How do we measure trade elasticity for services?

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Abstract This paper presents our attempt at identifying trade elasticities through variations in the exchange rate for possible applications to the case of services whose physical transactions are veiled in trade statistics. The regression analysis to estimate the elasticity entails a situation where the explanatory variable is leaked into the error term through the latent supply equation, causing an endogeneity problem for which an instrumental variable cannot be found. Our identification strategy is to utilize the normalizing condition, which enables the supply parameter to be identified, along with the reduced-form equation of the system of demand and supply equations. We evaluate the performance of the method proposed by applying to several different tangible goods, whose benchmark trade elasticities are estimable by utilizing the information on their physical transactions.

Keywords Trade in services · Armington elasticity · Endogeneity · Exchange rates

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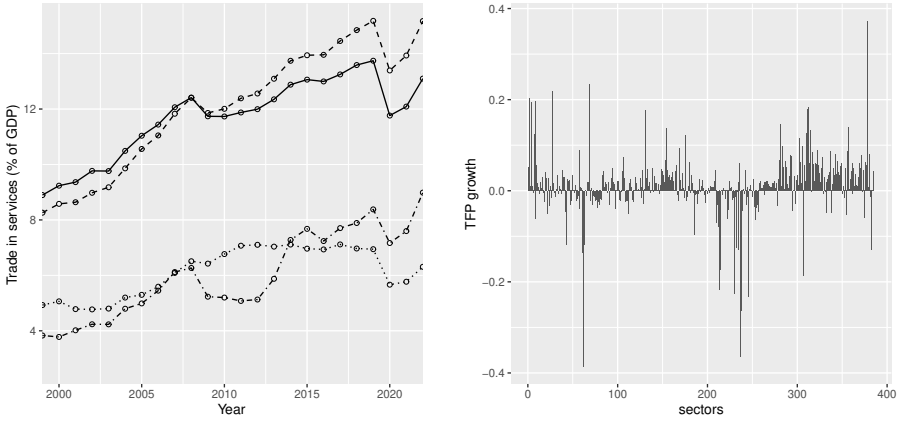

Fig. 1: Left: Trade in services measured in percent share of GDP from 1999 to 2022. Solid, dashed, dotted and dash-dotted lines correspond to World, OECD countries, US, and Japan, respectively (source: The World Bank). Right: Sectoral total factor productivity growth from 2000 to 2005 for Japan, based on the Törnqvist index. Service sectors (tertiary industries) are indexed between 283 and beyond (source: 2000-2005 linked input-output tables for Japan).

1 Introduction

Trade in services is rapidly gaining presence in the world economy (see Figure 1 left). Furthermore, the productivity of service sectors is growing (see Figure 1 right), making services less expensive in real terms. Under these circumstances, it is tempting to study the impact of increased productivity of service sectors on the structure of trade in services. As we follow demand-driven trade theory, trade structures (i.e., how much of what is imported from where) will depend on the price of commodities from various countries on the soil of the importing country and, in particular, its elasticity of substitution among commodities from different countries (i.e., the trade elasticity, or the Armington elasticity).[1] For trade in services, the latter has not been measured by means of standard techniques, since a physical measure for services is lacking in trade statistics.

The trade elasticity for services, nevertheless, has been the subject of measurement in the literature (e.g., Rouzet et al, 2017; Christen et al, 2019; Blank et al, 2022). Theory states that the supply under monopolistic competition together with the demand derived from CES utility associate the markup ratio of the monopolistic supplier with the elasticity of substitution. To project this theory onto international trade, an exporting country as a whole must behave as a monopolist facing a downward-sloping demand schedule of the differentiated commodity consumed in the importing country.[2] Previous studies measure the trade elasticity of services by the markup ratios obtained from firm data, whereby implicitly framing the elasticity measurement of substitution among intranational varieties. Such an elasticity is, of course, not what we are looking for.

[1] Armington elasticity is the key parameter in international trade policy analysis under the general equilibrium modeling framework (Bajzik et al, 2020).

