TCER Working Paper Series

The welfare effects of partial tariff reduction in Japan

Akihito Asano
Michiru Sakane

February 2023

Working Paper E-177
https://www.tcer.or.jp/wp/pdf/e177.pdf

TOKYO CENTER FOR ECONOMIC RESEARCH
1-7-10-703 Iidabashi, Chiyoda-ku, Tokyo 102-0072, Japan

Abstract

When some sectors are more heavily protected than others, will removing lightly protected sectors' tariffs improve welfare? We argue that this second-best question is highly relevant in Japan, wherein its government made some exceptions to the across-the-board tariff elimination during the Trans-Pacific Partnership negotiations. We have calibrated a specific factor model with multiple import-competing sectors to the 2015 Japanese economy and conducted some counterfactual exercises. Although the partial tariff removal policy in question barely affects Japanese welfare, when it is combined with the agricultural sector tariff removal (across-the-board tariff elimination) the effect on Japanese welfare is made positive. Furthermore, the positive welfare effect more than doubles if it is combined with the removal of the subsidy in the agricultural sector. Both of these findings indicate the severity of the existing distortion stemming from the Japanese agricultural sector protection as well as the importance of lowering the protection to render the non-agricultural sector tariff removal meritorious.

Akihito Asano
Sophia University
Faculty of Liberal Arts
7-1 Kioi-cho, Chiyoda-ku, Tokyo, 102-8554
Japan
aki.asano@sophia.ac.jp

Michiru Sakane
TCER
and
Sophia University
Faculty of Liberal Arts
7-1 Kioi-cho, Chiyoda-ku, Tokyo, 102-8554
Japan
michiru-s@sophia.ac.jp

The welfare effects of partial tariff reduction in Japan*

Akihito Asano† Michiru Sakane‡

Sophia University Sophia University

February 2, 2023

Abstract

When some sectors are more heavily protected than others, will removing lightly protected sectors' tariffs improve welfare? We argue that this second-best question is highly relevant in Japan, wherein its government made some exceptions to the across-the-board tariff elimination during the Trans-Pacific Partnership negotiations. We have calibrated a specific factor model with multiple import-competing sectors to the 2015 Japanese economy and conducted some counterfactual exercises. Although the partial tariff removal policy in question barely affects Japanese welfare, when it is combined with the agricultural sector tariff removal (across-the-board tariff elimination) the effect on Japanese welfare is made positive. Furthermore, the positive welfare effect more than doubles if it is combined with the removal of the subsidy in the agricultural sector. Both of these findings indicate the severity of the existing distortion stemming from the Japanese agricultural sector protection as well as the importance of lowering the protection to render the non-agricultural sector tariff removal meritorious.

Keywords: Tariff policy, distortion, welfare, Japanese economy

JEL Classification: F11, F13

*The authors are grateful to Taiji Furusawa for discussing an earlier version of this paper at the Japanese Economic Association (JEA) Spring Meeting. We benefitted immensely from his criticism and constructive comments. The authors would also like to thank participants of Economic Theory Seminar at the Australian National University, the Asia Pacific Trade Seminars (APTS), the JEA Spring Meeting, and the Midwest Economic Theory and International Trade Conference for the feedback, and in particular, Naoto Jinji, Tsutomu Miyagawa and Martin Richardson for their detailed and helpful comments. Part of this project was conducted when Asano was visiting the Australian National University, and he thanks the Research School of Economics for their hospitality. Sakane acknowledges the financial support of the Sophia Research Budget (SRB). All remaining errors are our own.

†Corresponding author. E-mail: aki.asano@sophia.ac.jp.

‡E-mail: michiru-s@sophia.ac.jp.

1 Introduction

Japan is one of the world's largest agro-food importing countries, and it is well known that significant support is provided to its producers. According to the Organisation for Economic Co-operation and Development (OECD, 2020), producer support estimates (PSE) for Japanese farmers in 2015 was 37.6 per cent of gross farm receipts, which was well beyond the PSE in most other OECD countries (see Figure 1). Indeed, Table 1 indicates that high average tariff rates were imposed on Japanese agricultural imports such as dairy products (69.1 per cent), cereals and preparations (31.1 per cent), and sugars and confectionery (19.0 per cent).

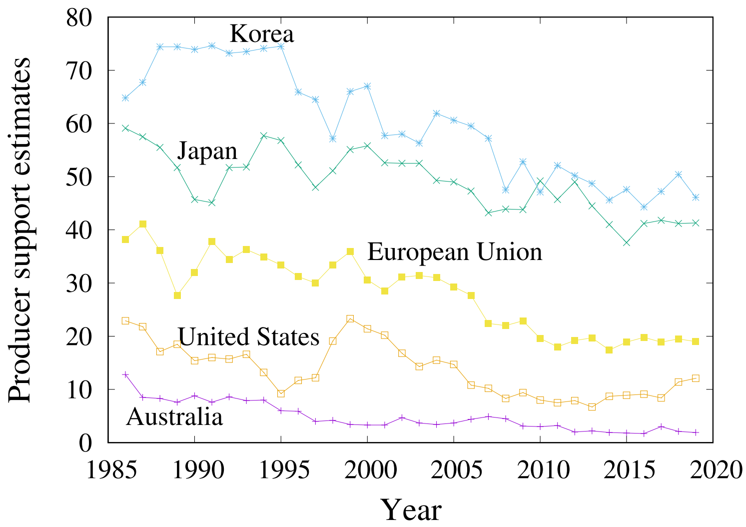


Figure 1: Producer support estimates (% of gross farm receipts). **Source:** OECD (2020).

Agricultural producer support in Japan is also distinctive in terms of government subsidies. Table 2 suggests that the government subsidy allocated to the 'Agriculture, forestry and fishery' sector is the second largest behind the 'Medical service, health, social security and nursing care' sector. Focussing only on primary and manufacturing sectors, the subsidy allocated to the 'Agriculture, forestry and fishery' sector is roughly 80 per

Product group	Average tariff (%)
Dairy products	69.1
Cereals & preparations	31.1
Sugars and confectionery	19.0
Beverages & tobacco	14.1
Coffee, tea	13.8
Animal products	10.7
⋮	⋮
Clothing	9.0
Textiles	5.4
⋮	⋮

Source: WTO, ITC and UNCTAD (2016).
Notes: The figures are MFN applied duties.

Table 1: Japan's tariff by product group in 2015

cent of the total subsidy. On the contrary, protection for other import-competing sectors — *e.g.* 'Textile products' and 'Wearing apparel and other textile products' — have been rather modest in terms of both import tariffs and subsidies.

Unsurprisingly, during the negotiations on the Trans-Pacific Partnership (TPP), a number of rallies to oppose participation in the TPP were held in Japan as one of the TPP's objectives of achieving across-the-board tariff elimination was clearly against the interests of producers, especially of those of the agricultural sector (see, for example, The Japan Times, 2013; BBC Monitoring Asia Pacific, 2011). Although there were some proponents for liberalising the agricultural sector, it became difficult for the Japanese government to remove tariff lines across the board.[1] Eventually the situation was settled through political compromise. Namely, the majority of the five sensitive items (rice, wheat and barley, sugar and starch, beef and pork, and dairy products) were placed in to the exception list, essentially watering down the whole idea of across-the-board tariff removal. For these items the tariff lines were to remain the same or to be removed gradually over time.[2] Another example of partial tariff reduction can be found in the more recent

[1]For anecdotes on the strong political influence of the Japanese agricultural sector, see, for example, Harimaya et al. (2010) and Kagitani and Harimaya (2017).

[2]According to Ministry of Agriculture, Forestry and Fisheries (2016), 459 tariff lines were to remain

Sector	Subsidy	Ratio (%)
Medical service, health, social security and nursing care	765,487	23.5
Agriculture, forestry and fishery	754,911	23.2
Finance, insurance and real estate	549,100	16.8
Other civil construction	257,706	7.9
Water supply	225,525	6.9
Transport and postal service	149,093	4.6
Education and research	142.840	4.4
Food and beverages	127,036	4.1
⋮	⋮	⋮
Textile products	23	0.0
⋮	⋮	⋮
Wearing apparel and other textile products	20	0.0
⋮	⋮	⋮
Total	3,260,409	100.0

Source: Ministry of Economy, Trade and Industry, Japan (2015).

Table 2: Subsidy allocation in Japan by sector in 2015 (in million Japanese yen)

Regional Comprehensive Economic Partnership (RCEP) agreement, wherein the Japanese five sensitive items were exempted again from any tariff reductions or eliminations.[3]

Examining economic gains/losses accruing to a country from any potential sizeable regional economic trade agreement is of great importance to researchers and policymakers, especially now that a number of regional trade agreements are in force around the world.[4] The economic effects of the TPP have indeed been examined by a number of studies, and according to a succinct survey of Gilbert et al. (2018), more than 35 studies have been conducted to assess the effect of the TPP using the method of computable general equilibrium (CGE) modelling. Although there are variations in magnitude, these studies generally reveal positive welfare effects of the TPP on its participating members.[5]

out of the total of 9321, all of which are in agriculture, forestry and fisheries. The vast majority of the remaining tariff lines are applied to these five sensitive items.

[3]See Ministry of Agriculture, Forestry and Fisheries (2020) for the details of the RCEP agreement.

[4]More than 300 regional trade agreements were in force as of June 1, 2020. Facts and figures are available from the World Trade Organization (World Trade Organization, 2020).

[5]For example, Petri and Plummer (2016) estimate the annual welfare gains from TPP for the members (Japan) to be \$312–\$525 billion (\$92–\$156, respectively). Cabinet Secretariat, Japan (2015) estimates that Japan's real GDP will increase by 2.6 per cent in the new long-run equilibrium path.

However, to the best of our knowledge, there is no existing work in this line of inquiry, which has explicitly focussed on the distorted characteristics of the Japanese economy we have discussed above. In this paper, we aim to uncover the welfare effect of a partial tariff removal policy such as the one that came out of the TPP negotiations on the Japanese economy, paying special attention to the distorted characteristics of the Japanese economy. More specifically, we theoretically examine how the present distortion is related to the welfare effect of such a partial tariff removal policy, also quantifying its welfare effect to allow a comparison with those identified in the existing work.

To theoretically examine the welfare effect of the tariff reform of our interest, we employ a specific factor model (Jones, 1971b; Mussa, 1974) that comprises two import-competing sectors (calling them Sectors A and B) and an export sector (calling it Sector C). Not only is the specific factor model ideal for examining the short-run effect of a partial tariff removal policy, but its parsimonious nature also helps us to clearly interpret our quantitative results. In our model, both import-competing sectors are protected by tariffs but only one of them (Sector A, namely Agriculture) is supported by a production subsidy. Our particular interest is the welfare effect of lowering the Sector B tariff when it is lower than Sector A's tariff. Examining this circumstance, which involves multiple distortions, is clearly a question under the theory of second best.

In their seminal work, Lipsey and Lancaster (1956) examined a question that is similar to ours as an example that illustrates the theory of second best, although they do not consider any domestic distortion. A thread of the literature followed examining welfare-improving piecemeal policy changes in a more general multi-sector framework.[6] Earlier papers include Foster and Sonnenschein (1970), Bruno (1972) and Hatta (1977a,b) amongst others, and established the two types of tariff reforms that are welfare-improving: (i) lower every distortion in an equal percentage (uniform reduction rule); and (ii) reduce the highest distortion to the next highest (concertina rule). The main results established in the earlier work were extended by many succeeding papers — Fukushima (1979), Diewert

[6]See Corden (1984), Dixit (1985), Vousden (1990) and Falvey and Kreickemeier (2013) for the survey on this topic as well as on trade and domestic distortion.

et al. (1991), Turunen-Red and Woodland (1991), Abe (1992), Ju and Krishna (2000) and Anderson and Neary (2007), to name a few — which also focussed on sufficient conditions for the welfare improving policy rules. However, little has been done in terms of examining the welfare effect of the reform of our interest.[7]

To quantitatively assess the short-run welfare effect in question, we extend our specific-factor model to 13 sectors and calibrate it to the 2015 Japanese economy. According to our calibration, the partial tariff reduction policy in question (i.e. removing the Sector B tariff only) marginally lowers the Japanese economy's welfare. The equivalent variation of the policy is 0.02 per cent of the Japanese GDP. However, our main counterfactual exercise reveals that if it is accompanied by a significant reduction in the Sector A tariff, the welfare effect is positive, within the range of that reported in the existing literature. These quantitative exercises identify the severity of the existing distortion, which critically affects the welfare effects of the trade policy on the Japanese economy. We show that the present distortion renders the partial tariff reduction policy ineffective, implying the significant importance of gradual tariff eliminations/reductions with regard to agricultural products for the Japanese economy to achieve welfare improvement.

The effectiveness of the partial tariff reduction policy in question is also influenced by the domestic distortion created by the government subsidy. In another counterfactual exercise, we show that the removal of the Sector A subsidy makes the partial tariff reduction policy welfare improving. The positive welfare effect in this case is, in fact, greater than that when the Sector A tariff was completely removed (but with no subsidy removal), indicating the significance of the Sector A subsidy protection. We also find that this positive welfare effect of the Sector A subsidy removal becomes less important as the Sector A tariff is lowered, but it still accounts for more than half of the positive welfare

[7]Once a distortion is added to any framework, the mathematical analysis in general becomes more complex than otherwise, even in a standard two-sector model. For example, Johnson (1966) employs a numerical approach to sketch the production possibility frontier for the two-by-two model with a domestic distortion. Jones (1971a) provides mathematical explanation on the concavity of the production possibility frontier under the same situation, although complicated expressions make it difficult for us to interpret the results intuitively. Ohyama (1972) provides some mathematical analysis of tariff policies under domestic distortion, but relies on an *ad hoc* means of modelling the distortion. It is no surprise that classical work examining the relationship between trade and domestic distortion relies on graphical analysis (Bhagwati and Ramaswami, 1963; Bhagwati, 1967, for example).

effect even when Sector A tariffs are completely removed. These results are related to the work of Swiecki (2017). Using a multi-sector version of the Ricardian model of Eaton and Kortum (2002), Swiecki (2017) reveals the importance of the effects of inter-sectoral distortions on welfare gains from trade. Our paper is complementary to Swiecki (2017) in the sense that we quantify the welfare effects of various policies in the presence of inter-sectoral distortions on the Japanese economy, but applying a different model. In our paper, inter-sectoral domestic distortions are created by the Sector A subsidy. We find that the welfare effect of the partial tariff reduction in question is significantly affected by the domestic distortion and varies with the extent of domestic distortion created by the Sector A subsidy.

