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Theory and Methods

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The Effects of Trade Liberalisation in a Vertical Structure[*]

By

Yao Liu and Arijit Mukherjee

Abstract:

Despite the importance of international trade on intermediate goods, the literature did not pay much attention to this aspect in determining the effects of trade liberalisation in the presence of labour unions. We take up this issue here and show the effects of trade liberalisation on the final goods and/or the intermediate goods, where the domestic firm pays unionised wage and imports intermediate goods from another country. We show that trade liberalisation on the intermediate goods (final goods) increases (reduces) the unionised wage, labour union's utility and the domestic profit. Trade liberalisation on both the final goods and intermediate goods may either increase or reduce the domestic unionised wage, labour union's utility and the domestic profit depending on the input coefficients and the initial tariff levels. Our qualitative results are robust with respect to the intermediate goods market structure, the pricing strategy of the intermediate goods producer, the union's objective function and input substitution, yet they affect the results quantitatively.

Key words: Intermediate good; Labour union; Trade liberalisation
JEL Classification: F12; L11; J50

Non-technical summary

The general belief is that trade liberalisation benefits the consumers and increases welfare of the importing country, yet there is concern about its effect on the workers. While the earlier papers have mainly concentrated on competitive labour markets, recent works focus on labour market imperfection due to the presence of labour unions. The concern about the effect of trade liberalisation on unionised wage is more severe in countries such as Europe, where the presence of labour unions is prominent in many countries. This concern has created significant interest in this topic. However, to our surprise, the literature did not pay much attention to the import of intermediate goods, while a large part of total world trade is on intermediate goods, and the proportion has been growing continuously.

The purpose of this paper is to show the effects of trade liberalisation on final goods and/or intermediate goods in the presence of labour union. We show that the effects of trade liberalisation on an import competing industry depend on whether trade liberalisation is on the final goods market and/or the intermediate goods. In this respect, the technology of the firms, which affect the input coefficients, may play an important role. More specifically, considering that the domestic firm pays unionised wage and imports intermediate goods from another country, we show that trade liberalisation on the intermediate goods (final goods) increases (reduces) the unionised wage, labour union's utility and the domestic profit. Trade liberalisation on both the final goods and intermediate goods may either increase or reduce the domestic unionised wage, labour union's utility and the domestic profit depending on the input coefficients and the initial tariff levels. Hence, the technologies of the firms, which affect the input coefficients, may be important factors in determining the effects of trade liberalisation if trade liberalisation is viewed broadly to include tariff reduction on both the final goods and the intermediate goods. Our qualitative results are robust with respect to the intermediate goods market structure (i.e., perfectly competitive, monopolistic or firm-specific), the pricing strategy of the intermediate goods producer (i.e., uniform pricing or price discrimination), the union's objective function and input substitution (fixed or flexible input-coefficient technologies), yet they affect the results quantitatively.

The Effects of Trade Liberalisation in a Vertical Structure

1. Introduction

The general belief is that trade liberalisation benefits the consumers and increases welfare of the importing country, yet there is concern about its effect on the workers. The seminal paper by Stolper and Samuelson (1941) showing the effects of a product-price change on factor prices creates substantial interest on this topic. However, Stolper and Samuelson (1941) consider perfectly competitive factor markets, while the real world situation is often different. For example, the presence of labour unions often creates imperfection in the labour markets, which encourages more recent works to examine the effects of trade liberalisation on unionised wage and employment. The concern about the effect of trade liberalisation on unionised wage is more severe in countries such as Europe, where the presence of labour unions is prominent in many countries.[1]

Rodrik (1997) points out that globalisation reduce the power of the trade unions and create an adverse wage effect. As documented in Niblett (2005), the negative perception in the European Union towards increased globalisation is an important reason for the rejection of the European Constitution by French and Dutch voters. The theoretical results of Huizinga

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[1] Union agreements cover over 67% of workforce on average in the European Nations, while it covers 14% in the USA (OECD, 2004).

(1993) and Sørensen (1993), which show that unionised wage is higher under autarky than under free trade, confirm this concern.

However, there are other views, which suggest that trade liberalisation may increase unionised wage. The factors attributed to the beneficial wage effect of trade liberalisation are two-way trade liberalisation (Naylor, 1998 and 1999, Munch and Skaksen, 2002 and Bastos and Kreickemeier, 2009), efficient union-firm bargaining [2] (Gaston and Trefler, 1995), Bertrand competition (Gūrthzgen, 2002), open shop unions (Bastos et al., 2009), formal-informal productions (Maiti and Mukherjee, 2010) and endogenous domestic market structure (Mukherjee, 2010). The empirical evidence on this topic, although scarce, is also mixed (see, Gaston and Trefler, 1995 and Konings and Vandenbussche, 1995).

Although the above mentioned papers provide interesting insights, they ignore an important empirical regularity, viz. trade in intermediate goods. It is well known that a large part of total world trade is on intermediate goods and the proportion has been growing continuously. During 1975-1985, 50% of developing countries' imports were accounted for intermediate inputs (López and Panagariya 1992). According to World Trade Organization (2009), trade in intermediate goods (excluding fuel) was 40% of total world trade. Although vertical specialisation and international trade in intermediate goods is the focus of many recent theoretical and empirical studies, such as Ardnt (1997), Feenstra and Hanson (1996a,

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[2] The efficient bargaining model, which stipulates that the firms and the unions bargain over wages and employment, is an alternative to the right-to-manage model, where the firms and unions bargain only over wages. See, Layard et al. (1991) for arguments in favour of the right-to-manage models.

b), Jones and Kierzkowski (2001), McLaren (2000), Grossman and Helpman (2003 and 2005), Chen et al. (2004) and Yi (2003), to name a few,[3] little attention has been paid to determine the effects trade liberalisation in the presence of trade in intermediate goods and labour union. This paper is a step to fills this gap.