[2] In other words, such an assumption is needed to measure trade elasticities from sector-level data, as done in Egger et al (2021).

For tangible goods, trade elasticity is usually measured by regressing import value shares onto the prices observed on the soil of the importing country. The price in this context equals the product of 1) the price at shipment from the exporter's border (i.e., the FOB price), 2) a factor representing various transportation costs (or the CIF/FOB ratio), 3) the ad valorem equivalent tariff rate, and 4) the rate to exchange the exporter's currency into the importer's. This means that the regression coefficient (with which the elasticity is measured) is common to all four factors 1) –4). Because of this property, Hertel et al (2007) and Fontagné et al (2022) focus on identifying trade elasticities entirely through variations in tariffs.[3] While the same strategy cannot be applied on the matter of services (because ad valorem tariffs are not levied on services), we may consider using the fourth factor: the exchange rate.

In that event, we still face omitted variable bias, as we are omitting the primary factor, i.e., 1) the export price, from the explanatory variables of the regression. The fundamental source of the problem is the latent supply function, where the importer's demand (the response variable) is fed back into the exporter's price, which is then included in the error term. In this situation, the explanatory variable (i.e., the exchange rate) will leak into the error term, causing an endogeneity problem. An instrumental variable to fix the bias pertaining to such endogeneity, therefore, must be uncorrelated with the exchange rate leaked into the error term and, yet, must strongly be correlated with the explanatory variable, that is, the exchange rate. The nonexistence of such objects leads us to exclude the instrumental variable approach from our work.

Our identification strategy is to utilize two endogeneity-free regression equations. The first is the equilibrium equation, which combines the demand and supply functions. This identifies a mix of demand and supply parameters. The second is the price-normalizing condition that the true share parameter agrees with the value share. This condition turns out to be a cross-sectional regression equation that identifies the supply parameter without the concern of endogeneity. The trade elasticity is thus estimated by the two equations, using observations on import value shares and exchange rates, in a panel setting. We assess the performance of this approach with respect to other means (i.e., Feenstra's method (Feenstra, 1994; Hillberry and Hummels, 2013; Feenstra et al, 2018) and extensions) to combat endogeneity without employing instrumental variables.

We evaluate the performance of the abovementioned alternatives by applying them to several different tangible goods whose elasticities are estimated by the standard technique with instrumental variables. As mentioned above, trade elasticity can be estimated by the prices where all four factors are monitorable for the case of tangible goods. Nevertheless, the latent supply function will feed the importer's demand into the exporter's price, but now it is observed as the FOB price and is part of the explanatory variables of the regression, not in the error term. The error term thus represents a pure demand shock for the importer. In this situation, the endogeneity caused by the latent supply function can be remedied by the exchange rate, which must be correlated with the explanatory variable of being its own component, but uncorrelated with the error term of being independent of the demand shocks.[4]

The remainder of the paper proceeds as follows. In the following section, we introduce the model of Armington aggregation, deriving the regression equations for estimating the trade elasticity, while specifically addressing concerns of reverse-causality and omitted variable endogeneity. We also explain our method of estimating trade elasticities from value shares and exchange rates. In Section 3, we first estimate benchmark trade elasticities for

[3] In these studies, however, country-specific elasticities are not of concern, whereas in this study they are.

[4] Erkel-Rousse and Mirza (2002) and Nakano and Nishimura (2024) employ the exchange rate as an instrument to combat endogeneity when estimating trade elasticities for tangible goods.

several tangible goods by means of a standard technique applicable to the case where prices are available. We then proceed to assess the performance of alternative methods that utilize exchange rates instead of prices. We finally apply the alternative methods to estimate the trade elasticity for services. Section 4 concludes the paper. Replication data for this study are available at Nakano and Nishimura (2023).