In the following section, we begin with the analysis of a two-sector specific factor model that incorporates domestic distortion, which helps intuitively uncover the effect of a tariff policy under domestic distortion. In Section 3, our model is extended to three sectors, adding another import-competing sector. We first show that concertina-type tariff reform will increase welfare in our specific factor model setup. Then, for the tariff reform of our interest, some robust patterns in the welfare effects are illustrated using numerical simulations. In Section 4, we extend our model to 13 sectors, calibrate it to the 2015 Japanese economy, and conduct a few counterfactual exercises to identify the severity of the present distortion. Section 5 concludes.

2 The two-sector model with a domestic distortion

2.1 The setup

We consider a two-sector specific factor model in a small open economy setting. We assume two goods, Good A and Good C. These goods are produced in two sectors, Sectors A and C, respectively. Outputs are denoted as Y_A and Y_C, respectively. The international prices of the two goods are denoted as P_A and P_C.

There are two production factors. Labour in Sector A, L_A, and that in Sector C, L_C, are mobile across the two sectors. Capital in Sector A, K_A, and that in Sector C, K_C, are specific factors. We assume Cobb-Douglas production technology for both sectors. More specifically,

$$Y_A = Z_A L_A^{\alpha} K_A^{1-\alpha}, \tag{1}$$

$$Y_C = Z_C L_C^{\gamma} K_C^{1-\gamma}, \tag{2}$$

where $0 < \alpha < 1$ and $0 < \gamma < 1$. Z_A and Z_C are the total factor productivity (TFP) for Sectors A and C, respectively. The aggregate quantity of labour in the economy is given as $\overline{L}$, hence,

$$\overline{L} = L_A + L_C. \tag{3}$$

We assume that Sector A is an import-competing sector, which is subject to an ad valorem tariff, $\tau_A \geq 0$, and whose production is subsidised by the government. More specifically, the Sector A producer receives $P_A(1+\tau_A)(1+s_A)$ per unit of production, where s_A is the subsidy rate. Sector C is an export sector.[8]

The profit functions of each sector are

$$\pi_A = P_A(1+\tau_A)(1+s_A)Y_A - wL_A - r_A K_A,$$
$$\pi_C = P_C Y_C - wL_C - r_C K_C,$$

where w, r_A and r_C are the wage and the rental prices of capital in each sector, respectively.

[8] $s_A < 0$ corresponds to the case when Good A production is taxed. Although our interest is the case where $s_A > 0$, we do not impose any condition on its sign in this section, as it has an important implication on our discussion in the next subsection.

Solving the profit maximisation problems, we obtain the following first-order conditions.[9]

$$w = P_A(1+\tau_A)(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha}, \tag{4}$$

$$w = P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}, \tag{5}$$

$$r_A = P_A(1+\tau_A)(1+s_A)(1-\alpha) Z_A L_A^{\alpha} K_A^{-\alpha}, \tag{6}$$

$$r_C = P_C(1-\gamma) Z_C L_C^{\gamma} K_C^{-\gamma}. \tag{7}$$

The consumer's utility stems from the consumption of the two goods, denoted by Q_A and Q_C. We assume a standard Cobb-Douglas utility function as

$$U(Q_A, Q_C) = Q_A^{\nu} Q_C^{1-\nu}, \tag{8}$$

where $0 < \nu < 1$. Then the consumer's utility maximisation requires

$$\frac{Q_A}{Q_C} = \frac{\nu}{1-\nu} \frac{P_C}{P_A(1+\tau_A)}. \tag{9}$$

The consumer's budget constraint is given as

$$P_A(1+\tau_A)Q_A + P_C Q_C = wL_A + wL_C + r_A K_A + r_C K_C - T, \tag{10}$$

where T is a lump-sum tax, which is the difference between the value of Sector A subsidy and the tariff revenue. That relationship is equivalent to the government budget constraint which is given as

$$T = P_A(1+\tau_A)s_A Y_A - \tau_A P_A(Q_A - Y_A). \tag{11}$$

(1), (2), (4)–(7), (10), and (11) boil down to the balance-of-payment constraint, which is

$$P_A M_A = P_C X_C, \tag{12}$$

[9] Throughout this paper, we omit the second-order sufficient conditions for brevity as all our setups are standard and they are trivially satisfied.

where M_A and X_C are defined as

$$M_A \equiv Q_A - Y_A, \tag{13}$$

$$X_C \equiv Y_C - Q_C. \tag{14}$$

The equilibrium of the model is characterised by (1)-(9) and (12)-(14).

2.2 Welfare effects of a tariff policy

Let us examine the welfare effects of an increase in the import tariff, τ_A.[10] Partially differentiating $U(Q_A, Q_C)$ in (8) with respect to τ_A, we get

$$\begin{aligned} \frac{\partial U}{\partial \tau_A} &= \nu \left(\frac{Q_A}{Q_C}\right)^{\nu-1} \frac{\partial Q_A}{\partial \tau_A} + (1-\nu)\left(\frac{Q_A}{Q_C}\right)^{\nu} \frac{\partial Q_C}{\partial \tau_A} \\ &= \nu \left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu-1} \frac{\partial Q_A}{\partial \tau_A} + (1-\nu)\left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu} \frac{\partial Q_C}{\partial \tau_A}. \end{aligned} \tag{15}$$

The second equality follows from (9). The close examination of various terms leads to the following proposition.

Proposition 1. *In the two-sector model, an increase in the import tariff reduces welfare for any (non-negative) level of government subsidy.*

Proof. Except for the trivial case where there is no distortion ($\tau_A = s_A = 0$), we show that $\frac{\partial U}{\partial \tau_A} < 0$ for any $s_A \geq 0$ in Appendix B. □

There is a simple intuition behind this result. Initially, the economy is distorted by the two policies: the import tariff, τ_A, and the government subsidy, s_A. Both policies distort production by encouraging more labour to be allocated in Sector A than otherwise, where the former also distorts consumption by affecting the consumer relative price. A further increase in the import tariff works to distort both production and consumption in the

[10] Although our focus is the welfare effect of a *reduction* in a tariff, in the most of the text we will discuss the opposite, *i.e.* the welfare effect of an *increase* in a tariff. Focussing on the latter is less confusing as it is what the (partial) derivative of the maximised utility with respect to a tariff in question means.

same direction, in which case, it should have a negative welfare effect. Of course, as in the argument for protection à la Hagen (1958), an increase in τ_A could improve welfare if it alleviates an existing distortion. In our context, if s_A was (very) negative such that the initial production was biased towards Sector C, a marginal increase in τ_A would lead to an efficiency gain in production, and could increase the economy's welfare so long as the efficiency loss in consumption it created was smaller.

3 A model with two import-competing sectors

3.1 The setup

Let us add another import-competing sector, Sector B, to the two-sector model we developed in the previous section. Good B is produced in this sector, which is denoted as Y_B. The government protects this sector by imposing an import tariff, $\tau_B \geq 0$; however, there is no production subsidy in this sector. As in the previous section, Sector A is subject to both a tariff and a subsidy, and from this section onwards, the Sector A subsidy is assumed to be non-negative, that is, $s_A \geq 0$.

For Sector B, the specific factor and its price are denoted as K_B and r_B, respectively; labour allocated to this sector is L_B.

The production function of Sector B is given as

$$Y_B = Z_B L_B^{\beta} K_B^{1-\beta}, \tag{16}$$

where $0 < \beta < 1$ and Z_B is Sector B's TFP.

The Sector B producer's profit maximisation requires that the following first-order conditions be met.

$$w = P_B(1+\tau_B)\beta Z_B L_B^{\beta-1} K_B^{1-\beta}, \tag{17}$$

$$r_B = P_B(1+\tau_B)(1-\beta) Z_B L_B^{\beta} K_B^{-\beta}. \tag{18}$$

The labour market clearing condition is modified as

$$L_A + L_B + L_C = \overline{L}. \tag{19}$$

We continue to assume Cobb-Douglas preferences for the consumer. Denoting the consumption of Good B as Q_B, the utility function is now given as

$$U(Q_A, Q_B, Q_C) = Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi}, \tag{20}$$

where $0 < \nu < 1$, $0 < \phi < 1$, and $0 < \nu+\phi < 1$. Then the consumer's utility maximisation requires

$$\frac{Q_A}{Q_B} = \frac{\nu}{\phi}\frac{P_B(1+\tau_B)}{P_A(1+\tau_A)}, \tag{21}$$

$$\frac{Q_B}{Q_C} = \frac{\phi}{1-\nu-\phi}\frac{P_C}{P_B(1+\tau_B)}. \tag{22}$$

The balance-of-payment constraint is now modified as

$$P_A M_A + P_B M_B = P_C X_C, \tag{23}$$

where

$$M_B \equiv Q_B - Y_B. \tag{24}$$

The equilibrium of this economy is characterised by (1), (2), (4)–(7), (13), (14), and (16)–(24).

3.2 Welfare effects of a tariff policy

Let us consider an increase in one of the tariffs to see how economic welfare is affected. We first examine the effect of a tariff increase that magnifies the highest existing distortion. Unsurprisingly increasing the tariff of this sort leads to lowering the economic welfare in our model, comforming to the well-established concertina rule in the literature. Then we examine the effect of an increase in the tariff of the less-distorted sector, which is our main interest. The complexity of the second-best problem makes it difficult to obtain a clear-cut result, but we illustrate some interesting regularities with the help of numerical simulations.

3.2.1 Magnifying the highest distortion

Consider an increase in τ_A. Taking the partial derivative of $U(Q_A, Q_B, Q_C)$ in (20) with respect to τ_A, we obtain

$$\frac{\partial U}{\partial \tau_A} = Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi} \left\{ \nu \frac{1}{Q_A} \frac{\partial Q_A}{\partial \tau_A} + \phi \frac{1}{Q_B} \frac{\partial Q_B}{\partial \tau_A} + (1-\nu-\phi) \frac{1}{Q_C} \frac{\partial Q_C}{\partial \tau_A} \right\}. \tag{25}$$

It turns out that there are sufficient conditions for the sign of this partial derivative to be negative, which are summarised in the following lemma.

Lemma 1. *(i) For any* $s_A > 0$,

$$\frac{\partial U}{\partial \tau_A} < 0 \quad \textit{if} \quad \phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B) \geq 0 \quad \textit{and} \quad (1+\tau_A)(1+s_A) \geq 1+\tau_B.$$

(ii) When $s_A = 0$,

$$\frac{\partial U}{\partial \tau_A} < 0 \quad \textit{if} \quad \tau_A \geq \tau_B \quad \textit{and} \quad \tau_A > 0.$$

Proof. See Appendix C. □

Lemma 1 (i) simply states that when the Sector A subsidy exists, if a marginal increase in τ_A magnifies both consumption and production inefficiencies (i.e. the existing distortions), it surely harms the economy. The left-hand side of the first inequality, $\phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B)$, represents an incremental consumption inefficiency caused by an increase in τ_A. It shows that as long as $\tau_A, \tau_B > 0$, a marginal increase in τ_A will always lead to further overconsumption of Good C, and if $\tau_A > \tau_B$, Good B's overconsumption is also raised.

The second inequality, $(1+\tau_A)(1+s_A) \geq 1+\tau_B$, relates to a production inefficiency. The two sides of the inequality represent the protection levels for Sectors A and B, respectively. Even if $\tau_B > \tau_A$, a high enough production subsidy in Sector A, $s_A > 0$, can make Sector A a more protected sector. Hence, this part of Lemma 1 (i) essentially states that as long as Sector A is protected no less than Sector B, an increase in τ_A leads to a further inefficiency in production.

Our interest is the case wherein $s_A > 0$, which is summarised in the following proposition (without proof, as it is a special case of Lemma 1).

Proposition 2. *For any $s_A > 0$,*

$$\frac{\partial U}{\partial \tau_A} < 0 \quad \textit{if} \quad \tau_A \geq \tau_B.$$

Because $s_A > 0$, as long as $\tau_A \geq \tau_B$, Sector A is more protected than Sector B. Also, $\tau_A \geq \tau_B$ implies that the first inequality condition in Lemma 1 (i) will be trivially met. It is because a marginal increase in τ_A magnifies an inefficiency in consumption as it leads to overconsumption in both Good B and Good C, as long as $\tau_A \geq \tau_B$. Therefore, it suffices to have $\tau_A \geq \tau_B$ for a marginal increase in τ_A to be harmful when $s_A > 0$.

Lemma 1 (ii) is the case under which the two tariffs are the only distortions. In this case, $\frac{\partial U}{\partial \tau_A} < 0$ if $\tau_A \geq \tau_B$ and $\tau_A > 0$, meaning that a marginal increase in the highest tariff reduces the welfare of the economy. Hence, we have demonstrated that the well-known concertina rule (*e.g.* Hatta, 1977a) holds in our specific factor model with two import-competing sectors.

An increase in τ_B can be examined in a similar fashion. Taking the partial derivative of $U(Q_A, Q_B, Q_C)$ in (20) with respect to τ_B,

$$\frac{\partial U}{\partial \tau_B} = Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi} \left\{ \nu \frac{1}{Q_A} \frac{\partial Q_A}{\partial \tau_B} + \phi \frac{1}{Q_B} \frac{\partial Q_B}{\partial \tau_B} + (1-\nu-\phi) \frac{1}{Q_C} \frac{\partial Q_C}{\partial \tau_B} \right\}. \tag{26}$$

The next lemma states the sufficient condition for an increase in τ_B to be harmful.