We show that the effects of trade liberalisation on an import competing industry depend on whether trade liberalisation is on the final goods market and/or the intermediate goods. In this respect, the technology of the firms, which affect the input coefficients, may play an important role. More specifically, considering that the domestic firm pays unionised wage and imports intermediate goods from another country, we show that trade liberalisation on the intermediate goods (final goods) increases (reduces) the unionised wage, labour union's utility and the domestic profit. Trade liberalisation on both the final goods and intermediate goods may either increase or reduce the domestic unionised wage, labour union's utility and the domestic profit depending on the input coefficients and the initial tariff levels. Hence, the technologies of the firms, which affect the input coefficients, may be important factors in determining the effects of trade liberalisation if trade liberalisation is viewed broadly to include tariff reduction on both the final goods and the intermediate goods. Our qualitative results are robust with respect to the intermediate goods market structure (i.e., perfectly competitive, monopolistic or firm-specific),[4] the pricing strategy of the intermediate goods

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[3] See Sanyal and Jones (1982) for an earlier work on international trade in intermediate goods.
[4] As we mention below, the assumption of perfectly competitive intermediate goods market and monopoly

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producer (i.e., uniform pricing or price discrimination), the union's objective function and input substitution (fixed or flexible input-coefficient technologies), yet they affect the results quantitatively.

It may worth pointing out that, although Gaston and Trefler (1995) and Gūrthzgen (2002) show that unilateral trade liberalisation may either increase or decrease unionised wage, our reason is different from theirs. Unlike Gaston and Trefler (1995), the labour union in our analysis determines only wage and not employment. Unlike Gūrthzgen (2002), we consider Cournot competition in the final goods market. *Trade liberalisation on the intermediate goods is important for our results.*

To the best of our knowledge, there is one more paper by Amiti and Davis (2008), which considers wage effects of trade liberalisation on both the final goods and the intermediate goods. However, they ignore all the strategic aspects considered in our paper. More specifically, our paper differs from their work in the following important ways. First, they consider perfect labour market with fair wage, while labour market is imperfectly competitive in our analysis. Wage in our analysis is determined by the labour union (or by bargaining between the firm and the labour union), which may give same or different weights on employment and wage. Hence, unlike us, they ignore strategic wage determination. Second, their consideration of monopolistic competition in the final goods market ignores strategic interaction in the product market. Third, competitive intermediate goods market in their analysis ignores strategic choice by the intermediate goods producers. Finally, unlike them,

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intermediate goods producer can have different interpretations. If there are symmetric intermediate goods producers with power and competing in prices with no capacity constraint, it will generate results similar to a perfectly competitive intermediate goods market. On the other hand, if these intermediate goods producers fully cooperate to their pricing strategies, it will generate outcomes similar to monopoly intermediate goods producer.

we also show the effects of endogenous technology choice in the final goods market.

The remainder of the paper is organised as follows. Section 2 describes the basic model and derives the results under perfectly competitive intermediate goods market. We extend the model in Section 3 to consider market power of the intermediate goods producers. Section 4 discusses the implications of different utility functions of the labour union and the effects of technology choice. Section 5 concludes.

2. The basic model

There are two firms D and F, located in the countries, called domestic and foreign respectively. These firms compete in the domestic country like Cournot duopolists. The inverse demand function in the domestic country is $P = a - Q_D - Q_F$, where Q_D and Q_F are the outputs of firms D and F respectively.

Both firms require an intermediate good and labour for production. Assume that firms D and F have similar technologies. Each of them requires δ units of the intermediates good and λ workers to produce one unit of the output. We assume that both firms purchase the intermediate good from world suppliers, which are located either in the foreign country or in a third country that is different from both the domestic and the foreign countries. We assume that labour market in the domestic country is unionised, whereas the labour market in the foreign country is perfectly competitive. The reservation wages for the workers in the

domestic and in the foreign countries are respectively d and w_F, where $d \overset{\geq}{\underset{<}{=}} w_F$, and the marginal cost of production for the intermediate goods is c.

We assume that the domestic country has imposed a per-unit tariff T on the output of firm F and a per-unit tariff t on firm D's import of the intermediate goods. If the intermediate goods producers are from the foreign country, it is then trivial that there is no tariff imposed by the foreign country on the intermediate goods. However, we assume for simplicity that even if the intermediate goods producers are from a third country, there is no tariff on firm F's import of the intermediate goods.[5]

To show the effects of domestic trade liberalisation, we start our analysis with a perfectly competitive intermediate goods sector. Alternatively, we can consider that several symmetric intermediate goods producers with market powers compete in prices with no capacity constraint. The latter situation will generate outcome similar to a perfectly competitive intermediate goods sector. As an example, consider Intel and AMD supply processors to the computer manufacturers and compete in prices with no capacity constraint.

We consider the following game. At stage 1, the price of the intermediate good and the wages are determined simultaneously. Given that the foreign labour market and the intermediate goods market are perfectly competitive, the equilibrium wage in the foreign country and the equilibrium price of the intermediate goods are trivially set to w_F and c

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[5] Since we are interested in determining the effects of domestic country's trade liberalisation, a positive tariff rate on firm F's import of the intermediate goods does not affect our result.

respectively. Hence, the effective choice is made by the domestic labour union. At stage 2, firms D and F determine their outputs simultaneously and the profits are realised. We solve the game through backward induction.

Given the foreign wage and the price of the intermediate goods as w_F and c respectively, the profits of firms D and F are respectively

$$\pi_D = \left[P - \lambda w_D - \delta(c+t) \right] Q_D \tag{1a}$$

$$\pi_F = \left[P - \lambda w_F - \delta c - T \right] Q_F . \tag{1b}$$

Maximising the profit functions, we get the equilibrium outputs of firms D and F, respectively, as:

$$Q_D^{\ pc} = \frac{a - 2\lambda w_D + \lambda w_F - \delta c - 2\delta t + T}{3} \tag{2a}$$

$$Q_F^{\ pc} = \frac{a - 2\lambda w_F + \lambda w_D - \delta c + \delta t - 2T}{3}, \tag{2b}$$

where the superscript *pc* represents perfect competition in the intermediate goods market.