2 Analytical framework

2.1 The model

Below are an Armington aggregator and the corresponding dual function for a kind of service g (index suppressed) imported into a home country from N different countries:

$$Y = \left(\sum_{i=1}^{N} (\lambda_i)^{\frac{1}{\sigma}} (X_i)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \qquad Q = \left(\sum_{i=1}^{N} \lambda_i (P_i)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{1}$$

where X_i denotes the virtual quantity (of service) imported from the ith country and P_i denotes the corresponding virtual price in terms of the home country's LCU (local currency unit). Let us hereafter call P_i the import price. Similarly, Y denotes the partial utility for aggregated imports, and Q denotes the corresponding unit value. As for the parameters, σ denotes the elasticity of substitution among imports from different countries (i.e., the Armington elasticity), and $\lambda_i \geq 0$ denotes the preference parameter where $\sum_{i=1}^{N} \lambda_i = 1$. The duality asserts that $QY = \sum_{i=1}^{N} P_i X_i = \sum_{i=1}^{N} V_i$ in all cases.

Applying Shephard's lemma for the dual function yields the following:

$$\frac{P_i}{Q} \frac{\partial Q}{\partial P_i} = \frac{P_i}{Q} \frac{X_i}{Y} = \frac{V_i}{\sum_{i=1}^{N} V_i} = S_i = \lambda_i \left(\frac{P_i}{Q} \right)^{1-\sigma} \tag{2}$$

where S_i denotes the value share of imports from the ith country. As we index the observations by $t = 1, \cdots, T$, the above condition implies the following regression equation:

$$\ln S_{it} = \ln \lambda_i - \gamma \ln Q_t + \gamma \ln P_{it} + \varepsilon_{it} \tag{3}$$

where $\gamma = 1 - \sigma$ and ε_{it} denotes the disturbance term.[5] At a glance, we may consider estimating γ via two-way fixed effects estimation, eliminating the country-specific effects $\ln \lambda_i$ as well as the time-specific effects $-\gamma \ln Q_t$, by double-demeaning on both sides of the equation as follows:

$$[\ln S_{it}] = \gamma [\ln P_{it}] + [\varepsilon_{it}] \tag{4}$$

where square brackets indicate double-demeaning.[6]

Of course, regression (4) is impossible since the explanatory variable P_i is only partly available. Specifically, $P_i = Z_i \pi_i$ is available for part of the exchange rate Z_i but unavailable for the part of the service's export price π_i in terms of country i's LCU. Moreover, even if $\pi_i = V_i / X_i / Z_i$ were available such as for any non-service commodities whose X_i are

[5] The disturbance term consists of demand shocks including myriad non-tariff barriers. Appendix 3 provides some analysis based on survey data for non-tariff barriers to trade in services.

[6] Specifically, for example: $[\varepsilon_{it}] = \varepsilon_{it} - \frac{1}{T} \sum_{t=1}^{T} \varepsilon_{it} - \frac{1}{N} \sum_{i=1}^{N} \varepsilon_{it} + \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \varepsilon_{it}$.

available, regression (4) would suffer from an endogeneity problem, since the export price π_i must be affected by the import demand shock ε_i through the supply function. Below, we write the corresponding demand and supply equations:

$$\ln S_{it} = \ln \lambda_i - \gamma \ln Q_t + \gamma (\ln Z_{it} + \ln \pi_{it}) + \varepsilon_{it} \tag{5}$$

$$\ln \pi_{it} = \tau + \omega \ln S_{it} + \delta_{it} \tag{6}$$

The demand equation (5) is merely a copy of Equation (3). The supply parameter ω denotes the elasticity of the export price π_{it} with respect to the value share demanded S_{it}, and δ_{it} denotes the disturbance term concerning supply shocks. For sake of simplicity, the supply equation (6) does not have a time- or country-specific term but a constant, τ. In addition, we believe that it is legitimate to make the following assumption.[7]

Assumption 1. *The supply shocks δ_{it}, demand shocks ε_{it}, and (growth rate of) exchange rates* $\ln Z_{it}$ *are mutually independent, i.e.,*

$$\operatorname{cov}(\delta_{it}, \varepsilon_{it}) = \operatorname{cov}(\delta_{it}, \ln Z_{it}) = \operatorname{cov}(\ln Z_{it}, \varepsilon_{it}) = 0 \tag{7}$$