Lemma 2. *(i) For any* $s_A > 0$,

$$\frac{\partial U}{\partial \tau_B} < 0 \quad \textit{if} \quad \nu(\tau_B - \tau_A) + (1 - \nu - \phi)(1 + \tau_A)\tau_B > 0 \quad \textit{and} \quad 1 + \tau_B \geq (1 + \tau_A)(1 + s_A).$$

(ii) When $s_A = 0$,

$$\frac{\partial U}{\partial \tau_B} < 0 \quad \textit{if} \quad \tau_B \geq \tau_A \quad \textit{and} \quad \tau_B > 0.$$

Proof. See Appendix D. □

Lemma 2 (i) has exactly the same interpretation as Lemma 1 (i); namely, when $s_A > 0$, it is sufficient for the economic welfare to fall if the rise in τ_B creates an efficiency loss in consumption ($\nu(\tau_B - \tau_A) + (1 - \nu - \phi)(1 + \tau_A)\tau_B > 0$) and if Sector B is at least as protected as Sector A even considering the subsidy in that sector ($(1 + \tau_B) \geq (1 + \tau_A)(1 + s_A)$). In fact, when $s_A > 0$, the latter condition implies $\tau_B > \tau_A$, which means that the condition on the consumption inefficiency becomes redundant (*i.e.* trivially met). Consequently Lemma 2 collapses to the following proposition.

Proposition 3. *For any* $s_A > 0$,

$$\frac{\partial U}{\partial \tau_B} < 0 \quad \textit{if} \quad 1 + \tau_B \geq (1 + \tau_A)(1 + s_A).$$

Propositions 2 and 3 illustrate that when one of the import-competing sectors is more distorted than the other — in terms of both consumption and production — increasing the tariff of the former sector (i.e. magnifying the distortions) is harmful to the economy. Our next question is what happens if the other tariff is increased?

3.2.2 A change in the tariff of the less-distorted sector

Unfortunately, the complexity of the second-best problem prevents us from obtaining as clear-cut results as those we previously obtained. However, the following numerical examples illustrate fairly robust patterns in the welfare effects, which are intuitively appealing. In the following, we examine $\frac{\partial U}{\partial \tau_B}$ for three economies. The following parameters values are fixed for the three economies: $\alpha = \beta = \gamma = 1/2$, $P_A = P_B = P_C = 1$, $Z_A = Z_B = Z_C = 1$, and $\tau_B = 0.05$. However, they differ in terms of capital stock endowments or consumer preferences. These details for the three economies are summarised in Table 3. We examine each economy in turn.

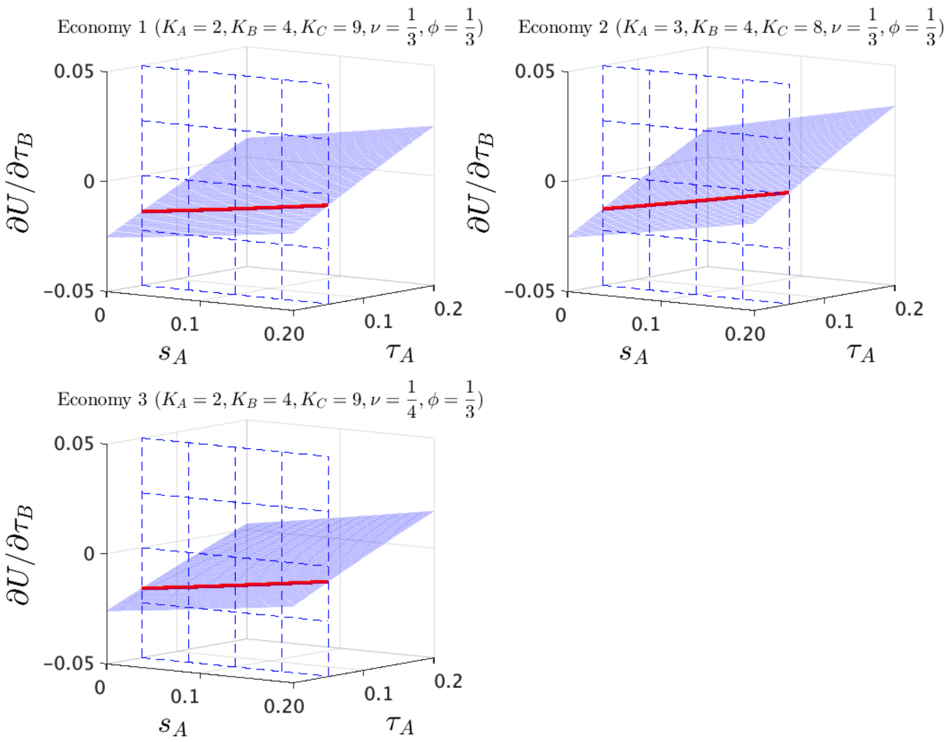
	Economy 1	Economy 2	Economy 3
K_A	2	3	2
K_B	4	4	4
K_C	9	8	9
ν	1/3	1/3	1/4
ϕ	1/3	1/3	1/3

Table 3: Parameter values for each economy

- **Economy 1**: $K_A = 2$, $K_B = 4$, $K_C = 9$, $\nu = 1/3$ and $\phi = 1/3$. The first 3D plot in Figure 2 illustrate the $\frac{\partial U}{\partial \tau_B}$ schedules for this benchmark economy, wherein the levels of subsidy in Sector A (s_A) and the tariff in Sector A (τ_A) are measured on the two horizontal axes. From the diagram, we can gather that the $\frac{\partial U}{\partial \tau_B}$ plot is sloped upwards, meaning that the welfare effect of a marginal increase in τ_B is more likely to be positive as Sector A's distortion becomes greater.

  In fact, the first diagram in Figure 3 illustrates it more clearly, describing a set of contour plots for this economy wherein those to northeast correspond to higher levels of $\frac{\partial U}{\partial \tau_B}$. The downward sloping contours show substitutability between the two policy tools to protect Sector A: τ_A and s_A. In other words, if one policy tool — say τ_A — is fixed to protect Sector A, then $\frac{\partial U}{\partial \tau_B}$ increases as the other policy tool

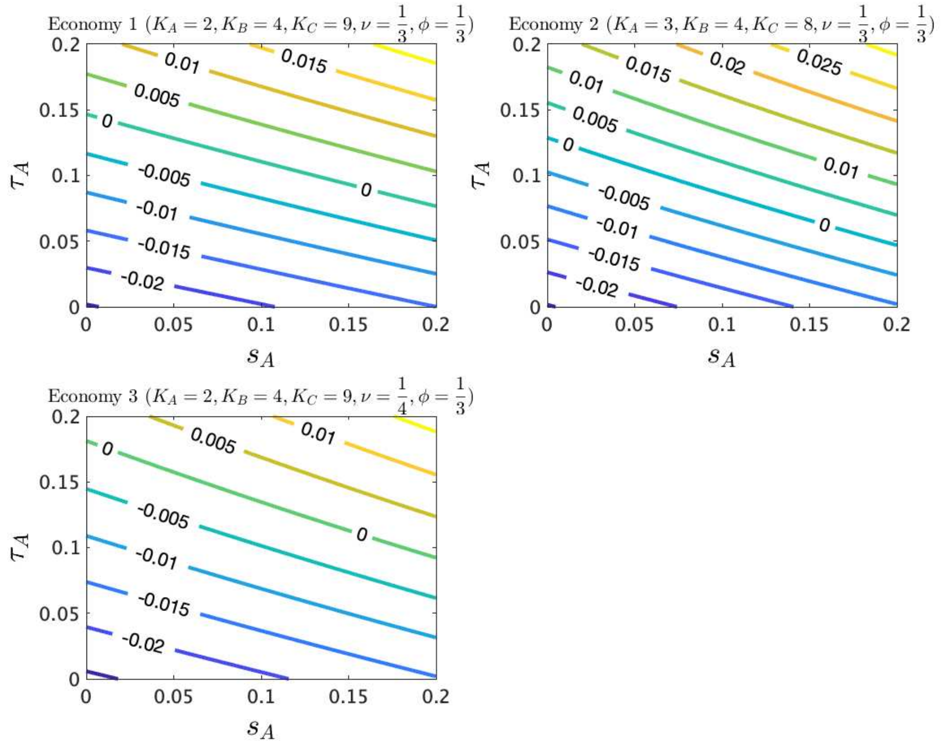
— s_A — rises. The bold red curve in the first diagram in Figure 2 illustrates this relationship when $\tau_A = 0.05$.



Note: These 3D plots illustrate the welfare effect of a marginal increase in τ_B for combinations of (τ_A, s_A) for Economies 1, 2 and 3, respectively. The red curve in each diagram shows that the welfare effect is increasing in s_A when $\tau_A = 0.05$. For each economy, other than the parameter values explicitly mentioned in Table 3, the following values are used: $\alpha = \beta = \gamma = 1/2$, $P_A = P_B = P_C = 1$, $Z_A = Z_B = Z_C = 1$, and $\tau_B = 0.05$.

Figure 2: The effect of a marginal increase in τ_B on the welfare: 3D plot

- **Economy 2**: $K_A = 3$, $K_B = 4$, $K_C = 8$, $\nu = 1/3$ and $\phi = 1/3$. The second diagrams in Figures 2 and 3 correspond to this economy. In this exercise, we altered Economy 1's capital stock endowment so that Economy 2 is more evenly allocated between the sectors. Compared with Economy 1, Economy 2 has more (less) capital stock in Sector A (C, respectively). Hence, we can expect that adding an extra distortion to Sector B will have a greater effect in alleviating Sector A's inefficiency in *production*. Indeed, the 3D plot for Economy 2 in Figure 2 is positioned above



Note: These diagrams illustrate contour maps of the welfare effect of a marginal increase in τ_B for combinations of (τ_A, s_A) for Economies 1, 2 and 3, respectively. The values on each of the contours indicate the levels of $\frac{\partial U}{\partial \tau_B}$. For each economy, other than the parameter values explicitly mentioned in Table 3, the following values are used: $\alpha = \beta = \gamma = 1/2$, $P_A = P_B = P_C = 1$, $Z_A = Z_B = Z_C = 1$, and $\tau_B = 0.05$.

Figure 3: The effect of a marginal increase in τ_B on the welfare: Contour map

that for Economy 1. The contour map for Economy 2 in Figure 3 exhibits a negative relationship between τ_A and s_A as in Economy 1, showing that $\frac{\partial U}{\partial \tau_B}$ is increasing in one of them, given a particular level of the other. The bold red curve in the second diagram in Figure 2 illustrates this relationship for Economy 2 when $\tau_A = 0.05$, which lies above its counterpart for Economy 1.

- **Economy 3**: $K_A = 2$, $K_B = 4$, $K_C = 9$, $\nu = 1/4$ and $\phi = 1/3$. The third diagrams in Figures 2 and 3 corresponds to this economy. In this instance, we changed Economy 1's preferences so that Economy 3's expenditure share of Good A (C) is smaller (larger, respectively). Hence, in comparison with Economy 1, we can expect that adding an extra distortion to Sector B will have a smaller effect in alleviating Sector A's inefficiency in *consumption*. As expected, the 3D plot for Economy 3 in Figure 2 is positioned below that for Economy 1. The contour map for Economy 3 in Figure 3 exhibits a negative relationship between τ_A and s_A as in Economies 1 and 2. The bold red curve in the third diagram in Figure 2 illustrates this relationship for Economy 3 when $\tau_A = 0.05$, which lies below its counterpart for Economy 1.

All in all, fairly robust relationships emerge from our numerical exercises. The upward sloping $\frac{\partial U}{\partial \tau_B}$ plots in these simulations suggest that the welfare effect of a policy to change τ_B depends positively on the production subsidy in Sector A, s_A, as well as the Sector A tariff, τ_A. Given a particular τ_A, the welfare effect of a change in τ_B is increasing in s_A (and vice versa). Our findings imply that the sign of the welfare effect could be reversed by manipulating τ_A and/or s_A. Focussing on Economy 1, for example, when $s_A = 0.2$, a marginal *decrease* in τ_B is a welfare-improving policy if $\tau_A = 0.05$, but it is a harmful policy if $\tau_A = 0.1$.

If τ_B is to be lowered, should τ_A be lowered together (if changing s_A is not an option)? If so, how much reduction is necessary in τ_A to make the tariff policy beneficial? They are quantitative questions that depend on the current levels of τ_A and s_A, which can be only addressed using the real data. In the next section, we quantitatively assess the welfare effect of a policy to remove τ_B using the data of the 2015 Japanese economy.

4 The welfare effect for the 2015 Japanese economy

First, we extend the model to include the non-traded goods sector, which accounts for roughly 78 (81) per cent of the Japanese economy in terms of value added (worker hours, respectively). Also, Sectors A, B, and C are further divided into 2, 4, and 1 subsector(s), respectively. We denote the non-traded sector as N, which is divided into 6 subsectors.

4.1 A 13-sector model

For each of the subsectors, the production function is given as

$$Y_{A,ia} = Z_{A,ia} L_{A,ia}^{\alpha_{ia}} K_{A,ia}^{1-\alpha_{ia}}, \quad \text{for } ia = 1, 2, \tag{27}$$

$$Y_{B,ib} = Z_{B,ib} L_{B,ib}^{\beta_{ib}} K_{B,ib}^{1-\beta_{ib}}, \quad \text{for } ib = 1, ..., 4, \tag{28}$$

$$Y_{C,ic} = Z_{C,ic} L_{C,ic}^{\gamma_{ic}} K_{C,ic}^{1-\gamma_{ic}}, \quad \text{for } ic = 1, \tag{29}$$

$$Y_{N,in} = Z_{N,in} L_{N,in}^{\delta_{in}} K_{N,in}^{1-\delta_{in}}, \quad \text{for } in = 1, ..., 6, \tag{30}$$

where $Y_{h,ij}$, $Z_{h,ij}$, $L_{h,ij}$, and $K_{h,ij}$ ($h = A, B, C, N$ and $j = a, b, c, n$) are the output, TFP, labour, the specific factor of each subsector, respectively. α_{ia}, β_{ib}, γ_{ic}, and δ_{in} are the labour shares of each subsector, and we assume $0 < \alpha_{ia} < 1$, $0 < \beta_{ib} < 1$, $0 < \gamma_{ic} < 1$, and $0 < \delta_{in} < 1$.