Domestic labour union determines w_D to maximise a simple Stone-Geary type utility function:[6]

$$U = (w_D - d)\lambda Q_D. \tag{3}$$

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[6] We will show in the following sections that the qualitative effects of trade liberalisation are the same under different market structure of the intermediate goods and the pricing behaviours of the intermediate goods producers. However, for simplicity, all the results are derived under a simple union utility, where the union has full bargaining power and gives the same weight to wage and employment. Section 5 will show that our results are not the outcome of this simple union utility function, and the main conclusions hold under different utility functions of the domestic labour union.

The equilibrium domestic wage is:

$$w_D{}^{pc} = \frac{a - \delta(c + 2t) + T}{4\lambda} + \frac{2d + w_F}{4} \ .$$

(4)

Using $w_D{}^{pc}$, we get the union utility and the domestic profit, respectively, as:

$$U^{pc} = \frac{1}{24}\left(a - 2d\lambda + w_F\lambda - \delta c - 2\delta t + T\right)^2$$

(5a)

$$\pi_D^{pc} = \left(\frac{a - 2d\lambda + \lambda w_F - \delta c - 2\delta t + T}{6}\right)^2 .$$

(5b)

Proposition 1: *(i) If the intermediate goods market is perfectly competitive, domestic tariff reduction on the intermediate goods increases the unionised wage, labour union's utility and the domestic firm's profit, but domestic tariff reduction on the final goods lowers the unionised wage, labour union's utility and the domestic firm's profit.*

(ii) If the domestic tariffs are reduced by the same amount on the final goods and on the intermediate goods, it increases (decreases) the unionised wage, labour union's utility and the domestic firm's profit for $\delta > (<)1/2$.

If the domestic tariffs are reduced by the same proportion on the final goods and on the intermediate goods, it increases (decreases) the unionised wage, labour union's utility and the domestic firm's profit for $\delta > (<)T/2t$.

Proof: (i) We get from (4), (5a) and (5b) that

$$\frac{\partial w_D{}^{pc}}{\partial t} = -\frac{\delta}{2\lambda} < 0, \ \frac{\partial w_D{}^{pc}}{\partial T} = \frac{1}{4\lambda} > 0,$$

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$$\frac{\partial U^{pc}}{\partial t} = -\frac{2\lambda\delta\left(w_D^{\,pc} - d\right)}{3} < 0 \text{ and } \frac{\partial U^{pc}}{\partial T} = \frac{\lambda\left(w_D^{\,pc} - d\right)}{3} > 0 \text{ , as } w_D^{\,pc} - d > 0 \text{ ,}$$

$$\text{and } \frac{\partial \pi_D^{\,pc}}{\partial T} = \frac{Q_D^{pc}}{3} > 0 \text{ and } \frac{\partial \pi_D^{\,pc}}{\partial t} = -\frac{2\delta Q_D^{pc}}{3} < 0 \text{ , as } Q_D^{pc} > 0 \text{ .}$$

(ii)   Now consider changes in both t and T, and assume that $dT = dt$. We get that

$$\frac{dw_D^{\,pc}}{dT} = \frac{1-2\delta}{4\lambda} < (>)0 \qquad , \qquad \frac{dU^{pc}}{dT} = \lambda\left(\frac{w_D^{\,pc} - d}{3}\right)(1-2\delta) > (<)0 \qquad \text{and}$$

$$\frac{d\pi_D^{\,pc}}{dT} = \frac{Q_D^{pc}}{3}(1-2\delta) > (<)0 \text{ for } \delta > (<)\frac{1}{2} \text{ .}$$

$$\text{If} \qquad \frac{dT}{T} = \frac{dt}{t} \qquad , \qquad \text{we} \qquad \text{have} \qquad \frac{dw_D^{\,pc}}{dT} = \frac{t}{4\lambda T}\left(\frac{T}{t} - 2\delta\right) < (>)0 \qquad ,$$

$$\frac{dU^{pc}}{dT} = \frac{\lambda\left(w_D^{\,pc} - d\right)(T - 2t\delta)}{3T} > (<)0 \text{ and } \frac{d\pi_D^{\,pc}}{dT} = \frac{Q_D^{pc}(T - 2t\delta)}{3T} > (<)0 \text{ for } \delta > (<)\frac{T}{2t} \text{ .} \blacksquare$$

The reasons for the above results are as follows. Ceteris paribus, a tariff reduction on the intermediates goods increases the domestic firm's output, which increases the labour demand faced by the domestic labour union. The higher labour demand helps to increase the domestic unionised wage. On the other hand, ceteris paribus, a tariff reduction on the final goods increases the foreign firm's output and reduces the output of the domestic firm. Hence, the domestic firm's demand for labour falls and reduces the unionised wage. Hence, the "output effects" of tariff reductions are responsible for these results.

If the domestic country reduces tariffs on both the final goods and the intermediate goods, the net effect of tariff reductions on the domestic unionised wage is determined by the relative strengths of the above-mentioned effects, which depend on the initial tariff levels (T,

t) and the intermediate input coefficient (δ). A relatively large δ means a large share of the intermediate goods in the unit cost of the final goods. In this situation, the effect of trade liberalisation on the intermediate goods dominates the effect of trade liberalisation on the final goods due to the significant savings of the cost of production, thus increasing the unionised wage.

It follows from (5a) that the qualitative effects of trade liberalisation will be the same on unionised wage, domestic employment and union utility. Hence, a tariff reduction on the intermediate goods increases the union utility by increasing both the unionised wage and domestic employment, while a tariff reduction on the final goods decreases the union utility by reducing both the unionised wage and domestic employment. Similarly, if the tariffs are reduced by same amount or by the same proportion on the intermediate goods and on the final goods, the value of δ that makes the union utility unchanged following trade liberalisation will be the same to the value of δ that makes the unionised wage unchanged.

We have shown the above result under full bargaining power of the labour union, which gives the same weight on employment and wage. We will show in section 5 that similar conclusions will hold even if the labour union gives different weights to employment and wage, and the wage is determined by bargaining between the firm and the union.

3. Market power of the intermediate goods producers

Now we want to show the implications of market power of the intermediate goods producers. To show this, we will consider the following cases: (i) monopolist intermediate goods producer charging either uniform price or discriminatory prices to the final goods producers, and (ii) intermediate goods producers are specific to the final goods producers.