Let us modify the demand equation further as follows:

$$\ln S_{it} = \ln \lambda_i - \gamma \ln Q_t + \gamma \ln Z_{it} + \left(\gamma \ln \pi_{it} + \varepsilon_{it}\right) \tag{8}$$

where the parentheses indicate the error term. We could double-demean both sides of Equation (8) to yield the following equation:

$$[\ln S_{it}] = \gamma [\ln Z_{it}] + \left[\gamma \ln \pi_{it} + \varepsilon_{it}\right] \tag{9}$$

Unlike Equation (4), the explanatory variable for this equation is available. However, an endogeneity problem lies in that the explanatory variable is likely to be correlated with the error term, as Z_{it} enters π_{it} via S_{it}, according to Equations (5) and (6).[8] What makes the matter worse is that there is no clue in finding an instrument to remedy the problem. The explanatory variable Z_{it} (exchange rate for the ith country) is considered exogenous (i.e., established outside of the market of the service concerned), and while it may be easy to find variables that are correlated with Z_{it}, we can never be certain that any one such variable is uncorrelated with the invisible π_{it} that we suppose is contaminated with Z_{it}.

2.2 Identification strategy

Let us eliminate the latent export price π_{it} from the demand and supply equations (5) and (6), as follows:

$$\ln S_{it} = \frac{1}{1-\gamma\omega} \ln \lambda_i + \frac{\gamma}{1-\gamma\omega}(\tau - \ln Q_t) + \frac{\gamma}{1-\gamma\omega} \ln Z_{it} + \frac{\gamma\delta_{it} + \varepsilon_{it}}{1-\gamma\omega} \tag{10}$$

[7] Independence between demand and supply shocks is a common assumption (made in, e.g., Feenstra, 1994; Feenstra et al, 2018). An obvious small market assumption of a single commodity against the entire currency market implies noncorrelation between demand/supply shocks with the currency exchange rates. Similar assumption is made in Erkel-Rousse and Mirza (2002) and Nakano and Nishimura (2024).

[8] This state of affairs is also known as the exchange rate pass-through (ERPT). According to Goldberg and Knetter (1997), ERPT is defined as an elasticity $\phi = \partial \ln P / \partial \ln Z$, in terms of the variables previously defined. ERPT can therefore be evaluated by way of the estimable parameters, viz., $\phi = 1/(1-\gamma\omega)$.

and call this reduced form the equilibrium equation. If we knew the true share parameter λ_i, this regression equation could identify both γ and ω, where by Assumption 1, without endogeneity problems. While we could not know the true share parameter, we know by virtue of equations (1) and (2) that they will coincide with the value shares at the state where $P_i = 1$ for $i = 1, \cdots, N$. So we let ourselves to virtually normalize all import prices at some point in time $t = \theta$, as follows:

$$\ln P_{i\theta} = \ln Z_{i\theta} + \ln \pi_{i\theta} = 0 \qquad i = 1, \cdots, N \tag{11}$$

By virtue of equation (11), the demand and supply equations become as follows:

$$\ln S_{i\theta} = \ln \lambda_i - \gamma \ln Q_\theta + \varepsilon_{i\theta} \tag{12}$$

$$-\ln Z_{i\theta} = \tau + \omega \ln S_{i\theta} + \delta_{i\theta} \tag{13}$$

Note that (13) is a regression equation with which the supply parameter ω can be identified. Furthermore, Equation (12) indicates that regression equation (13) is endogeneity-free, in light of the following expansion:

$$\operatorname{cov}(\ln S_{i\theta}, \delta_{i\theta}) = \operatorname{cov}\left(\ln \lambda_i - \gamma \ln Q_\theta + \varepsilon_{i\theta}, \delta_{i\theta}\right) \tag{14}$$

$$= \operatorname{cov}(\ln \lambda_i, \delta_{i\theta}) - \operatorname{cov}\left(\gamma \ln Q_\theta, \delta_{i\theta}\right) + \operatorname{cov}(\varepsilon_{i\theta}, \delta_{i\theta}) = 0 \tag{15}$$

which holds true by virtue of Assumption 1 and the nonrandomness of λ_i.