Solving the producer's profit maximisation problem, we obtain the following first-order conditions.[11]

$$
\begin{aligned}
w &= P_{A,ia}(1+\tau_{A,ia})(1+s_{A,ia})\alpha_{ia}Z_{A,ia}L_{A,ia}^{\alpha_{ia}-1}K_{A,ia}^{1-\alpha_{ia}}, \quad \text{for } ia = 1,2, & (31)\\
w &= P_{B,ib}(1+\tau_{B,ib})\beta_{ib}Z_{B,ib}L_{B,ib}^{\beta_{ib}-1}K_{B,ib}^{1-\beta_{ib}}, \quad \text{for } ib = 1,...,4, & (32)\\
w &= P_{C,ic}\gamma_{ic}Z_{C,ic}L_{C,ic}^{\gamma_{ic}-1}K_{C,ic}^{1-\gamma_{ic}}, \quad \text{for } ic = 1, & (33)\\
w &= P_{N,in}\delta_{in}Z_{N,in}L_{N,in}^{\delta_{in}-1}K_{N,in}^{1-\delta_{in}}, \quad \text{for } in = 1,...,6, & (34)
\end{aligned}
$$

where $P_{h,ij}(h = A, B, C$ and $j = a, b, c)$ is the international price of goods produced in each subsector in Sectors A, B, and C; $P_{N,in}$ is the price of goods produced in each subsector in Sector N; $\tau_{A,ia}$ and $\tau_{B,ib}$ are the levels of ad valorem tariff of each subsector in Sector A and B, respectively; and $s_{A,ia}$ is the subsidy rate of each subsector in Sector A.

The labour market clearing condition is rewritten as

$$\sum_{ia=1}^{2} L_{A,ia} + \sum_{ib=1}^{4} L_{B,ib} + \sum_{ic=1}^{1} L_{C,ic} + \sum_{in=1}^{6} L_{N,in} = \overline{L}. \tag{35}$$

Denoting the consumption of goods produced by each subsector as $Q_{A,ia}$, $Q_{B,ib}$, $Q_{C,ic}$, and $Q_{N,in}$, respectively, the utility function is modified as

$$
\begin{aligned}
& U(Q_{A1}, Q_{A2}, Q_{B1}, ..., Q_{B4}, Q_{C1}, Q_{N1}, ..., Q_{N6}) \\
&= \prod_{ia=1}^{2} Q_{A,ia}^{\nu_{ia}} \prod_{ib=1}^{4} Q_{B,ib}^{\phi_{ib}} \prod_{ic=1}^{1} Q_{C,ic}^{\omega_{ic}} \prod_{in=1}^{6} Q_{N,in}^{\psi_{in}},
\end{aligned} \tag{36}
$$

where $0 < \nu_{ia} < 1$, $0 < \phi_{ib} < 1$, $0 < \omega_{ic} < 1$, $0 < \psi_{in} < 1$, and $\sum_{ia=1}^{2} \nu_{ia} + \sum_{ib=1}^{4} \phi_{ib} +$

[11] The equivalent conditions for r for each of the subsectors are inessential for the rest of the analysis and hence are not presented here in the interest of brevity.

$\sum_{ic=1}^{1} \omega_{ic} + \sum_{in=1}^{6} \psi_{in} = 1$. The consumer's utility maximisation requires

$$\frac{Q_{A,ia}}{Q_{N,1}} = \frac{\nu_{ia}}{\psi_1} \frac{P_{N,1}}{P_{A,ia}(1+\tau_{A,ia})}, \quad \text{for } ia = 1, 2, \tag{37}$$

$$\frac{Q_{B,ib}}{Q_{N,1}} = \frac{\phi_{ib}}{\psi_1} \frac{P_{N,1}}{P_{B,ib}(1+\tau_{B,ib})}, \quad \text{for } ib = 1, ..., 4, \tag{38}$$

$$\frac{Q_{C,ic}}{Q_{N,1}} = \frac{\omega_{ic}}{\psi_1} \frac{P_{N,1}}{P_{C,ic}}, \quad \text{for } ic = 1, \tag{39}$$

$$\frac{Q_{N,in}}{Q_{N,1}} = \frac{\psi_{in}}{\psi_1} \frac{P_{N,1}}{P_{N,in}}, \quad \text{for } in = 2, ..., 6. \tag{40}$$

The market-clearing conditions for subsectors in Sector N are given as

$$Y_{N,in} = Q_{N,in}, \quad \text{for } in = 1, ..., 6. \tag{41}$$

The balance-of-payment constraint is rewritten as

$$\sum_{ia=1}^{2} P_{A,ia} M_{A,ia} + \sum_{ib=1}^{4} P_{B,ib} M_{B,ib} = \sum_{ic=1}^{1} P_{C,ic} X_{C,ic} \tag{42}$$

where $M_{A,ia}$ and $M_{B,ib}$ are the imports and $X_{C,ic}$ the export.

4.2 Data and specification of model parameters

4.2.1 Data

We obtain sectoral Japanese data for 2015 from JIP Database 2021 (Research Institute of Economy, Trade and Industry, 2021). Table 6 in Appendix A shows how we have converted the 100 sectors in its input-output (IO) table in to our 13 sectors.[12] As for $\tau_{A,ia}$ and $\tau_{B,ib}$, we have used the tariff figures in World Tariff Profiles 2016 (WTO, ITC and UNCTAD, 2016) and calculated the average tariff rate of each of our subsectors, which are summarised in Table 7 in Appendix A.

[12]The following 9 sectors from the IO table are omitted: 'Prepared animal foods and organic fertilizers,' 'Miscellaneous business oriented machinery,' 'Ordnance,' 'Printing,' 'Furniture and fixtures,' 'Watches and clocks,' 'Miscellaneous manufacturing industries,' 'Housing,' 'Activities not elsewhere classified.' Our data cover roughly 90 per cent of the Japanese economy in terms of value added.

4.2.2 Specification of model parameters

Our specification of model parameters follows three main procedures. First, we determine the values of the parameters that do not rely on the solution of the model. These include tariff rates ($\tau_{A,ia}$ and $\tau_{B,ib}$), the share of labour in each sector (α_{ia}, β_{ib}, γ_{ic}, and δ_{in}), prices of the goods ($P_{A,ia}$, $P_{B,ib}$, and $P_{C,ic}$), the aggregate quantity of labour in the economy ($\overline{L}$), the levels of capital in each sector ($K_{A,ia}$, $K_{B,ib}$, $K_{C,ic}$, and $K_{N,in}$), and the preference parameters of Sector N (ψ_{in}). We also set the levels of TFP of each sector ($Z_{A,ia}$, $Z_{B,ib}$, $Z_{C,ic}$, and $Z_{N,in}$) using the production functions. Next, the rates of production subsidy in Sector A ($s_{A,ia}$) is calibrated using the first-order conditions of the producer's profit maximisation problem, (31). Finally, we calibrate the preference parameters of Sectors A, B, and C (ν_{ia}, ϕ_{ib}, and ω_{ic}) to minimise the sum of squared differences between implied sectoral ratios of imports or exports to value added in data and our model. More details on above procedures are explained in the rest of this subsection whilst the values of the pre-determined and calibrated parameters are provided in Table 4.

To determine α_{ia}, β_{ib}, γ_{ic}, and δ_{in}, we are guided by the following definition of the labour share in Fukao and Makino (2021):

$$\text{Labour share} = \frac{\text{Nominal Labour Cost}}{\text{Nominal Value Added – Net Indirect Tax}}.$$

For nominal labour cost, nominal value added, and net indirect tax (defined as "indirect tax minus subsidies"), we use the data provided by JIP Database 2021 (Research Institute of Economy, Trade and Industry, 2021).

We assume $P_{A,ia}$, $P_{B,ib}$, and $P_{C,ic}$ to be unity; $\overline{L}$ is also normalised to one without loss of generality. Accordingly we also normalise $K_{A,ia}$, $K_{B,ib}$, $K_{C,ic}$, and $K_{N,in}$ by dividing the real net capital stock of each sector by the total worker hours of 13 sectors. $\psi_{N,in}$ is assumed to be the same as the share of household final consumption in each of the subsectors in Sector N.

Given the pre-determined parameters described above, $Z_{A,ia}$, $Z_{B,ib}$, $Z_{C,ic}$, and $Z_{N,in}$ are calculated using the production functions, (27)–(30) given the data of the value added, the

Tariff rates										
$\tau_{A,1}$	$\tau_{A,2}$	$\tau_{B,1}$	$\tau_{B,2}$	$\tau_{B,3}$	$\tau_{B,4}$					
0.151	0.008	0.057	0.013	0.080	0.007					
Shares of labour										
α_1	α_2	β_1	β_2	β_3	β_4	γ_1	δ_1	δ_2	δ_3	δ_4
0.45	0.66	0.65	0.45	0.66	0.20	0.53	0.71	0.59	0.41	0.34
δ_5	δ_6									
0.43	0.75									
Levels of capital										
$K_{A,1}$	$K_{A,2}$	$K_{B,1}$	$K_{B,2}$	$K_{B,3}$	$K_{B,4}$	$K_{C,1}$	$K_{N,1}$	$K_{N,2}$	$K_{N,3}$	$K_{N,4}$
0.26	0.07	0.02	0.78	0.07	0.04	1.02	1.73	0.54	0.09	0.63
$K_{N,5}$	$K_{N,6}$									
1.46	5.38									
Preference parameters of Sector N										
ψ_1	ψ_2	ψ_3	ψ_4	ψ_5	ψ_6					
0.034	0.193	0.074	0.060	0.083	0.308					
Production subsidies in Sector A										
$s_{A,1}$	$s_{A,2}$									
0.62	0.04									
Levels of TFP										
$Z_{A,1}$	$Z_{A,2}$	$Z_{B,1}$	$Z_{B,2}$	$Z_{B,3}$	$Z_{B,4}$	$Z_{C,1}$	$Z_{N,1}$	$Z_{N,2}$	$Z_{N,3}$	$Z_{N,4}$
1.14	1.66	1.25	1.36	1.40	2.02	1.62	1.34	2.47	4.55	0.93
$Z_{N,5}$	$Z_{N,6}$									
0.84	1.89									
Preference parameters of Sectors A, B and C										
ν_1	ν_2	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ω_1				
0.0465	0.0077	0.0017	0.1216	0.0093	0.0177	0.0435				

Table 4: Predetermined and calibrated parameters

share of labour, the amount of labour, and the level of capital in each sector. The rate of production subsidy in Sector A ($s_{A,ia}$) is calibrated using the first-order conditions of the producer's profit maximisation problem, (31). For w, we use the average compensation per 1000 worker hours computed using the data of compensation of employees obtained from the IO table and the data of worker hours.

Finally, we calibrate ν_{ia}, ϕ_{ib}, and ω_{ic} to minimise the sum of squared differences between the actual sectoral ratios of imports or exports to value added and those implied by the model:

$$\sum_{ia=1}^{2}\left(\frac{M_{A,ia}}{Y_{A,ia}}-\text{Target}_{A,ia}\right)^2+\sum_{ib=1}^{4}\left(\frac{M_{B,ia}}{Y_{B,ib}}-\text{Target}_{B,ib}\right)^2+\left(\frac{X_{C,1}}{Y_{C,1}}-\text{Target}_{C,1}\right)^2,$$

where $\text{Target}_{A,ia}$, $\text{Target}_{B,ib}$ and $\text{Target}_{C,1}$ are the actual sectoral ratios of imports or exports to value added implied by the data.

4.3 The effect of the partial tariff removal

Based on the calibrated parameters, we can obtain the short-run welfare effect of removing all the Sector B tariffs. Table 5 and Figure 4 summarise the results of our main experiment along with some counterfactual exercises. We examine each of them in turn.

Our main scenario in Table 5 involves the elimination of all the Sector B tariffs ($\tau_{B,ib} = 0$ for $ib = 1, ..., 4$) keeping all Sector A distortions intact. The results reveal that this policy is harmful to the Japanese economy. The equivalent variation of the policy is 82 billion Japanese Yen, which is around 0.02 per cent of Japanese GDP (in our data). Although this figure per se is not significant by any means, the fact that the policy is harmful indicates existing severe distortion stemming from the heavy Sector A protection.