3.1. Monopoly intermediate goods producer

This section considers a world supplier of the intermediate goods, thus considering a situation opposite to Section 2, where the intermediate goods market is characterised by either perfect competition or price competition between the symmetric intermediate goods suppliers with market powers and no capacity constraint. Alternatively, we can assume in this section that symmetric intermediate goods producers with market power fully cooperate to their pricing strategies. For example, consider that either Intel is supplying processors to different computer manufacturers, or Intel and AMD are supplying processors to the computer manufacturers and also fully cooperating to the pricing for processors, thus creating an effective monopoly in the market for computer processors.

Consider a monopoly intermediate goods producer for the following two situations: (i) where the intermediate goods producer charges a uniform price p_I to firms D and F, and (ii) where the intermediate goods producer charges discriminatory prices p_D and p_F to firms

D and *F* respectively. For both the cases, we will consider the following game structure. At stage 1, the price of the intermediate good and the wages are determined simultaneously. Given that the foreign labour market is perfectly competitive, the equilibrium wage in the foreign country is trivially set to w_F. Hence, the effective choices are made by the intermediate goods producer and the domestic labour union. At stage 2, firms *D* and *F* determine their outputs simultaneously and the profits are realised. We solve the game through backward induction.

3.1.1. Uniform pricing by the intermediate goods producer

Given that the foreign wage as w_F, if the intermediate goods producer charges a uniform price, firms *D* and *F* determine their outputs to maximise the following expressions respectively:

$$\pi_D = \left[P - \lambda w_D - \delta \left(p_I + t \right) \right] Q_D \tag{6a}$$

$$\pi_F = \left[P - \lambda w_F - \delta p_I - T \right] Q_F. \tag{6b}$$

Maximising the profit functions, we get the equilibrium outputs of firms *D* and *F*, respectively, as:

$$Q_D{}^m = \frac{a - 2\lambda w_D + \lambda w_F - \delta p_I - 2\delta t + T}{3} \tag{7a}$$

$$Q_F{}^m = \frac{a - 2\lambda w_F + \lambda w_D - \delta p_I + \delta t - 2T}{3}, \tag{7b}$$

where the superscript *m* represents the case of monopoly intermediate goods producer.

The intermediate goods producer and the domestic labour union maximise the following expressions simultaneously to determine p_I and w_D respectively:

$$\pi_I = (p_I - c)\delta(Q_D + Q_F) \tag{8}$$

$$U = (w_D - d)\lambda Q_D. \tag{9}$$

The equilibrium price of the intermediate goods and the domestic unionised wage can be found as:

$$p_I{}^m = \frac{7a - \lambda 5w_F + 8c\delta - 2d\lambda - 2\delta t - 5T}{15\delta} \tag{10}$$

$$w_D{}^m = \frac{2a + 5\lambda w_F + 8\lambda d - 2\delta c - 7\delta t + 5T}{15\lambda}. \tag{11}$$

Using (10) and (11), we get the union utility and the profit of the domestic firm, respectively, as:

$$U^m = \frac{2}{3}\left(\frac{2a + 5\lambda w_F - 7\lambda d - 2\delta c - 7\delta t + 5T}{15}\right)^2 \tag{12a}$$

$$\pi_D^m = \frac{4}{9}\left(\frac{2a + 5\lambda w_F - 7\lambda d - 2\delta c - 7\delta t + 5T}{15}\right)^2. \tag{12b}$$

Proposition 2: *(i) If the intermediate goods producer is a monopolist, a domestic tariff reduction on the intermediate goods (final goods) will increase (decrease) the domestic unionised wage, labour union's utility and the domestic firm's profit.*

The marginal change of the unionised wage after tariff reduction on intermediate goods (final goods) is less (more) under a monopolist intermediate goods producer compared to the perfectly competitive intermediate goods market. But the situations for union utility and the domestic profit are ambiguous.

(ii) If the domestic tariffs are reduced by the same amount on the intermediate goods and the final goods, they increase (decrease) the domestic unionised wage, labour union's utility and the domestic firm's profit for $\delta > (<)5/7$ (in contrast to $\delta > (<)1/2$ under perfectly competitive intermediate goods market).

If the domestic tariffs are reduced by the same proportion on the intermediate goods and the final goods, they increase (decrease) the domestic unionised wage, labour union's utility and the domestic firm's profit for $\delta > (<)5T/7t$ (in contrast to $\delta > (<)T/2t$ under perfectly competitive intermediate goods market).

Proof: (i) We get from (4), (5a) and (5b), and from (11), (12a) and (12b) that

$$\frac{\partial w_D{}^m}{\partial t} = -\frac{7\delta}{15\lambda} < 0 \text{, and } 0 > \frac{\partial w_D{}^m}{\partial t} > \frac{\partial w_D{}^{pc}}{\partial t} = -\frac{\delta}{2\lambda}$$

$$\frac{\partial w_D{}^m}{\partial T} = \frac{1}{3\lambda} > 0 \text{, and } \frac{\partial w_D{}^m}{\partial T} > \frac{\partial w_D{}^{pc}}{\partial T} = \frac{1}{4\lambda} > 0$$

$$\frac{\partial U^m}{\partial t} = -\frac{14\delta\lambda}{45}\left(w_D{}^m - d\right) < 0 \text{ and } \frac{\partial U^m}{\partial T} = \frac{2\lambda}{9}\left(w_D{}^m - d\right) > 0 \text{, as } w_D{}^m > d \text{,}$$

$$\frac{\partial \pi_D{}^m}{\partial t} = -\frac{28\delta Q_D^m}{45} < 0 \text{ and } \frac{\partial \pi_D{}^m}{\partial T} = \frac{4Q_D^m}{9} > 0 \text{, as } Q_D^m > 0 \text{.}$$

We have $\dfrac{\partial U^{pc}}{\partial T} > (<)\dfrac{\partial U^m}{\partial T}$ and $\dfrac{\partial \pi^{pc}}{\partial T} > (<)\dfrac{\partial \pi^m}{\partial T}$ depending on

$13a - 35w_F\lambda - 13\delta c + 22\lambda d + 22\delta t - 35T > (<)0$.