To identify the elasticity parameter γ, we return to the equilibrium equation (10) reiterated as follows:

$$\ln S_{it} = \phi \ln \lambda_i + \kappa\left(\tau - \ln Q_t\right) + \kappa \ln Z_{it} + \phi(\varepsilon_{it} + \gamma \delta_{it}) \tag{16}$$

where $\phi = \frac{1}{1-\gamma\omega}$ and $\kappa = \frac{\gamma}{1-\gamma\omega}$. As mentioned previously, there is also no endogeneity problem for this regression equation. By way of fixed effects or double-demeaned regression, κ can be identified. The double-demeaned version of Equation (16) is described as follows:

$$[\ln S_{it}] = \kappa [\ln Z_{it}] + \phi\left[\varepsilon_{it} + \gamma \delta_{it}\right] \tag{17}$$

Finally, the trade elasticity is identified by utilizing the estimates of regressions (13) and (17) in the following manner:

$$\hat{\sigma} = 1 - \hat{\gamma} = 1 - \frac{\hat{\kappa}}{1 + \hat{\kappa}\hat{\omega}} \tag{18}$$

Since the error terms of (13) and (17) seem to be correlated, we use SUR (seemingly unrelated regressions) to efficiently estimate the elasticity, via (18).

3 Empirical analysis

In addition to the identification strategy presented above, to estimate the trade elasticity from the demand shares and exchange rates, we examine two further alternatives, which we describe in detail in Appendix 1. The first is to directly apply Feenstra's method, which we refer to as FM, where the trade elasticity is identified by (23). The second, which we refer to as IIV, is to apply the implicit instrumental variable of Feenstra's method (as defined thereof) to the explanatory variable of (8). Together with these two alternatives, we examine our strategy, referred to as SUR, which is to perform regression analyses for the supply equation

Table 1: Benchmark IVFE estimation in the presence of quantity.

	FE	FE(IV)			
commodity	$\hat{\sigma}$ (s.e.)	$\hat{\sigma}$ (s.e.)	1F[*1]	overid.[*2]	endog.[*3]
Coffee	1.614 (0.071)	3.446 (0.500)	36.84	0.52 (0.469)	16.69 (0.000)
Beef	3.071 (0.122)	2.424 (0.351)	50.98	0.30 (0.582)	4.06 (0.044)
Blue fish	1.892 (0.106)	1.594 (0.238)	83.00	0.17 (0.680)	1.88 (0.170)
Chicken	1.649 (0.068)	0.792 (0.363)	15.69	0.48 (0.489)	6.85 (0.009)
Rocks	0.829 (0.101)	0.795 (0.893)	14.26		0.00 (0.988)
Salmon	1.809 (0.113)	6.575 (1.287)	11.87	0.79 (0.373)	29.42 (0.000)
Wine	1.165 (0.027)	0.671 (0.184)	27.90	1.23 (0.267)	8.39 (0.004)
Cotton	1.179 (0.171)	1.035 (0.725)	11.24	3.02 (0.082)	0.04 (0.839)
Beer	1.270 (0.051)	−0.701 (0.796)	16.79		9.43 (0.002)
Crabs	0.799 (0.075)	−1.313 (0.590)	12.94	0.02 (0.899)	23.03 (0.000)
Shrimps	1.538 (0.050)	−2.551 (1.168)	8.94	0.90 (0.343)	35.56 (0.000)
Flat fish	1.411 (0.129)	−1.796 (1.116)	14.68	1.79 (0.181)	11.36 (0.001)

[*1] First-stage (Cragg-Donald Wald) F statistic for 2SLS FE estimation. The rule of thumb to reject the hypothesis that the explanatory variable is correlated with the instrument is for this to exceed 10.
[*2] Overidentification test by Sargan statistic. Rejection of the null indicates that the instruments are correlated with the residuals. Blank indicates that a secondary instrument could not be found.
[*3] Endogeneity test by Davidson-MacKinnon F statistic. Rejection of the null indicates that the instrumental variable fixed effects estimator should be employed.