One way to appreciate the significance of this distortion is examining the welfare effect of eliminating the Sector B tariffs *at the same time* reducing all the Sector A tariffs equiproportionally. Denoting the proportional reduction as x, the Sector A tariffs in this counterfactual (CF1) can be written as $\tau_{A,ia}(1-x)$ for $ia = 1, 2$. CF1 is in line with the spirit of the TPP, wherein the tariff lines for many agricultural items are to be gradually

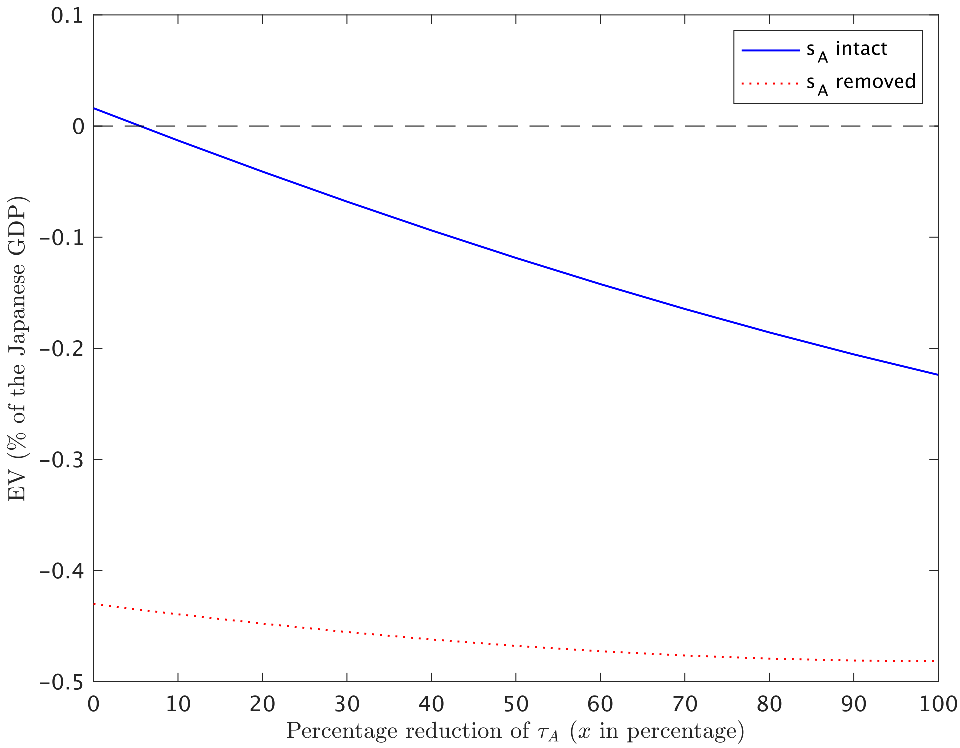
	Sector A		Sector B	EV (% of GDP) against
	Tariffs	Subsidies	Tariffs	No policy
No policy	Yes	Yes	Yes	—
Main	Intact	Intact	Remove	0.02
CF1	−6%	Intact	Remove	0.00
CF1	−100%	Intact	Remove	−0.22
No policy	Yes	Yes	Yes	—
CF2	Intact	Remove	Remove	−0.43
CF2	−100%	Remove	Remove	−0.48

Note: In our main calibration (Main), all the tariffs and subsidies in Sector A are kept intact but all the Sector B tariffs are removed. EV is the equivalent variation of the policy showing a reduction in income that would achieve the same welfare if the policy did not occur. The positive sign of EV indicates that the policy is equivalent to an income reduction. The first counterfactual (CF1) shows that sector A tariff reduction and EV are negatively related. When the Sector B tariff removal is accompanied by the Sector A tariff removal, EV is equal to −0.22% of the Japanese GDP. The second counterfactual (CF2) examines the effect of the Sector A *subsidy* removal, for different levels of Sector A tariff reduction.

Table 5: The short-run welfare effect of removing the Sector B tariff

removed over time. The result of CF1 is described by a solid curve in Figure 4, and those for particular cases are also presented in Table 5.

In Figure 4, the welfare effect, measured in percentage of the Japanese GDP, is on the vertical axis and the percentage reduction rates in the Sector A tariffs are measured on the horizontal axis. The vertical intercept of the solid curve (0.02) shows the welfare effect (EV) of eliminating the Sector B tariffs when the Sector A tariffs are kept intact, which is the EV of our main experiment presented in Table 5. As anticipated, the welfare effect (EV) is negatively related to the reduction in τ_A and turns negative when τ_A is reduced equi-proportionally by 6%. It is noteworthy that when τ_A is completely removed, the EV decreases to −0.22% of the Japanese GDP, which is within the range of the TPP effects reported in the existing literature. For example, Gilbert et al. (2018) estimate that the annual welfare effect of the TPP, when tariff eliminations/reductions proceed as agreed (when tariffs are fully removed), is 0.31% (0.48%, respectively) of the Japanese GDP in the long run. Our counterfactual result illustrates a massive distortion caused



Note: The curves illustrate the welfare effect of eliminating τ_B when it is accompanied by different percentage reductions in τ_A. The solid (dotted) curve corresponds to the scenario in which the Sector A subsidy is kept intact (fully removed, respectively).

Figure 4: CF1 and CF2: Counterfactual welfare effect of a τ_B removal on the Japanese economy for different percentage reductions in τ_A

by the huge differences in sectoral tariff protections, suggesting the critical importance of eliminating/reducing the Sector A tariffs in order for Japan to enjoy the benefit of the Sector B tariff removal policy.

To further identify the distortion in Sector A, we also conducted our second counterfactual (CF2), wherein CF1 is combined with complete removal of the Sector A subsidies. The welfare effect of CF2 is described in the dotted curve in Figure 4. As anticipated, the dotted curve lies below the solid one. The vertical intercept of the dotted curve corresponds to the case wherein Sector B tariffs and Sector A subsidies are both completely removed but Sector A tariffs remain intact. The EV is -0.43% of the Japanese GDP. Given that the EV of the across-the-board tariff elimination is -0.22% of the Japanese GDP, this result indicates that the provision of the subsidies is the predominant source of Sector A distortion.

As Sector A tariffs are reduced, the gap between the two curves become narrower in Figure 4. It shows that the welfare effect of removing Sector A subsidies becomes gradually less important as Sector A tariffs are reduced. Hence, removing Sector A subsidies is especially effective when the process of Sector A tariff removal is sluggish. However, even when Sector A tariffs are 100% removed, completely removing Sector A subsidy still contributes to decreasing the EV by 0.26 percentage points of the Japanese GDP (from -0.22% to -0.48%), which consolidates our previous finding on the severity of the distortion created by Sector A subsidies.

In summary, our findings from CF2 are: (i) the Sector A distortion in question predominantly stems from the provision of subsidies rather than heavy tariff protection; and (ii) the reductions/removals of Sector A subsidy could be an effective welfare-improving policy especially during the early stages of the gradual reduction in the tariff rates of Sector A import items.

5 Conclusion

Agricultural producer support in Japan is distinctive in terms of both imposed tariffs on agricultural products and government subsidies, whereas both forms of protection in other import-competing sectors are rather modest. To incorporate these characteristics of the Japanese economy, we constructed a specific factor model that has multiple import-competing sectors, all of which are protected by tariffs, but only some of them enjoy production subsidies. Perhaps, often politically, because it would be quite costly to reduce protection in heavily protected sectors, a general movement towards free trade tends to result in tariff reductions in only modestly protected sectors, which we consider to have been the outcome of recent TPP negotiations. We calibrated our model to the 2015 Japanese economy to understand the short-run welfare effect of such a partial tariff removal policy.

Our main counterfactual result suggests that the partial tariff removal policy has almost no welfare effect on the Japanese economy. The welfare loss of removing all the tariffs other than those for agriculture is revealed to be equivalent to 0.02 per cent of the Japanese GDP. This figure is extremely small in comparison with the medium- and long-run benefits reported in existing studies examining the welfare effects of the TPP. We also demonstrated that this policy, if accompanied by tariff eliminations/reductions in the agricultural sector, is beneficial to the Japanese economy, resulting in a gain equivalent to 0.22 per cent of the Japanese GDP for the full reduction. These exercises highlight the significance of the existing heavy distortion caused by the difference in import protection across sectors, which in turn suggests the importance of smoothly carrying out the gradual elimination/reduction of tariff rates of the agricultural import items. The existing distortion matters. Merely removing the tariffs of the non-agricultural items will create no benefit at all (or will be marginally harmful).

We also demonstrated that reducing the subsidies given to the agricultural sector is effective for alleviating the distortion especially when the tariff rates of agricultural items are still high. Indeed, complete removal of the subsidy from the agricultural sector has a greater welfare effect than complete tariff removals on agricultural items. However, given that the Japanese government has been introducing a variety of subsidy programmes, one after another, to agro-producers, it may be politically more difficult to even reduce the subsidies, let alone removing them.[13] If the subsidy reduction is not a realistic alternative, it becomes even more important that the gradual tariff elimination/reduction will be smoothly implemented.

Our specific factor model is tractable, which aids in clearly following and interpreting our calibration results. However, the use of a simple economic model imposes some limitations. For example, a specific factor model assumes a set of fixed international prices, *i.e.* the country in question is considered a small open economy, but whether it is applicable to Japan is debatable. A similar analysis can be conducted by constructing a two-country model, wherein the prices of the traded-goods are also endogenously determined, but the result could be difficult to interpret. A set of fixed international prices also implies that no tariff change has occurred elsewhere. Of course, in reality, trade policy negotiations occur with other economies, and our setup is restricted to examining a unilateral tariff reform. These agenda are beyond the scope of the current paper and are left for future research.

[13]For example, in 2010 the Japanese government launched the initiation of 'Roku-ji Sangyo-ka' (Sixth Industrialization) of the agricultural sector, which encourages agro-producers to undertake not only production but also the processing and distribution of their products. Various supports are provided under this scheme, which include purchasing of machinery/facilities for processing/distribution and training sessions related to a range of subjects in agro-management.

References

Abe, Kenzo (1992) "Tariff Reform in a Small Open Economy with Public Production," *International Economic Review*, Vol. 33, pp. 209–22.

Anderson, James E. and J. Peter Neary (2007) "Welfare versus market access: The implications of tariff structure for tariff reform," *Journal of International Economics*, Vol. 71, pp. 187 – 205.

BBC Monitoring Asia Pacific (2011) "Opponents, supporters of Trans-pacific Partnership hold rallies in Japan capital," BBC Monitoring Asia Pacific – Political Supplied by BBC Worldwide Monitoring, October 26.

Bhagwati, Jagdish (1967) "Non-economic Objectives and the Efficiency Properties of Trade," *Journal of Political Economy*, Vol. 75, pp. 738–42.

Bhagwati, Jagdish and V. K. Ramaswami (1963) "Domestic Distortions, Tariffs and the Theory of Optimum Subsidy," *Journal of Political Economy*, Vol. 71, pp. 44–50.

Bruno, Michael (1972) "Market Distortions and Gradual Reform," *The Review of Economic Studies*, Vol. 39, pp. 373–83.

Cabinet Secretariat, Japan (2015) "TPP Kyotei no Keizai Koka Bunseki (Analysis of the Economic Effects of the TPP)," `http://www.cas.go.jp/jp/tpp/kouka/pdf/151224/151224_tpp_keizaikoukabunnseki02.pdf`, (Accessed on 27 August 2017).

Corden, W.M. (1984) "The normative theory of international trade," in R. W. Jones and P. B. Kenen eds. *Handbook of International Economics*, Vol. 1: Elsevier, pp. 63–130.

Diewert, W. E., A. H. Turunen-Red, and A. D. Woodland (1991) "Tariff Reform in a Small Open Multi-Household Economy with Domestic Distortions and Nontraded Goods," *International Economic Review*, Vol. 32, pp. 937–57.

Dixit, Avinash (1985) "Tax policy in open economies," in A. J. Auerbach and M. Feldstein eds. *Handbook of Public Economics*, Vol. 1: Elsevier, pp. 313–74.

Eaton, Jonathan and Samuel Kortum (2002) "Technology, Geography, and Trade," *Econometrica*, Vol. 70, pp. 1741–79.

Falvey, Rod and Udo Kreickemeier (2013) "The Theory of Trade Policy and Reform," in D. Bernhofen, R. Falvey, D. Greenaway, and U. Kreickemeier eds. *Palgrave Handbook of International Trade*: Palgrave Macmillan UK, pp. 265–94.

Foster, Edward and Hugo Sonnenschein (1970) "Price Distortion and Economic Welfare," *Econometrica*, Vol. 38, pp. 281–97.

Fukao, Kyoji and Tatsuji Makino (2021) "JIP deeta beesu 2021 futaihyou "sangyoubetsu roudou bumpairitsu · sangyoubetsu heikin maakuappuritsu" no sanshutsuhouhou ni tsuite (On the Calculation Method Used in JIP Database 2021 Supplementary Table "Industry-level Labour Share and Industry-level Average Markup Rate")," `https://www.rieti.go.jp/jp/database/JIP2021/data/jip2021_5-1_calc.pdf`, (Accessed on 18 August 2022).

Fukushima, Takashi (1979) "Tariff Structure, Nontraded Goods and Theory of Piecemeal Policy Recommendations," *International Economic Review*, Vol. 20, pp. 427–35.

Gilbert, John, Taiji Furusawa, and Robert Scollay (2018) "The economic impact of the Trans- Pacific Partnership: What have we learned from CGE simulation?," *The World Economy*, Vol. 41, pp. 831–65.

Hagen, Everett E. (1958) "An Economic Justification of Protectionism," *The Quarterly Journal of Economics*, Vol. 72, pp. 496–514.

Harimaya, Kozo, Koichi Kagitani, and Hirofumi Tominaga (2010) "Political Economy of Government Spending for Trade Liberalization: Politics of Agriculture Related Government Spending for the Uruguay Round in Japan," *Japanese Economic Review*, Vol. 61, pp. 159–74.

Hatta, Tatsuo (1977a) "A Recommendation for a Better Tariff Structure," *Econometrica*, Vol. 45, pp. 1859–69.

——— (1977b) "A Theory of Piecemeal Policy Recommendations," *The Review of Economic Studies*, Vol. 44, pp. 1–21.

Johnson, Harry G. (1966) "Factor Market Distortions and the Shape of the Transformation Curve," *Econometrica*, Vol. 34, pp. 686–98.

Jones, Ronald W. (1971a) "Distortions in Factor Markets and the General Equilibrium Model of Production," *Journal of Political Economy*, Vol. 79, pp. 437–59.

——— (1971b) "A Three-factor Model in Theory, Trade, and History," in J.N. Bhagwati, R.W. Jones, R.A. Mundell, and J. Vanek eds. *Trade, balance of payments and growth: papers in international economics in honor of Charles P. Kindleberger*: North-Holland, pp. 3–21.

Ju, Jiandong and Kala Krishna (2000) "Welfare and market access effects of piecemeal tariff reform," *Journal of International Economics*, Vol. 51, pp. 305–16.

Kagitani, Koichi and Kozo Harimaya (2017) "Electoral motives, constituency systems, ideologies, and a free trade agreement: The case of Japan joining the Trans-Pacific Partnership negotiations," *Journal of the Japanese and International Economies*, Vol. 45, pp. 51–66.

Lipsey, R. G. and Kelvin Lancaster (1956) "The General Theory of Second Best," *The Review of Economic Studies*, Vol. 24, pp. 11–32.

