-0.156	0.609	0.360	0.165	-0.015	0.144	0.773	0.140	-0.118	-0.215	-0.131	0.696
$\sigma_{u,k}$	0.293	0.274	0.314	0.266	0.123	0.561	0.481	0.492	0.464	0.053*	0.323	0.297	0.334	0.289	0.102
$\sigma_{u,t}$	-0.620	-0.610	-0.614	-0.613	0.000***	-0.388	-0.557	-0.797	-0.532	0.000***	-0.618	-0.606	-0.607	-0.609	0.000***
$\sigma_{s,s}$	-2.199	-1.548	-1.292	-1.528	0.000***	-1.342	-0.899	-0.700	-0.900	0.019*	-2.140	-1.508	-1.265	-1.489	0.000***
$\sigma_{u,u}$	-2.027	-2.171	-2.464	-2.028	0.002***	-1.284	-1.262	-1.368	-1.178	0.097*	-2.053	-2.191	-2.480	-2.047	0.004***
$\sigma_{k,k}$	-0.439	-0.288	-0.194	-0.277	0.009***	-0.734	-0.538	-0.411	-0.525	0.000***	-0.452	-0.302	-0.208	-7.932	0.000***

*** Significant at 1% level with two tailed test. * Significant at 10% level with two tailed test.
Note: Because of the limited space in the table, I do not present the elasticity value in every year of the study period. For the purpose of projecting the value of elasticity throughout the study period, I present the elasticity value for only three years.

Table 11 - Cross-Price Elasticities – Model C

	SUR	*p-value*	*3SLS*	*p-value*	*A3SLS*	*p-value*
Skilled-Imports	0.179	0.000***	0.117	0.032*	0.163	0.000***
Unskilled-Imports	-0.014	0.609	0.013	0.773	-0.012	0.696
Skilled-Capital	-0.158	0.001***	0.020	0.735	-0.141	0.004***
Unskilled-Capital	0.095	0.123	0.163	0.053*	0.103	0.102

*** Significant at 1% level with two tailed test. * Significant at 10% level with two tailed test.

6. Concluding Remarks

In this paper, I investigate the impact of imports on the demand for labour in Australia using a model that accounts for traditional displacement effects of imports, as well as positive effects of imports, subject to domestic labour downstream processes. The main results suggest that imports substitute for domestic aggregate labour. Contrary to standard trade theory, I find that imports have actually compressed the demand gap between skilled and unskilled labour in Australia.

Meanwhile, I find capital accumulation and skilled labour to be complements, and capital accumulation and unskilled labour to be substitutes. This indicates that capital accumulation has played a far more important role in the demand disparity between skilled and unskilled workers in Australia. However with the latest mining boom II in Australia, there has been concern regarding the 'Dutch disease' in which the expansion of the minerals sector drains resources from the manufacturing sector. Specifically, the improvement in the terms of trade and appreciation of the AUD as well cheap imports from emerging Asian economies may have caused 'de-industrialisation' of unskilled manufacturing whilst boosting the demand of skilled workers in the booming mining sector. While this is true, unskilled workers in the booming mining sector also benefit due to the downstream processes of imports. Investigation into the earnings disparity between skilled and unskilled workers in the 'post mining boom II' would be an interesting topic for future research given data availability at the firm's level.

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