(13) and the equilibrium equation (17) simultaneously to obtain the trade elasticity by (18). We examine these three alternatives (FM, IIV, and SUR) to estimate the trade elasticities for commodities whose physical quantities are available. Note that γ can be estimated by Equation (3) via fixed effects while applying the exchange rate Z_{it} as an instrument to fix the endogenous explanatory variable $\ln P_{it}$, where $P_{it} = Z_{it}V_{it}/X_{it}$ if quantities X_{it} are available. We use this estimator, which we refer to as IVFE, as the benchmark for assessing the abovementioned three alternatives. In addition, we note that the import values V_{it} used in the benchmark estimations will not include tariffs, since the analyses are intended for the comparative assessment of alternative means applicable to services.

3.1 Data

Our main strategy to identify the supply parameter based on Equation (13) is reliant on the cross-sectional variety of exporters of a commodity. For this reason, we mainly examine the imports of food, whose origins are in general diverse. Specifically, we gather Japan's monthly import value and quantity data from Trade Statistics (2022) spanning from 2008 January to 2022 December for 11 commodities, namely, coffee, beer, wine, beef, chicken, salmon, blue fish, flat fish, crabs, shrimp, and Rocks. More details are appended to Appendix 2. Monthly exchange rates pertaining to all partner countries involved are drawn from Fxtop (2022).

3.2 Results

First, we estimate benchmark trade elasticities for the 11 commodities mentioned above by IVFE. The results are shown in Table 1. The instrumental variables we applied to the en-

Table 2: Estimation via supply and equilibrium equations.

	SUR	Equation (13)[*2]		Equation (17)
Sector	$\hat{\sigma}$ (s.e.)[*1]	$\hat{\omega}$ (s.e.)	const. (s.e.)	$\hat{\kappa}$ (s.e.)
Coffee	2.070 (0.441)	0.554 (0.271)	2.238 (1.402)	−0.672 (0.126)
Beef	1.494 (0.183)	−0.654 (0.093)	−5.444 (0.524)	−0.729 (0.242)
Blue fish	1.461 (0.171)	−0.846 (0.504)	−5.165 (1.883)	−0.757 (0.403)
Chicken	0.938 (0.088)	−0.596 (0.221)	−4.082 (1.206)	0.060 (0.110)
Rocks	0.965 (0.125)	−1.756 (0.691)	−6.178 (2.631)	0.033 (0.143)
Salmon	3.772 (2.572)	0.720 (0.250)	0.283 (1.202)	−0.925 (0.144)
Wine	0.690 (0.154)	0.384 (0.236)	−1.491 (1.369)	0.352 (0.176)
Cotton	−6.721 (13.69)	−1.128 (0.025)	−5.502 (0.063)	0.795 (0.146)
Beer	0.195 (0.606)	−0.880 (0.436)	−5.347 (1.771)	0.471 (0.179)
Crabs	1.132 (0.021)	−1.224 (0.262)	−5.167 (1.223)	−0.158 (0.030)
Shrimps	1.110 (0.020)	0.898 (0.250)	3.191 (1.265)	−0.100 (0.020)
Flat fish	0.287 (0.493)	−0.989 (0.438)	−5.807 (1.492)	0.418 (0.150)

[*1] Delta method standard errors.
[*2] The point of normalization was selected at the final year, 2020.

dogenous variable $\ln P_{it}$ of Equation (3) are $\ln Z_{it}$ and Z_{it} whenever they pass the overidentification test. Ultimately, where overidentification test statistic is blank, only the primary instrument $\ln Z_{it}$ was applied. According to the endogeneity test statics, we employ fixed effects (FE) estimators for blue fish and rocks, while instrumental variable estimators are employed for the rest of the commodities. We exclude beer, crabs, shrimp and flat fish from further analyses, since a negative elasticity does not support the microfoundation of the model we support. The employed benchmark elasticities are reiterated in Table 3 (IVFE column).