Ministry of Agriculture, Forestry and Fisheries (2016) "TPP ni okeru Norinsuisanbutsu Kanzei no Saishu Kekka (The final outcome of the TPP tariff negotiations on agricultural, forestry and fishery products)," `http://www.maff.go.jp/j/kokusai/tpp/pdf/1_kousyou_kekka_hs2012.pdf`, (Accessed on 23 August 2017).

——— (2020) "RCEP Norinsuisanbutsu Kanren no Goi Gaiyo (A summary of agreements of the RCEP tariff negotiations on agricultural, forestry and fishery products)," `https://www.maff.go.jp/j/kokusai/renkei/fta_kanren/f_rcep/attach/pdf/index-17.pdf`, (Accessed on 1 April 2022).

Ministry of Economy, Trade and Industry, Japan (2015) "Updated Input-Output Tables 2015," http://www.meti.go.jp/statistics/tyo/entyoio/result.html, (Accessed on 16 March 2020).

Mussa, Michael (1974) "Tariffs and the Distribution of Income: The Importance of Factor Specificity, Substitutability, and Intensity in the Short and Long Run," *Journal of Political Economy*, Vol. 82, pp. 1191–203.

OECD (2020) "Agricultural support (indicator)," doi:10.1787/6ea85c58-en, (Accessed on 14 August 2020).

Ohyama, Michihiro (1972) "Domestic Distortions and the Theory of Tariffs," *Keio Economic Studies*, Vol. 9, pp. 1–14.

Petri, Peter A. and Michael G. Plummer (2016) "The Economic Effects of the Trans-Pacific Partnership: New Estimates," Peterson Institute for International Economics, Working Paper 16-2.

Research Institute of Economy, Trade and Industry (2021) "JIP Database 2021," http://www.rieti.go.jp/en/database/JIP2021/index.html, (Accessed on 3 August 2022).

Swiecki, Tomasz (2017) "Intersectoral distortions and the welfare gains from trade," *Journal of International Economics*, Vol. 104, pp. 138–56.

The Japan Times (2013) "LDP ranks, like-minded lobbies rally against TPP," The Japan Times, February 8.

Turunen-Red, Arja H. and Alan D. Woodland (1991) "Strict Pareto-Improving Multilateral Reforms of Tariffs," *Econometrica*, Vol. 59, pp. 1127–52.

Vousden, Neil (1990) *The Economics of Trade Protection*: Cambridge University Press.

World Trade Organization (2020) "Regional Trade Agreements: Facts and Figures," https://www.wto.org/english/tratop_e/region_e/region_e.htm#facts, (Accessed on 17 August 2020).

WTO, ITC and UNCTAD (2016) "World Tariff Profiles 2016," https://www.wto.org/english/res_e/publications_e/world_tariff_profiles16_e.htm, (Accessed on 13 August 2020).

Appendix A Sector classification

Table 6: Sectors in the JIP Database 2021 IO Table (Research Institute of Economy, Trade and Industry, 2021) and in our model

Sector No.	Sector name	Sector in our model
1	Agriculture	
6	Livestock products	
8	Flour and grain mill products	
9	Miscellaneous foods and related products	
10	Beverages	
12	Tobacco	A1
3	Forestry	
15	Pulp, paper, and coated and glazed paper	
16	Paper products	
53	Lumber and wood products	A2
4	Fisheries	
7	Seafood products	B1
5	Mining	
17	Chemical fertilizers	
18	Basic inorganic chemicals	
19	Basic organic chemicals	
20	Organic chemicals	
21	Pharmaceutical products	
22	Miscellaneous chemical products	
24	Coal products	
25	Glass and its products	
26	Cement and its products	
27	Pottery	
28	Miscellaneous ceramic, stone and clay products	
29	Pig iron and crude steel	
30	Miscellaneous iron and steel	
31	Smelting and refining of non-ferrous metals	
32	Non-ferrous metal products	
33	Fabricated constructional and architectural metal products	
34	Miscellaneous fabricated metal products	
55	Plastic products	B2
13	Textile products (except chemical fibers)	
14	Chemical fibers	
56	Rubber products	

Continued on next page

Sector No.	Sector name	Sector in our model
57	Leather and leather products	B3
23	Petroleum products	B4
35	General-purpose machinery	
36	Production machinery	
37	Office and service industry machines	
40	Semiconductor devices and integrated circuits	
41	Miscellaneous electronic components and devices	
42	Electrical devices and parts	
43	Household electric appliances	
44	Electronic equipment and electric measuring instruments	
45	Miscellaneous electrical machinery equipment	
46	Image and audio equipment	
47	Communication equipment	
48	Electronic data processing machines, digital and analog computer equipment and accessories	
49	Motor vehicles (including motor vehicles bodies)	
50	Motor vehicle parts and accessories	
51	Other transportation equipment	C1
60	Electricity	
61	Gas, heat supply	
62	Waterworks	
63	Water supply for industrial use	
64	Sewage disposal	
66	Construction	
67	Civil engineering	N1
68	Wholesale	
69	Retail	N2
82	Finance	
83	Insurance	N3
85	Real estate	N4
70	Railway	
72	Water transportation	
73	Air transportation	
74	Other transportation and packing	
78	Communications	
79	Broadcasting	N5
2	Agricultural services	
65	Waste disposal	
71	Road transportation	

Continued on next page

Sector No.	Sector name	Sector in our model
75	Mail	
76	Hotels	
77	Eating and drinking services	
80	Information services	
81	Image information, sound information and character information production	
86	Research	
87	Advertising	
88	Rental of office equipment and goods	
89	Automobile maintenance services	
90	Other services for businesses	
91	Public administration	
92	Education	
93	Medical service, health and hygiene	
94	Social insurance and social welfare	
95	Nursing care	
96	Entertainment	
97	Laundry, beauty and bath services	
98	Other services for individuals	
99	Membership organizations	N6

Table 7: Product groups in World Tariff Profiles 2016 (WTO, ITC and UNCTAD, 2016) and import-competing sectors in our model

Product group	Ave. tariff (%)	Import share (%)	Sector in our model
Animal products	10.7	1.6	
Dairy products	69.1	0.2	
Fruit, vegetables, plants	9.3	1.2	
Coffee, tea	13.8	0.4	
Cereals & preparations	31.1	1.3	
Oilseeds, fats & oils	5.4	0.8	
Sugars and confectionery	19.0	0.1	
Beverages & tobacco	14.1	1	
Other agricultural products	2.9	0.7	
	($\tau_{A1} = 0.151$)		A1
Wood, paper, etc.	0.8	3	
	($\tau_{A2} = 0.008$)		A2
Fish & fish products	5.7	1.9	
	($\tau_{B1} = 0.057$)		B1
Minerals & metals	1	23.7	
Chemicals	2.2	8.5	
	($\tau_{B2} = 0.013$)		B2
Textiles	5.4	1.9	
Clothing	9	3.7	
Leather, footware, etc.	8.9	1.7	
	($\tau_{B3} = 0.080$)		B3
Petroleum	0.7	19.4	
	($\tau_{B4} = 0.007$)		B4

Appendix B Proof of Proposition 1

Proof. (9), (12), (13), and (14) imply that Q_A is written as

$$Q_A = \frac{1}{P_A}\left\{\frac{\nu}{\nu + (1-\nu)(1+\tau_A)}\right\}(P_A Y_A + P_C Y_C). \tag{43}$$

It follows from (9) that Q_C is obtained as a function of Q_A as

$$Q_C = \frac{1-\nu}{\nu}\frac{P_A(1+\tau_A)}{P_C}Q_A. \tag{44}$$

Now we take the partial derivatives of Q_A and Q_C in (43) and (44) with respect to τ_A. Utilising (1), (2), and $\frac{\partial L_C}{\partial \tau_A} = -\frac{\partial L_A}{\partial \tau_A}$ implied by (3), we obtain

$$\begin{aligned}\frac{\partial Q_A}{\partial \tau_A} &= -\frac{1}{P_A}\frac{\nu(1-\nu)}{\{\nu + (1-\nu)(1+\tau_A)\}^2}\left(P_A Z_A L_A^{\alpha} K_A^{1-\alpha} + P_C Z_C L_C^{\gamma} K_C^{1-\gamma}\right)\\ &+\frac{1}{P_A}\left\{\frac{\nu}{\nu + (1-\nu)(1+\tau_A)}\right\}\frac{\partial L_A}{\partial \tau_A}\left(P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}\right),\end{aligned} \tag{45}$$

and

$$\begin{aligned}\frac{\partial Q_C}{\partial \tau_A} &= \frac{1}{P_C}\frac{\nu(1-\nu)}{\{\nu + (1-\nu)(1+\tau_A)\}^2}\left(P_A Z_A L_A^{\alpha} K_A^{1-\alpha} + P_C Z_C L_C^{\gamma} K_C^{1-\gamma}\right)\\ &+\frac{1}{P_C}\left\{\frac{(1-\nu)(1+\tau_A)}{\nu + (1-\nu)(1+\tau_A)}\right\}\frac{\partial L_A}{\partial \tau_A}\left(P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}\right).\end{aligned} \tag{46}$$

Substituting (45) and (46) into (15), it follows that

$$\begin{aligned}\frac{\partial U}{\partial \tau_A} = \quad & -\frac{\nu^2(1-\nu)\tau_A}{P_A(1+\tau_A)\{\nu + (1-\nu)(1+\tau_A)\}^2}\left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu-1}\\ & \times\left(P_A Z_A L_A^{\alpha} K_A^{1-\alpha} + P_C Z_C L_C^{\gamma} K_C^{1-\gamma}\right)\\ & +\frac{\nu}{P_A\{\nu + (1-\nu)(1+\tau_A)\}}\left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu-1}\frac{\partial L_A}{\partial \tau_A}\\ & \times\left(P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}\right),\end{aligned} \tag{47}$$

where $-\frac{\nu^2(1-\nu)\tau_A}{P_A(1+\tau_A)\{\nu+(1-\nu)(1+\tau_A)\}^2}\left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu-1} \leq 0$ and $\frac{\nu}{P_A\{\nu+(1-\nu)(1+\tau_A)\}}\left\{\frac{\nu}{1-\nu}\frac{P_C}{P_A(1+\tau_A)}\right\}^{\nu-1} > 0$ since $0 < \nu < 1$. It is straightforward to see that $P_A Z_A L_A^{\alpha} K_A^{1-\alpha} + P_C Z_C L_C^{\gamma} K_C^{1-\gamma} > 0$. Therefore, to analyse the sign of (47), we are now left with analysing the sign of $\frac{\partial L_A}{\partial \tau_A}$ and $P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}$.

The sign of $\frac{\partial L_A}{\partial \tau_A}$ follows from an implicit function of L_A. Due to the wage equalisation, (3), (4), and (5) yield

$$P_A(1+\tau_A)(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C (\overline{L} - L_A)^{\gamma-1} K_C^{1-\gamma} = 0, \tag{48}$$

where the left hand side is an implicit function of L_A. Setting the left hand side as $f(L_A, \tau_A)$, and using the implicit function theorem,

$$\frac{\partial L_A}{\partial \tau_A} = -\frac{f_{\tau_A}}{f_{L_A}}, \tag{49}$$

where

$$f_{\tau_A} = P_A(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} > 0 \text{ when } s_A \geq 0,$$

and

$$f_{L_A} = P_A(1+\tau_A)(1+s_A)\alpha(\alpha-1) Z_A L_A^{\alpha-2} K_A^{1-\alpha} + P_C \gamma(\gamma-1) Z_C (\overline{L} - L_A)^{\gamma-2} K_C^{1-\gamma} < 0,$$

where the inequality follows from $0 < \alpha < 1$ and $0 < \gamma < 1$. Therefore, $\frac{\partial L_A}{\partial \tau_A} > 0$.

Next, due to the wage equalisation, (4) and (5) straightforwardly yield

$$P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma} = -P_A\left(\tau_A + s_A + \tau_A s_A\right)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \leq 0, \tag{50}$$

when $\tau_A + s_A + \tau_A s_A \geq 0$.