We have $\dfrac{\partial U^{pc}}{\partial t} > (<)\dfrac{\partial U^m}{\partial t}$ and $\dfrac{\partial \pi^{pc}}{\partial t} > (<)\dfrac{\partial \pi^m}{\partial t}$ depending on

$169a - 169\delta c - 254\delta t + 85T - 245d\lambda + 85\lambda w_F > (<)0$.

(ii) Now consider changes in both t and T, and assume that $dT = dt$. We get that

$$\frac{dw_D{}^m}{dT} = \frac{5-7\delta}{15\lambda} < (>)0 \quad , \qquad \frac{dU^m}{dT} = \frac{2\lambda\left(w_D{}^m - d\right)\left(5-7\delta\right)}{45} > (<)0 \quad \text{and}$$

$$\frac{d\pi_D{}^m}{dT} = \frac{Q_D^m\left(5-7\delta\right)}{45} > (<)0 \ \text{ for } \delta > (<)5/7, \text{ where } 5/7 > 1/2.$$

If $\dfrac{dT}{T} = \dfrac{dt}{t}$, we get that $\dfrac{dw_D{}^m}{dT} = \dfrac{5T - 7\delta t}{15\lambda T} < (>)0$,

$\dfrac{dU^m}{dT} = \dfrac{2\lambda\left(w_D{}^m - d\right)\left(5T - 7\delta t\right)}{45} > (<)0$ and $\dfrac{d\pi_D{}^m}{dT} = \dfrac{Q_D^m\left(5T - 7\delta t\right)}{45} > (<)0$ for $\delta > (<)5T/7t$

, where $5T/7t > T/2t$. ∎

The "output effect" of tariff reduction, discussed in the previous section, remains in the presence of monopoly intermediate goods producer. However, the market power of the monopolist input producer creates further effects. If the domestic country reduces tariff of the final goods (intermediate goods), it reduces (increases) firm D's output but increases (reduces) firm F's output. However, the total outputs of firms D and F, and therefore, the total demand for the intermediate goods, increase following a tariff reduction either on the final goods or on the intermediate goods. This "market expansion" effect for the intermediate goods producer tends to increase the price of the intermediate goods following a tariff reduction either on the final goods or on the intermediate goods, as evident from equation (10). The negative effect of the higher intermediate goods price tends to reinforce the wage

reduction effect of trade liberalisation on the final goods, but it tends to soften the wage increase effect of trade liberalisation on the intermediate goods, by increasing firm D's marginal cost of production for a given domestic unionised wage.

If the domestic country reduces tariffs on both the final goods and the intermediate goods, the negative effect of trade liberalisation on the intermediate goods price tends to reduce the unionised wage raising effect of trade liberalisation. Hence, the range of δ over which tariff reduction on both the final goods and the intermediate goods reduce the domestic unionised wage is higher under monopoly intermediate goods producer with uniform pricing compared to the situation with a perfectly competitive intermediate goods market.

The effects on the labour union's utility and domestic profit follow similarly.

3.1.2. Price discrimination by the intermediate goods producer

Now consider price discrimination by the monopolist intermediate goods producer. The game structure is similar to Section 3.1.1 with the exception that the intermediate goods producer can charge different price to firms D and F. Hence, firms D and F pay p_D and p_F respectively for the intermediate goods, and these prices are determined by maximising

$$\pi_I = \left(p_D - c \right) \delta Q_D + \left(p_F - c \right) \delta Q_F.$$

To avoid repetition, we skip the mathematical details. Instead, we report the equilibrium values and the effects of tariff reductions in Table 1. The inspection of Table 1 and the comparison of these values with Propositions 1 and 2 give the following results immediately.

Proposition 3: *(i) For the case of price discrimination by the monopolist intermediate goods producer, trade liberalisation on the intermediate goods (final goods) will increase (reduce) the domestic unionised wage, labour union's utility and domestic profit.*

The marginal changes of the unionised wage due to tariff reductions are less under price discrimination compared to uniform pricing. But the situations for union utility and the domestic profit are ambiguous.

(ii) If the domestic tariffs are reduced by the same amount on the intermediate goods and the final goods, they increase (decrease) the domestic unionised wage, labour union's utility and domestic profit for $\delta > (<)1/2$ (in contrast to $\delta > (<)5/7$ under uniform pricing).

If the domestic tariffs are reduced by the same proportion on the intermediate goods and the final goods, they increase (decrease) the domestic unionised wage, labour union's utility and domestic profit for $\delta > (<)T/2t$ (in contrast to $\delta > (<)5T/7t$ under uniform pricing).

The possibility of price discrimination increases the monopolist intermediate goods producer's flexibility compared to uniform pricing. A tariff reduction on the intermediate goods increases domestic output and reduces output of the foreign firm. Hence, price discrimination increases the intermediate goods producer's incentive for rent extraction from the domestic firm compared to the foreign firm, which reduces the domestic labour union's incentive for rent extraction. In this situation, the unionised wage raising effect of a tariff reduction on the intermediate goods is lower compared to uniform pricing by the intermediate goods producer.

A tariff reduction on the final goods reduces domestic output but increases foreign output. Therefore, it reduces the intermediate goods producer's incentive for rent extraction from the domestic firm compared to the foreign firm, but it increases rent extraction by the union from the domestic firm. Hence, the unionised wage reduction following a tariff reduction on the final goods is lower under price discrimination compared to uniform pricing by the intermediate goods producer.

If tariffs are reduced on the intermediate goods and on the final goods, both the above-mentioned forces are in action, and reduce the range of δ over which unionised wage falls compared to uniform pricing by the intermediate goods producer.

The effects on the labour union's utility and domestic profit follow similarly.

3.2. Firm-specific intermediate goods producers

Now we consider the case where the intermediate goods producers are specific to the final goods producers. Hence, assume that Intel and AMD are supplying processors to the specific computer manufacturers.

The game structure is similar to Section 3.1 with the exception that firm-specific intermediate goods producers charge p_D and p_F to firms D and F respectively, and these prices are determined by maximising $\pi_{I1} = (p_D - c)\delta Q_D$ and $\pi_{I2} = (p_F - c)\delta Q_F$ simultaneously.