Table 2 summarizes the result of our strategy to identify the demand parameter (i.e., trade elasticity) from the supply and equilibrium equations. Regarding supply equation (13), the point of normalization $t = \theta$, where we perform the cross-sectional regression, is arbitrary. Here, we select the point of normalization as to the minimum RSS of the cross-sectional regression. The second column of Table 2 shows the results of performing independent regressions for the supply equation (13) at the corresponding point of normalization. The third column shows the results of performing independent regressions for the equilibrium equation (17). Finally, the first column (entitled SUR) shows the results of performing seemingly unrelated regression for the system of equations (13) and (17). The estimated trade elasticities are reiterated in Table 3 (SUR).

Finally, Table 3 and Figure 2 summarize the point estimates by the three alternatives (FM, IIV, SUR) with the benchmark estimates (IVFE) of the trade elasticities. The estimates obtained via FM and IIV are transcribed from Table 5, which appears in Appendix 1. FM and IIV are very close in finding the benchmark elasticity for two commodities, salmon and coffee, whereas SUR was close for all seven commodities. The solid line in Figure 2 (right) is the regression line specified below:

$$\text{Benchmark Elasticity (IVFE)} = \underset{(0.176)}{-0.879} + \underset{(0.093)}{2.000} \times \text{Elasticity (SUR)} \tag{19}$$

Standard errors are in parentheses, and the adjusted $R^2 = 0.987$. Note that the trade elasticity for services can be estimated by means of SUR and further corrected for increased precision using this formula.

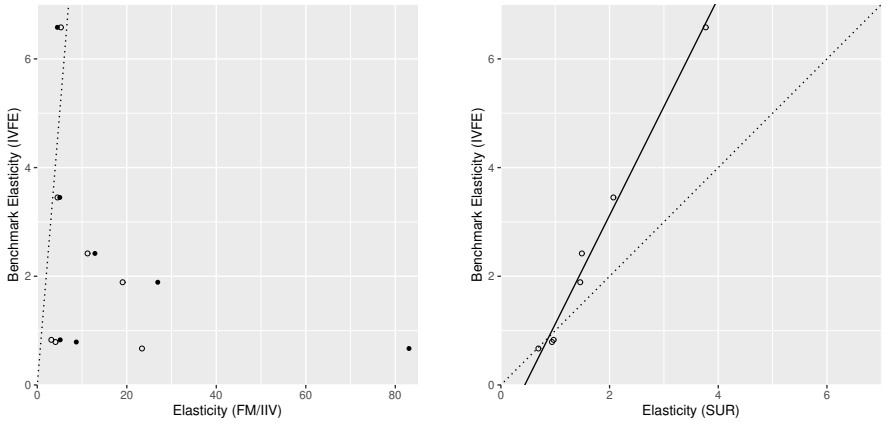

Fig. 2: For both figures, the vertical axis corresponds to the benchmark elasticity (estimated by means of IVFE) of commodities with relevant (nonnegative) point estimates, namely, salmon, coffee, beef, blue fish, Rocks, chicken, and wine, in descending order. The horizontal axis corresponds to the elasticity estimate by means of the alternatives, namely, FM (closed dots, left), IIV (open dots, left) and SUR (right). The dotted line is the 45 degree line.

Table 3: Summary of point estimates by various methods.

	IVFE	FM	IIV	SUR
commodity	$\hat{\sigma}$ (s.e.)	$\hat{\sigma}$ (s.e.)	$\hat{\sigma}$ (s.e.)	$\hat{\sigma}$ (s.e.)
Coffee	3.446 (0.500)	5.028 (0.322)	4.523 (0.332)	2.070 (0.441)
Beef	2.424 (0.351)	12.885 (1.579)	11.233 (1.874)	1.494 (0.183)
Blue fish	1.892 (0.106)	26.919 (3.321)	19.074 (1.130)	1.461 (0.171)
Chicken	0.792 (0.363)	8.721 (0.666)	4.068 (0.454)	0.938 (0.088)
Rocks	0.829 (0.101)	5.118 (0.308)	3.141 (0.389)	0.965 (0.125)
Salmon	6.575 (1.287)	4.488 (0.269)	5.283 (0.354)	3.772 (2.572)
Wine	0.671 (0.184)	83.064 (13.03)	23.395 (3.137)	0.690 (0.154)
Cotton[*1]	1.179 (0.171)			−6.721 (13.69)
Beer	−0.701 (0.796)	17.461 (1.425)	13.092 (1.011)	0.195 (0.606)
Crabs	−1.313 (0.590)	1.498 (0.061)	1.562 (0.063)	1.132 (0.021)
Shrimps	−2.551 (1.168)	2.604 (0.080)	1.698 (0.055)	1.110 (0.020)
Flat fish	−1.796 (1.116)	30.700 (5.020)	1.544 (0.351)	0.287 (0.493)