Collectively, it follows that

$$\frac{\partial U}{\partial \tau_A} \leq 0, \tag{51}$$

when $\tau_A + s_A + \tau_A s_A \geq 0$. For $\frac{\partial U}{\partial \tau_A} = 0$ to occur, (47) implies that both τ_A and $P_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} - P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}$ must be zero. (50) implies that it requires $\tau_A = s_A = 0$. Hence, except for the trivial case where there is no distortion ($\tau_A = s_A = 0$), we have shown that

$$\frac{\partial U}{\partial \tau_A} < 0,$$

for any $s_A \geq 0$. □

Appendix C Proof of Lemma 1

Proof. (13), (14), (23), and (24) imply that the partial derivatives of Q_A, Q_B, and Q_C with respect to τ_A are obtained as follows.

$$\begin{aligned}\frac{\partial Q_A}{\partial \tau_A} =& -\left(P_A + P_B \frac{Q_B}{Q_A} + P_C \frac{Q_C}{Q_A}\right)^{-2} \left\{ P_B \frac{\partial \left(\frac{Q_B}{Q_A}\right)}{\partial \tau_A} + P_C \frac{\partial \left(\frac{Q_C}{Q_A}\right)}{\partial \tau_A} \right\} (P_A Y_A + P_B Y_B + P_C Y_C) \\ &+ \left(P_A + P_B \frac{Q_B}{Q_A} + P_C \frac{Q_C}{Q_A}\right)^{-1} \left(P_A \frac{\partial Y_A}{\partial \tau_A} + P_B \frac{\partial Y_B}{\partial \tau_A} + P_C \frac{\partial Y_C}{\partial \tau_A}\right),\end{aligned} \tag{52}$$

$$\begin{aligned}\frac{\partial Q_B}{\partial \tau_A} =& -\left(P_A \frac{Q_A}{Q_B} + P_B + P_C \frac{Q_C}{Q_B}\right)^{-2} \left\{ P_A \frac{\partial \left(\frac{Q_A}{Q_B}\right)}{\partial \tau_A} \right\} (P_A Y_A + P_B Y_B + P_C Y_C) \\ &+ \left(P_A \frac{Q_A}{Q_B} + P_B + P_C \frac{Q_C}{Q_B}\right)^{-1} \left(P_A \frac{\partial Y_A}{\partial \tau_A} + P_B \frac{\partial Y_B}{\partial \tau_A} + P_C \frac{\partial Y_C}{\partial \tau_A}\right),\end{aligned} \tag{53}$$

$$\frac{\partial Q_C}{\partial \tau_A} = -\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-2}\left\{P_A\frac{\partial\left(\frac{Q_A}{Q_C}\right)}{\partial \tau_A}\right\}(P_AY_A + P_BY_B + P_CY_C)$$
$$+\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-1}\left(P_A\frac{\partial Y_A}{\partial \tau_A} + P_B\frac{\partial Y_B}{\partial \tau_A} + P_C\frac{\partial Y_C}{\partial \tau_A}\right). \tag{54}$$

Using (52), (53), and (54), we can rewrite (25) as follows.

$$\frac{\partial U}{\partial \tau_A} = Q_A^{\nu}Q_B^{\phi}Q_C^{1-\nu-\phi}\left\{\Omega_1\left(P_AY_A + P_BY_B + P_CY_C\right) + \Omega_2\left(P_A\frac{\partial Y_A}{\partial \tau_A} + P_B\frac{\partial Y_B}{\partial \tau_A} + P_C\frac{\partial Y_C}{\partial \tau_A}\right)\right\}, \tag{55}$$

where

$$\begin{aligned}
\Omega_1 \equiv\ & -\frac{\nu}{Q_A}\left(P_A + P_B\frac{Q_B}{Q_A} + P_C\frac{Q_C}{Q_A}\right)^{-2}\left\{P_B\frac{\partial\left(\frac{Q_B}{Q_A}\right)}{\partial \tau_A} + P_C\frac{\partial\left(\frac{Q_C}{Q_A}\right)}{\partial \tau_A}\right\} \\
& -\frac{\phi}{Q_B}\left(P_A\frac{Q_A}{Q_B} + P_B + P_C\frac{Q_C}{Q_B}\right)^{-2}\left\{P_A\frac{\partial\left(\frac{Q_A}{Q_B}\right)}{\partial \tau_A}\right\} \\
& -\frac{1-\nu-\phi}{Q_C}\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-2}\left\{P_A\frac{\partial\left(\frac{Q_A}{Q_C}\right)}{\partial \tau_A}\right\} \\
=\ & -\frac{1}{(P_AQ_A + P_BQ_B + P_CQ_C)^2} \\
& \left[\frac{P_AQ_A}{(1+\tau_A)(1+\tau_B)}\left\{\phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B)\right\}\right],
\end{aligned} \tag{56}$$

and

$$\begin{aligned}
\Omega_2 \equiv\ & \frac{\nu}{Q_A}\left(P_A + P_B\frac{Q_B}{Q_A} + P_C\frac{Q_C}{Q_A}\right)^{-1} + \frac{\phi}{Q_B}\left(P_A\frac{Q_A}{Q_B} + P_B + P_C\frac{Q_C}{Q_B}\right)^{-1} \\
& + \frac{1-\nu-\phi}{Q_C}\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-1} \\
=\ & \frac{1}{P_AQ_A + P_BQ_B + P_CQ_C}.
\end{aligned} \tag{57}$$

The second equality of (56) follows from (21), (22), and their partial derivatives with respect to τ_A.

(55) can be further rewritten as

$$\begin{aligned}
\frac{\partial U}{\partial \tau_A} &= \frac{Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi}}{P_A Q_A + P_B Q_B + P_C Q_C} \left[-\frac{P_A Q_A}{(1+\tau_A)(1+\tau_B)} \left\{ \phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B) \right\} \right. \\
&\quad \left. + \frac{\partial L_B}{\partial \tau_A} \left(P_B \frac{\partial Y_B}{\partial L_B} - P_A \frac{\partial Y_A}{\partial L_A} \right) + \frac{\partial L_C}{\partial \tau_A} \left(P_C \frac{\partial Y_C}{\partial L_C} - P_A \frac{\partial Y_A}{\partial L_A} \right) \right] \\
&= \frac{Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi}}{P_A Q_A + P_B Q_B + P_C Q_C} \left[-\frac{P_A Q_A}{(1+\tau_A)(1+\tau_B)} \left\{ \phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B) \right\} \right. \\
&\quad + \frac{P_A \left\{ (1+\tau_A)(1+s_A) - (1+\tau_B) \right\}}{1+\tau_B} \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_A} \\
&\quad \left. + P_A(\tau_A + s_A + \tau_A s_A) \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_A} \right]. \qquad (58)
\end{aligned}$$

The first equality of (58) follows from $P_A Y_A + P_B Y_B + P_C Y_C = P_A Q_A + P_B Q_B + P_C Q_C$ and

$$\begin{aligned}
& P_A \frac{\partial Y_A}{\partial \tau_A} + P_B \frac{\partial Y_B}{\partial \tau_A} + P_C \frac{\partial Y_C}{\partial \tau_A} = P_A \frac{\partial Y_A}{\partial L_A} \frac{\partial L_A}{\partial \tau_A} + P_B \frac{\partial Y_B}{\partial L_B} \frac{\partial L_B}{\partial \tau_A} + P_C \frac{\partial Y_C}{\partial L_C} \frac{\partial L_C}{\partial \tau_A} \\
&= P_A \frac{\partial Y_A}{\partial L_A} \left(-\frac{\partial L_B}{\partial \tau_A} - \frac{\partial L_C}{\partial \tau_A} \right) + P_B \frac{\partial Y_B}{\partial L_B} \frac{\partial L_B}{\partial \tau_A} + P_C \frac{\partial Y_C}{\partial L_C} \frac{\partial L_C}{\partial \tau_A} \\
&= \frac{\partial L_B}{\partial \tau_A} \left(P_B \frac{\partial Y_B}{\partial L_B} - P_A \frac{\partial Y_A}{\partial L_A} \right) + \frac{\partial L_C}{\partial \tau_A} \left(P_C \frac{\partial Y_C}{\partial L_C} - P_A \frac{\partial Y_A}{\partial L_A} \right). \qquad (59)
\end{aligned}$$

(The second equality in (59) follows from $\frac{\partial L_A}{\partial \tau_A} = -\frac{\partial L_B}{\partial \tau_A} - \frac{\partial L_C}{\partial \tau_A}$, which is implied by (19).) The second equality of (58) follows from

$$P_B \frac{\partial Y_B}{\partial L_B} - P_A \frac{\partial Y_A}{\partial L_A} = \frac{P_A \left\{ (1+\tau_A)(1+s_A) - (1+\tau_B) \right\}}{1+\tau_B} \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha}, \qquad (60)$$

which is implied by (4) and (17), and

$$P_C \frac{\partial Y_C}{\partial L_C} - P_A \frac{\partial Y_A}{\partial L_A} = P_A(\tau_A + s_A + \tau_A s_A) \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha}, \qquad (61)$$

which is implied by the wage equalisation yielded from (4) and (5).

In (58), we first analyse the signs of $\frac{\partial L_B}{\partial \tau_A}$ and $\frac{\partial L_C}{\partial \tau_A}$. We first need to solve for $\frac{\partial L_A}{\partial \tau_A}$, which entails implicit differentiation as follows. Equating (4) and (17), we obtain

$$L_B = \left[\frac{P_A(1+\tau_A)(1+s_A)\alpha Z_A K_A^{1-\alpha} L_A^{\alpha-1}}{P_B(1+\tau_B)\beta Z_B K_B^{1-\beta}} \right]^{\frac{1}{\beta-1}}. \tag{62}$$

Equating (5) and (17) and utilising (19), we obtain the following equation.

$$P_B(1+\tau_B)\beta Z_B L_B^{\beta-1} K_B^{1-\beta} - P_C \gamma Z_C (\overline{L} - L_A - L_B)^{\gamma-1} K_C^{1-\gamma} = 0. \tag{63}$$

Substituting (62) into (63), we obtain an implicit function of L_A. Defining the left hand side of (63) as $g(L_A, \tau_A)$ and using the implicit function theorem, we obtain the partial derivative of L_A with respect to τ_A as

$$\frac{\partial L_A}{\partial \tau_A} = -\frac{g_{\tau_A}}{g_{L_A}}, \tag{64}$$

where

$$\begin{aligned} g_{\tau_A} &= P_A(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} + \frac{\gamma-1}{\beta-1}\frac{1}{1+\tau_A}\frac{L_B}{L_C}(P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}) \\ &= P_A(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \left(1 + \frac{\gamma-1}{\beta-1}\frac{L_B}{L_C}\right). \end{aligned} \tag{65}$$

The second equality in (65) follows from the wage equalisation condition obtained by (4) and (5). Next, g_{L_A} is solved as

$$\begin{aligned} g_{L_A} &= \left\{P_A(1+\tau_A)(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha}\right\}(\alpha-1)\frac{1}{L_A} \\ &\quad +(P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma})(\gamma-1)\frac{1}{L_C}\left(1 + \frac{\alpha-1}{\beta-1}\frac{L_B}{L_A}\right) \\ &= \left\{P_A(1+\tau_A)(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha}\right\} \\ &\quad \times \left\{(\alpha-1)\frac{1}{L_A}\left(1 + \frac{\gamma-1}{\beta-1}\frac{L_B}{L_C}\right) + \frac{\gamma-1}{L_C}\right\}. \end{aligned} \tag{66}$$

The second equality in (66) follows from the wage equalisation condition obtained by (4) and (5).

Substituting (65) and (66) into (64), we obtain the partial derivative of L_A with respect to τ_A as

$$\begin{aligned}\frac{\partial L_A}{\partial \tau_A} &= \frac{(1-\gamma)L_A L_B + (1-\beta)L_A L_C}{(1+\tau_A)\left\{(\beta-1)(\gamma-1)L_A + (\alpha-1)(\gamma-1)L_B + (\alpha-1)(\beta-1)L_C\right\}} \\ &> 0. \end{aligned} \tag{67}$$

The inequality in (67) follows from the assumptions that $0 < \alpha < 1$, $0 < \beta < 1$, and $0 < \gamma < 1$.

Given (62) and (67), we obtain

$$\begin{aligned}\frac{\partial L_B}{\partial \tau_A} &= \frac{(\gamma-1)L_A L_B}{(1+\tau_A)\left\{(\beta-1)(\gamma-1)L_A + (\alpha-1)(\gamma-1)L_B + (\alpha-1)(\beta-1)L_C\right\}} \\ &< 0, \end{aligned} \tag{68}$$

where the inequality follows from the assumptions that $0 < \alpha < 1$, $0 < \beta < 1$, and $0 < \gamma < 1$. Substituting (67) and (68) into $\frac{\partial L_C}{\partial \tau_A} = -\frac{\partial L_A}{\partial \tau_A} - \frac{\partial L_B}{\partial \tau_A}$, which is implied by (19), it also follows that

$$\begin{aligned}\frac{\partial L_C}{\partial \tau_A} &= \frac{(\beta-1)L_A L_C}{(1+\tau_A)\left\{(\beta-1)(\gamma-1)L_A + (\alpha-1)(\gamma-1)L_B + (\alpha-1)(\beta-1)L_C\right\}} \\ &< 0, \end{aligned} \tag{69}$$

where the inequality follows from the assumptions that $0 < \alpha < 1$, $0 < \beta < 1$, and $0 < \gamma < 1$.

Finally, by examining the terms in (58), the conditions that yield $\frac{\partial U}{\partial \tau_A} < 0$ are derived as follows. First, we examine three terms in the square bracket of (58) in the case where $s_A > 0$.

- If $\phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B) \geq 0$, the first term in the square bracket of (58) becomes non-positive, i.e., $-\frac{P_A Q_A}{(1+\tau_A)(1+\tau_B)}\left\{\phi(\tau_A - \tau_B) + (1-\nu-\phi)\tau_A(1+\tau_B)\right\} \leq 0$.

- If $(1+\tau_A)(1+s_A) \geq 1+\tau_B$, since $\frac{\partial L_B}{\partial \tau_A} < 0$ (from (68)), the second term in the square bracket of (58) becomes non-positive, i.e., $\frac{P_A\{(1+\tau_A)(1+s_A)-(1+\tau_B)\}}{1+\tau_B}\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_A} \leq$

0.

- If $s_A > 0$, since it is assumed that $\tau_A \geq 0$, it follows that $\tau_A + s_A + \tau_A s_A > 0$. In this case, since $\frac{\partial L_C}{\partial \tau_A} < 0$ (from (69)), it follows that $P_A(\tau_A + s_A + \tau_A s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_A} < 0$.

Collectively, for any $s_A > 0$, $\frac{\partial U}{\partial \tau_A} < 0$ if $\phi(\tau_A - \tau_B) + (1 - \nu - \phi)\tau_A(1 + \tau_B) \geq 0$ and $(1 + \tau_A)(1 + s_A) \geq 1 + \tau_B$.

Next, we examine three terms in the square bracket of (58) in the case where $s_A = 0$.

- If $s_A = 0$, the second term in the square bracket of (58) collapses to $\frac{P_A(\tau_A - \tau_B)}{1+\tau_B} \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_A}$. If $\tau_A \geq \tau_B$, since $\frac{\partial L_B}{\partial \tau_A} < 0$ (from (68)), this term becomes non-positive.
- If $s_A = 0$, the third term in the square bracket of (58) collapses to $P_A \tau_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_A}$. Given that $\tau_A \geq 0$, this term becomes non-positive since $\frac{\partial L_C}{\partial \tau_A} < 0$ (from (69)).
- If $\tau_A \geq \tau_B$ and $\tau_A \geq 0$, it follows that $\phi(\tau_A - \tau_B) + (1 - \nu - \phi)\tau_A(1 + \tau_B) \geq 0$ and thus the first term in the square bracket of (58) becomes non-positive, i.e., $-\frac{P_A Q_A}{(1+\tau_A)(1+\tau_B)} \left\{\phi(\tau_A - \tau_B) + (1 - \nu - \phi)\tau_A(1 + \tau_B)\right\} \leq 0$.