The equilibrium values and the effects of tariff reductions are shown in Table 1, which confirm our qualitative results of the previous sections. The following proposition summarises results for the firm-specific intermediate goods producers.

Proposition 4: *(i) If the intermediate goods producers are firm-specific, domestic tariff reduction on the intermediate goods (final goods) increases (lowers) the unionised wage, labour union's utility and domestic profit.*

(ii) If the domestic tariffs are reduced by the same amount on the final goods and on the intermediate goods, they increase (decrease) the domestic unionised wage, labour union's utility and domestic profit for $\delta > (<)2/7$.

If the domestic tariffs are reduced by the same proportion on the final goods and on the intermediate goods, they increase (decrease) the domestic unionised wage, labour union's utility and domestic profit for $\delta > (<)2T/7t$.

The intuition for the above result is very much similar to the case of discriminatory prices charged by the monopolist intermediate good producer, with the exception that under firm-specific intermediate goods producers, the profit of the intermediate goods producer is coming only from the respective final goods producer. Hence, an intermediate goods producer does not care about the effect of its pricing strategy on the profitability of the other intermediate goods producer. Due to this difference in the intermediate goods producers' objective functions, even if the qualitative results for tariff reductions on the unionised wage remain the same, the marginal change is larger under price discrimination compared to firm-specific goods producers.

4. Discussions

So far, we have seen that the qualitative effects of trade liberalisation on the unionised wage are the same under different formulations. However, in all those analysis, we have considered a simple objective function of the union, which maximises the total union rent.

Further, like the previous papers mentioned in the introduction, we have considered that the final goods producers use fixed input-coefficient technologies, and therefore, cannot adjust the input coefficients depending on the input prices. Even if the restrictions on the adjustments of input coefficients may approximate several real life situations, it may also reasonable to think that the firms have some amount of flexibilities in adjusting input coefficients.[7]

The purpose of this section is to see the implications of different objective functions of the labour union and variable coefficient technologies on our results.

4.1. Implications of the union's objective function

To see the implications of different objective functions of the labour union, we will consider two cases: (i) the labour union gives different weights to wage and employment, and (ii) the union and the firm bargain for wage. Although a general model may consider these cases together, for analytical convenience, we will consider these cases separately. To show the implications of different objective functions of the labour union, we consider fixed-coefficient technologies and a perfectly competitive intermediate goods market. The game structure is similar to Section 2.

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[7] See Warren-Boulton (1974), Mallela and Nahata (1980) and Hwang et al. (2007) for some works with variable coefficient technologies in different contexts.

4.1.1. Different weights on wage and employment

Here we consider that the union gives different weights to wage and employment, but has the full bargaining power. So the union's utility function is

$$U = \left(w_D - d \right)^{\beta} \left(\lambda Q_D \right)^{1-\beta}, \ 0 < \beta < 1. \tag{13}$$

Taking the equilibrium output of firm D from 2(a) and maximising the utility function (13) with respect to the unionised wage, we get that

$$w_D^* = \frac{a + \lambda w_F - \delta c - 2\delta t + T}{2\lambda / \beta} + \left(1 - \beta\right) d. \tag{14}$$

We get from (13) and (14) that

$$U^* = \left(a + \lambda w_F - \delta c - 2\delta t + T - 2\lambda d \right) \left(1 - \beta\right)^{1-\beta} \left(\frac{2\lambda}{\beta} \right)^{-\beta} \left(\frac{\lambda}{3} \right)^{1-\beta}. \tag{15}$$

$$\pi_D^* = \left(\frac{a + \lambda w_F - \delta c - 2\delta t + T - 2\lambda d}{3} \right)^2 \left(1 - \beta\right)^2. \tag{16}$$

It is then immediate that

$$\frac{\partial w_D^*}{\partial T} > 0, \frac{\partial w_D^*}{\partial t} < 0, \frac{\partial U^*}{\partial T} > 0 \ \text{and} \ \frac{\partial U^*}{\partial t} < 0, \frac{\partial \pi_D^*}{\partial T} > 0 \ \text{and} \ \frac{\partial \pi_D^*}{\partial t} < 0.$$

Now consider changes in both t and T. Assuming $dT = dt$, we get $\dfrac{dw_D^*}{dT} > (<)0$, $\dfrac{dU^*}{dT} > (<)0$, and $\dfrac{d\pi_D^*}{dT} > (<)0$ if $\delta < (>)\dfrac{1}{2}$. However, if $\dfrac{dT}{T} = \dfrac{dt}{t}$, we get that $\dfrac{dw_D^*}{dT} > (<)0$, $\dfrac{dU^*}{dT} > (<)0$, and $\dfrac{d\pi_D^*}{dT} > (<)0$ if $\delta < (>)\dfrac{T}{2t}$.

4.1.2. Union-firm bargaining

Now consider the situation where the labour union gives the same weight to wage and employment, but bargains with firm D. Hence, the unionised wage is determined by maximising the following expression:

$$U = \left[(w_D - d)\lambda Q_D \right]^{\beta} \pi_D^{1-\beta}, \text{ where } 0 < \beta < 1. \tag{17}$$

Taking the equilibrium output of firm D from 2(a) and maximising the utility function (17) with respect to the unionised wage, we get that

$$w_D^* = \frac{\beta(a + \lambda w_F - \delta c - 2\delta t + T)}{4\lambda} + \frac{d(2-\beta)}{2}. \tag{18}$$

Using the equilibrium wage, we get the equilibrium union utility and the domestic profit, respectively, as

$$U^* = \left(a + \lambda w_F - \delta c - 2d\lambda - 2\delta t + T \right)^2 \left(\frac{2-\beta}{6} \right)^{2-\beta} \left(\frac{\beta}{4} \right)^{\beta}. \tag{19}$$

$$\pi_D^* = \left(a + \lambda w_F - \delta c - 2\lambda d - 2\delta t + T \right)^2 \frac{(2-\beta)^2}{36} \tag{20}$$

It is then immediate that $\dfrac{\partial w_D^*}{\partial T} = \dfrac{\beta}{4\lambda} > 0, \dfrac{\partial w_D^*}{\partial t} = -\dfrac{2\beta\delta}{4\lambda} < 0, \dfrac{\partial U^*}{\partial T} > 0, \dfrac{\partial U^*}{\partial t} < 0, \dfrac{\partial \pi_D^*}{\partial T} > 0$ and $\dfrac{\partial \pi_D^*}{\partial t} < 0$.