For $\frac{\partial U}{\partial \tau_A} < 0$, among the two conditions ($\tau_A \geq \tau_B$ and $\tau_A \geq 0$), only one strict inequality is needed. However, the case where $\tau_A > \tau_B$ and $\tau_A = 0$ is excluded since it is assumed that $\tau_B \geq 0$. Therefore, when $s_A = 0$, $\frac{\partial U}{\partial \tau_A} < 0$ if $\tau_A \geq \tau_B$ and $\tau_A > 0$.

□

Appendix D Proof of Lemma 2

Proof. (13), (14), (23), and (24) imply that the partial derivatives of Q_A, Q_B, and Q_C with respect to τ_B are obtained as follows.

$$\frac{\partial Q_A}{\partial \tau_B} = -\left(P_A + P_B \frac{Q_B}{Q_A} + P_C \frac{Q_C}{Q_A}\right)^{-2} \left(P_B \frac{\partial \left(\frac{Q_B}{Q_A}\right)}{\partial \tau_B}\right) (P_A Y_A + P_B Y_B + P_C Y_C)$$
$$+ \left(P_A + P_B \frac{Q_B}{Q_A} + P_C \frac{Q_C}{Q_A}\right)^{-1} \left(P_A \frac{\partial Y_A}{\partial \tau_B} + P_B \frac{\partial Y_B}{\partial \tau_B} + P_C \frac{\partial Y_C}{\partial \tau_B}\right), \quad (70)$$

$$\frac{\partial Q_B}{\partial \tau_B} = -\left(P_A\frac{Q_A}{Q_B} + P_B + P_C\frac{Q_C}{Q_B}\right)^{-2}\left(P_A\frac{\partial\left(\frac{Q_A}{Q_B}\right)}{\partial \tau_B} + P_C\frac{\partial\left(\frac{Q_C}{Q_B}\right)}{\partial \tau_B}\right)(P_AY_A + P_BY_B + P_CY_C)$$
$$+\left(P_A\frac{Q_A}{Q_B} + P_B + P_C\frac{Q_C}{Q_B}\right)^{-1}\left(P_A\frac{\partial Y_A}{\partial \tau_B} + P_B\frac{\partial Y_B}{\partial \tau_B} + P_C\frac{\partial Y_C}{\partial \tau_B}\right), \tag{71}$$

$$\frac{\partial Q_C}{\partial \tau_B} = -\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-2}\left(P_B\frac{\partial\left(\frac{Q_B}{Q_C}\right)}{\partial \tau_B}\right)(P_AY_A + P_BY_B + P_CY_C)$$
$$+\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-1}\left(P_A\frac{\partial Y_A}{\partial \tau_B} + P_B\frac{\partial Y_B}{\partial \tau_B} + P_C\frac{\partial Y_C}{\partial \tau_B}\right). \tag{72}$$

Using (70), (71), and (72), we can rewrite (26) as follows.

$$\frac{\partial U}{\partial \tau_B} = Q_A^{\nu}Q_B^{\phi}Q_C^{1-\nu-\phi}\left\{\Omega_3\left(P_AY_A + P_BY_B + P_CY_C\right) + \Omega_2\left(P_A\frac{\partial Y_A}{\partial \tau_B} + P_B\frac{\partial Y_B}{\partial \tau_B} + P_C\frac{\partial Y_C}{\partial \tau_B}\right)\right\}, \tag{73}$$

where Ω_2 is defined as in (57) and

$$\begin{aligned}
\Omega_3 \;\equiv\; & -\frac{\nu}{Q_A}\left(P_A + P_B\frac{Q_B}{Q_A} + P_C\frac{Q_C}{Q_A}\right)^{-2}\left(P_B\frac{\partial\left(\frac{Q_B}{Q_A}\right)}{\partial \tau_B}\right) \\
& -\frac{\phi}{Q_B}\left(P_A\frac{Q_A}{Q_B} + P_B + P_C\frac{Q_C}{Q_B}\right)^{-2}\left(P_A\frac{\partial\left(\frac{Q_A}{Q_B}\right)}{\partial \tau_B} + P_C\frac{\partial\left(\frac{Q_C}{Q_B}\right)}{\partial \tau_B}\right) \\
& -\frac{1-\nu-\phi}{Q_C}\left(P_A\frac{Q_A}{Q_C} + P_B\frac{Q_B}{Q_C} + P_C\right)^{-2}\left(P_B\frac{\partial\left(\frac{Q_B}{Q_C}\right)}{\partial \tau_B}\right) \\
= \; & -\frac{\phi P_AQ_A\left\{\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B\right\}}{\nu(P_AQ_A + P_BQ_B + P_CQ_C)^2(1+\tau_B)^2}.
\end{aligned} \tag{74}$$

The second equality of (74) follows follows from (21), (22), and their partial derivatives with respect to τ_B.

(73) can be further rewritten as

$$\begin{aligned}
\frac{\partial U}{\partial \tau_B} &= \frac{Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi}}{P_A Q_A + P_B Q_B + P_C Q_C} \left[-\frac{\phi P_A Q_A}{\nu(1+\tau_B)^2} \left\{ \nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B \right\} \right. \\
&\quad \left. + \frac{\partial L_B}{\partial \tau_B} \left(P_B \frac{\partial Y_B}{\partial L_B} - P_A \frac{\partial Y_A}{\partial L_A} \right) + \frac{\partial L_C}{\partial \tau_B} \left(P_C \frac{\partial Y_C}{\partial L_C} - P_A \frac{\partial Y_A}{\partial L_A} \right) \right] \\
&= \frac{Q_A^{\nu} Q_B^{\phi} Q_C^{1-\nu-\phi}}{P_A Q_A + P_B Q_B + P_C Q_C} \left[-\frac{\phi P_A Q_A}{\nu(1+\tau_B)^2} \left\{ \nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B \right\} \right. \\
&\quad + \frac{P_A \left\{ (1+\tau_A)(1+s_A) - (1+\tau_B) \right\}}{1+\tau_B} \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_B} \\
&\quad \left. + P_A(\tau_A + s_A + \tau_A s_A) \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_B} \right]. \qquad (75)
\end{aligned}$$

The first equality of (75) follows from $P_A Y_A + P_B Y_B + P_C Y_C = P_A Q_A + P_B Q_B + P_C Q_C$ and

$$\begin{aligned}
& P_A \frac{\partial Y_A}{\partial \tau_B} + P_B \frac{\partial Y_B}{\partial \tau_B} + P_C \frac{\partial Y_C}{\partial \tau_B} = P_A \frac{\partial Y_A}{\partial L_A} \frac{\partial L_A}{\partial \tau_B} + P_B \frac{\partial Y_B}{\partial L_B} \frac{\partial L_B}{\partial \tau_B} + P_C \frac{\partial Y_C}{\partial L_C} \frac{\partial L_C}{\partial \tau_B} \\
&= P_A \frac{\partial Y_A}{\partial L_A} \left(-\frac{\partial L_B}{\partial \tau_B} - \frac{\partial L_C}{\partial \tau_B} \right) + P_B \frac{\partial Y_B}{\partial L_B} \frac{\partial L_B}{\partial \tau_B} + P_C \frac{\partial Y_C}{\partial L_C} \frac{\partial L_C}{\partial \tau_B} \\
&= \frac{\partial L_B}{\partial \tau_B} \left(P_B \frac{\partial Y_B}{\partial L_B} - P_A \frac{\partial Y_A}{\partial L_A} \right) + \frac{\partial L_C}{\partial \tau_B} \left(P_C \frac{\partial Y_C}{\partial L_C} - P_A \frac{\partial Y_A}{\partial L_A} \right). \qquad (76)
\end{aligned}$$

(The second equality in (76) follows from $\frac{\partial L_A}{\partial \tau_B} = -\frac{\partial L_B}{\partial \tau_B} - \frac{\partial L_C}{\partial \tau_B}$, which is implied by (19).) The second equality of (75) follows from (60) and (61).

In (75), we first analyse the signs of $\frac{\partial L_B}{\partial \tau_B}$ and $\frac{\partial L_C}{\partial \tau_B}$. We first need to solve for $\frac{\partial L_A}{\partial \tau_B}$. Defining the left hand side of (63) as $g(L_A, \tau_B)$ and using the implicit function theorem, we obtain

$$\frac{\partial L_A}{\partial \tau_B} = -\frac{g_{\tau_B}}{g_{L_A}}, \qquad (77)$$

where

$$g_{\tau_B} = P_C \gamma(\gamma-1) Z_C (\overline{L} - L_A - L_B)^{\gamma-2} \frac{K_C^{1-\gamma} L_B}{(1-\beta)(1+\tau_B)}, \qquad (78)$$

where L_B is given as a function of L_A as written in (62), and g_{L_A} is given in (66). Substituting g_{τ_B} and g_{L_A} into (77) and utilising the wage equalisation condition (implied by (4) and (5)) and (19), it follows that

$$\frac{\partial L_A}{\partial \tau_B} = \frac{(\gamma-1)L_A L_B}{(1+\tau_B)\left\{(\beta-1)(\gamma-1)L_A + (\alpha-1)(\gamma-1)L_B + (\alpha-1)(\beta-1)L_C\right\}} < 0, \quad (79)$$

where the inequality follows from $0 < \alpha < 1$, $0 < \beta < 1$, and $0 < \gamma < 1$. (4) and (5) imply that

$$P_A(1+\tau_A)(1+s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} = P_C \gamma Z_C L_C^{\gamma-1} K_C^{1-\gamma}. \quad (80)$$

Taking the partial derivative of both sides of this equation with respect to τ_B,

$$P_A(1+\tau_A)(1+s_A)\alpha(\alpha-1) Z_A L_A^{\alpha-2} K_A^{1-\alpha} \frac{\partial L_A}{\partial \tau_B} = P_C \gamma(\gamma-1) Z_C L_C^{\gamma-2} K_C^{1-\gamma} \frac{\partial L_C}{\partial \tau_B}. \quad (81)$$

Since $\frac{\partial L_A}{\partial \tau_B} < 0$ as obtained in (79) and $0 < \alpha < 1$, the left hand side of (81) is positive. Since $0 < \gamma < 1$, from the right hand side of (81), we obtain

$$\frac{\partial L_C}{\partial \tau_B} < 0. \quad (82)$$

Given (79) and (82), it follows from (19) that

$$\frac{\partial L_B}{\partial \tau_B} = -\frac{\partial L_A}{\partial \tau_B} - \frac{\partial L_C}{\partial \tau_B} > 0. \quad (83)$$

Finally, by examining the terms in (75), the conditions that yield $\frac{\partial U}{\partial \tau_B} < 0$ are derived as follows. First, we examine three terms in the square bracket of (75) in the case where $s_A > 0$.

- If $1+\tau_B \geq (1+\tau_A)(1+s_A)$, since $\frac{\partial L_B}{\partial \tau_B} > 0$ (from (83)), the second term in the square bracket of (75) becomes non-positive, i.e., $\frac{P_A\{(1+\tau_A)(1+s_A)-(1+\tau_B)\}}{1+\tau_B}\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_B} \leq 0$.

- If $\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B \geq 0$, the first term in the square bracket of (75) becomes non-positive, i.e., $-\frac{\phi P_A Q_A}{\nu(1+\tau_B)^2}\left\{\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B\right\} \leq 0$.

Note that if $1+\tau_B \geq (1+\tau_A)(1+s_A)$ and $s_A > 0$, it follows that $\tau_B - \tau_A \geq s_A + \tau_A s_A > 0$. In this case, the second condition written above, i.e., $\nu(\tau_B-\tau_A)+(1-\nu-\phi)(1+\tau_A)\tau_B \geq 0$, does not hold with an equality. Further,

- If $s_A > 0$, it follows that $\tau_A + s_A + \tau_A s_A > 0$. In this case, since $\frac{\partial L_C}{\partial \tau_B} < 0$ (from (82)), it follows that $P_A(\tau_A + s_A + \tau_A s_A)\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_B} < 0$.

Collectively, for any $s_A > 0$, $\frac{\partial U}{\partial \tau_B} < 0$ if $\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B > 0$ and $1+\tau_B \geq (1+\tau_A)(1+s_A)$.

Next, we examine three terms in the square bracket of (75) in the case where $s_A = 0$.

- If $s_A = 0$, the second term in the square bracket of (75) collapses to $\frac{P_A(\tau_A-\tau_B)}{1+\tau_B}\alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_B}{\partial \tau_B}$. If $\tau_B \geq \tau_A$, since $\frac{\partial L_B}{\partial \tau_B} > 0$ (from (83)), this term becomes non-positive.

- If $s_A = 0$, the third term in the square bracket of (75) collapses to $P_A \tau_A \alpha Z_A L_A^{\alpha-1} K_A^{1-\alpha} \frac{\partial L_C}{\partial \tau_B}$. Given that $\tau_A \geq 0$, this term becomes non-positive since $\frac{\partial L_C}{\partial \tau_B} < 0$ (from (82)).

- If $\tau_B \geq \tau_A$ and $\tau_B \geq 0$, it follows that $\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B \geq 0$ and thus the first term in the square bracket of (75) becomes non-positive, i.e., $-\frac{\phi P_A Q_A}{\nu(1+\tau_B)^2}\left\{\nu(\tau_B - \tau_A) + (1-\nu-\phi)(1+\tau_A)\tau_B\right\} \leq 0$.

For $\frac{\partial U}{\partial \tau_B} < 0$, among the two conditions ($\tau_B \geq \tau_A$ and $\tau_B \geq 0$), only one strict inequality is needed. However, the case where $\tau_B > \tau_A$ and $\tau_B = 0$ is excluded since it is assumed that $\tau_A \geq 0$. Therefore, when $s_A = 0$, $\frac{\partial U}{\partial \tau_B} < 0$ if $\tau_B \geq \tau_A$ and $\tau_B > 0$.

□