If both t and T change, and $dT = dt$, we get $\dfrac{dw_D^*}{dT} > (<)0, \dfrac{dU^*}{dT} > (<)0 \dfrac{dU^*}{dT} > (<)0,$ and $\dfrac{d\pi_D^*}{dT} > (<)0$ if $\delta < (>)\dfrac{1}{2}$. However, if $\dfrac{dT}{T} = \dfrac{dt}{t}$, we get $\dfrac{dw_D^*}{dT} > (<)0, \dfrac{dU^*}{dT} > (<)0$ if $\delta < (>)\dfrac{T}{2t}$, and $\dfrac{d\pi_D^*}{dT} > (<)0$ if $\delta < (>)\dfrac{T}{2t}$.

Thus, we show that even if (i) the labour union gives different weights to wage and employment, and (ii) the union and the firm bargain for wage, our qualitative results of the previous sections remain.

4.2. Input substitution

Now we want to see the implications of variable coefficient technologies. To show the effects of input substitution, we assume a perfectly competitive intermediate goods market in this section. We also assume that the union has full bargaining power and give the same weight to wage and employment.

The timing of game is as follows. At stage 1, the price of the intermediate good and the wages are determined simultaneously. Given that the foreign labour market and the intermediate goods market are perfectly competitive, the equilibrium wage in the foreign country and the equilibrium price of the intermediate goods are trivially set to w_F and c respectively. Hence, the effective choice is made by the domestic labour union. At stage 2, firms D and F determine their input combinations. At stage 3, firms D and F compete like Cournot duopolists and the profits are realised. We solve the game through backward induction.

The equilibrium wage in the foreign country and the equilibrium price of the intermediate goods are trivially set to w_F and c respectively. Given the wages, the price of the intermediate good and the input coefficients, the profits of firms D and F are respectively:

$$\pi_D = \left[P - \lambda_D^* w_D - \delta_D^* (c+t) \right] Q_D \qquad (21a)$$

$$\pi_F = \left[P - \lambda_F^* w_F - \delta_F^* c - T \right] Q_F, \qquad (21b)$$

where λ_D^*, δ_D^*, λ_F^* and δ_F^* are the respective equilibrium input coefficients.

Maximising the profit functions, we get the equilibrium outputs of firms D and F, respectively, as:

$$Q_D^* = \frac{a - 2\lambda_D^* w_D - 2\delta_D^* (c+t) + \lambda_F^* w_F + \delta_F^* p_I + T}{3} \qquad (22a)$$

$$Q_F^* = \frac{a - 2\lambda_F^* w_F - 2(\delta_F^* c + T) + \lambda_D^* w_D + \delta_D^* (c+t)}{3}. \qquad (22b)$$

To consider input substitutability, we assume that both firms have the Cobb-Douglas production function, $Q = L^\alpha I^{1-\alpha}$, where L is the worker and I is the intermediate good. The equilibrium input coefficients for firm D can be obtained by minimising $\lambda_D w_D + \delta_D (c+t)$ subject to $\lambda_D^{\alpha} \delta_D^{1-\alpha} = 1$, where $\lambda_D = \dfrac{L}{Q}$ and $\delta_D = \dfrac{I}{Q}$. We get that the equilibrium input coefficients for firm D as $\lambda_D^* = \left(\dfrac{c+t}{w_D} \dfrac{\alpha}{1-\alpha} \right)^{1-\alpha}$ and $\delta_D^* = \left(\dfrac{w_D}{c+t} \dfrac{1-\alpha}{\alpha} \right)^{\alpha}$. Similarly, cost minimisation by firm F gives the equilibrium input coefficients for firm F as

$$\lambda_F^* = \left(\frac{c}{w_F} \frac{\alpha}{1-\alpha} \right)^{1-\alpha}, \ \delta_F^* = \left(\frac{w_F}{c} \frac{1-\alpha}{\alpha} \right)^{\alpha}.$$

Not surprisingly, the input coefficients are determined by the relative input prices. Given the constant wage in the foreign country and the constant price of the intermediate good, λ_F^*, δ_F^* and the marginal cost of firm F, which is $\lambda_F^* w_F + \delta_F^* c$, are constant. Hence, effectively the effect of a tariff reduction is on the technology choice of firm D.

Since the equilibrium wage in the foreign country and the equilibrium price of the intermediate goods are trivially set to w_F and c respectively, the effective choice at stage 1 is by the domestic labour union only. The equilibrium domestic unionised wage can be found by maximising the union utility $U = (w_D - d) \lambda_D Q_D$ with respect to w_D. The following equation determines the equilibrium domestic unionised wage:

$$\frac{a + c_F + T}{3} - \frac{(w_D - d)(a + c_F + T)(1 - \alpha) w_D^{-1}}{3}$$
$$- \frac{2\left[\left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha} + \left(\frac{1-\alpha}{\alpha}\right)^{\alpha}\right](c+t)^{1-\alpha} w_D^{\alpha-1}[d + 2\alpha(w_D - d)]}{3} = 0.$$

(23)

It is immediate from (23) that a lower T reduces left hand side of (23), which implies that w_D needs to fall to restore condition (23). Therefore, $\frac{w_D^*}{dT} > 0$. Similar logic gives that $\frac{w_D^*}{dt} < 0$.

Hence, a tariff reduction on the intermediate goods (final goods) increases (decreases) the domestic unionised wage even if the firms can adjust their input coefficients after the domestic wage determination.[8]

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[8] Although it is not possible for us to derive the analytical results for the effects of tariff reductions on union utility and domestic profit, we expect that, due to the same qualitative results of tariff reductions on the unionised wage under fixed and flexible technologies, the qualitative effects of tariff reductions on union utility and domestic profit would be the same under fixed and flexible technologies. The possibility of input

Even if the qualitative effects of a tariff reduction on the unionised wage remains the same under input substitution, it is intuitive that the quantitative effect will be different from the case with no input substitution. Intuitively, the absolute marginal change should be less under input substitution compared to the fixed coefficient case. For example, in the case of no input substitution, a tariff reduction on the final goods will lower the domestic wage. However, the possibility of input substitution will then encourage the domestic firm to use more labour, since labour is now relatively cheaper than the intermediate goods. This "substitution effect" between the inputs tends to increase the unionised wage. We find that the "output effect" dominates the input substitution effect, and a tariff reduction on the final goods reduces the domestic unionised wage. However, due to the input substitution effect, the extent of wage reduction following a tariff reduction on the final goods is lower under input substitution compared to no input substitution.

Similarly, due to the input substitution, a tariff reduction on the intermediate goods will increase the domestic wage less under input substitution compared to no input substitution, because the more expensive labour is now being substituted with cheaper intermediate goods which tend to reduce the union's labour demand and the unionised wage.

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substitution will create lower absolute marginal change compared to the fixed coefficient technology. However, since the effect of input substitution is an indirect effect due to a change in the input price, thus second order in nature, we would expect the "output effect" to dominate the "substitution effect".

It is now intuitive that if tariff reduces on both the final goods and the intermediate goods, unionised wage may either increase or decrease, depending on the parameter values.

5. Conclusion

Many countries are liberalising their trade policies, which create concerns about their effects on the domestic labour markets. In a simple model we show how trade liberalisation on the final goods and/or the intermediate goods affect domestic unionised wage, union utility and the domestic profit through the output effect, market expansion effect for the intermediate goods producers and the input substitution effect under flexible technologies.

We show that trade liberalisation only on the intermediate goods (final goods) increases (reduces) the domestic unionised wage, union's utility and the domestic profit. Trade liberalisation on both the final goods and intermediate goods may either increase or reduce the domestic unionised wage, labour union's utility and the domestic profit depending on the input coefficients and the initial tariff levels. Our qualitative results are robust with respect to the intermediate goods market structure, the pricing strategy of the intermediate goods producer, input substitution and the union's objective function, since the output effect dominates the other effects, yet the presence of the other effects creates different quantitative results.

Table 1: The equilibrium values under price discrimination and firm-specific producers

	price discrimination	firm-specific producers
p_D^*	$\dfrac{7c}{12}+\dfrac{5a-\lambda w_F-4\lambda d-T-4\delta t}{12\delta}$	$\dfrac{17c}{22}+\dfrac{5a+2\lambda w_F-7\lambda d+2T-7\delta t}{22\delta}$
p_F^*	$\dfrac{c}{2}+\dfrac{a-\lambda w_F-T}{2\delta}$	$\dfrac{7c}{11}+\dfrac{4a-5\lambda w_F+\lambda d+\delta t-5T}{11\delta}$
w_D^*	$\dfrac{2d}{3}+\dfrac{a+\lambda w_F-\delta c+T-2\delta t}{6\lambda}$	$\dfrac{15}{22}d+\dfrac{5a+2\lambda w_F-5\delta c+2T-7\delta t}{22\lambda}$
U^*	$\dfrac{2\lambda^2}{3}\left(w_D^*-d\right)^2$	$\dfrac{2\lambda^2}{3}\left(w_D^*-d\right)^2$
π_D^*	Q_D^{*2}	Q_D^{*2}
$\dfrac{\partial w_D^*}{\partial T}$	$\dfrac{1}{6\lambda}>0$	$\dfrac{1}{11\lambda}>0$
$\dfrac{\partial w_D^*}{\partial t}$	$-\dfrac{\delta}{3\lambda}<0$	$-\dfrac{7\delta}{22\lambda}<0$
$\dfrac{\partial U^*}{\partial T}$	$\dfrac{2\lambda}{9}\left(w_D^*-d\right)>0$	$\dfrac{4\lambda}{33}\left(w_D^*-d\right)>0$
$\dfrac{\partial U^*}{\partial t}$	$-\dfrac{4\delta\lambda}{9}\left(w_D^*-d\right)<0$	$\dfrac{-14\delta\lambda}{33}\left(w_D^*-d\right)<0$
$\dfrac{\partial \pi_D^*}{\partial T}$	$\dfrac{2}{9}Q_D^*>0$	$\dfrac{4}{33}Q_D^*>0$
$\dfrac{\partial \pi_D^*}{\partial t}$	$-\dfrac{4}{9}\delta Q_D^*<0$	$-\dfrac{14}{33}\delta Q_D^*<0$
$dT=dt$	$\dfrac{dw_D^*}{dT}\dfrac{dU^*}{dT}$ and $\dfrac{d\pi_D^*}{dT}\begin{cases}>0, if\ \delta<\frac{1}{2},\\=0, if\ \delta=\frac{1}{2},\\<0, if\ \delta>\frac{1}{2},\end{cases}$	$\dfrac{dw_D^*}{dT}\dfrac{dU^*}{dT}$ and $\dfrac{d\pi_D^*}{dT}\begin{cases}>0, if\ \delta<\frac{2}{7},\\=0, if\ \delta=\frac{2}{7},\\<0, if\ \delta>\frac{2}{7},\end{cases}$

$$\frac{dT}{T} = \frac{dt}{t}$$

$\dfrac{dw_D^{\,*}}{dT}\ \dfrac{dU^{*}}{dT}$ and $\dfrac{d\pi_D^{\,*}}{dT}$ $\begin{cases} > 0, if\ \delta < \frac{T}{2t} \\ = 0, if\ \delta = \frac{T}{2t} \\ < 0, if\ \delta > \frac{T}{2t} \end{cases}$

$\dfrac{dw_D^{\,*}}{dT}\ \dfrac{dU^{*}}{dT}$ and $\dfrac{d\pi_D^{\,*}}{dT}$ $\begin{cases} > 0, if\ \delta < \frac{2T}{7t} \\ = 0, if\ \delta = \frac{2T}{7t} \\ < 0, if\ \delta > \frac{2T}{7t} \end{cases}$

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