[*1] Estimation result for FM and IIV are blanked due to anomalies.

3.3 Application to services

We employ services imports data from WTO (2023). Selecting Japan as the reporting economy, yearly import values (in million USD) were drawn for 1) commercial services, 2) construction, 3) financial services, 4) goods-related services, 5) insurance and pension services, 6) telecommunications, computer, and information services, 7) transport, and 8) travel, spanning the timeline from 2005 to 2020. Corresponding yearly averaged exchange rates (in LCC/JPY) are obtained from Fxtop (2022). The point of normalization was selected at the

Table 4: Trade elasticity estimates for services.

	SUR	Equation (13)[*2]		Equation (17)
commodity	$\hat{\sigma}$ (s.e.)[*1]	$\hat{\omega}$ (s.e.)	const. (s.e.)	$\hat{\kappa}$ (s.e.)
1) Commercial	1.024 (0.032)	0.400 (0.092)	3.697 (0.736)	−0.024 (0.032)
2) Construction	1.107 (0.050)	0.295 (0.213)	2.981 (1.348)	−0.104 (0.047)
3) Financial	1.115 (0.049)	0.360 (0.150)	4.009 (1.121)	−0.111 (0.045)
4) Goods-related	0.794 (0.031)	0.430 (0.139)	4.066 (0.949)	0.226 (0.036)
5) Insurance	0.840 (0.035)	0.464 (0.137)	4.398 (0.935)	0.172 (0.041)
6) Telecom	1.066 (0.054)	0.298 (0.130)	3.246 (0.981)	−0.065 (0.052)
7) Transport	1.006 (0.027)	0.385 (0.110)	3.422 (0.801)	−0.006 (0.026)
8) Travel	1.063 (0.039)	0.485 (0.148)	3.848 (0.985)	−0.061 (0.037)

[*1] Delta method standard errors.
[*2] The point of normalization was selected at the final year, 2020.

last period ($\theta = 2020$) since the number of exporting countries (hence, the size of samples) increased over time.

Table 4 shows the result of estimating trade elasticities of the abovementioned eight different services, by means of SUR, based on regression equations (13) and (17). Since the point estimates are generally around unity, we opted not to use the correction formula (19). Note the peculiarity in this table that $\hat{\sigma} \approx 1 - \hat{\kappa}$, which indicates the ineffectiveness of $\hat{\omega}$ or supply equation (6) that can potentially cause endogeneity. Overall the elasticity estimates turned out to be near unity, meaning that the Arminton aggregators for services are generally Cobb-Douglas. As we know, under a Cobb-Douglas aggregator, import demand value (in terms of local currency) is unresponsive to changes in price. Furthermore, we note that 4) goods-related services and 5) insurance and pension services, among other services, are internationally complementary (i.e., $\hat{\sigma} < 1$) meaning that import demand quantity is relatively unresponsive to changes in price.

4 Concluding Remarks

Benz and Jaax (2020) presents a summary of the estimates of the trade elasticities for services provided by the aforementioned sources (i.e., Rouzet et al, 2017; Christen et al, 2019; Egger et al, 2021; Blank et al, 2022), which base their analyses on the framework of monopolistic competition and firm data. Benz and Jaax (2020) also provides the simple average of these estimates, which we transcribe as follows: 3.67 (communication), 3.21 (business services), 2.54 (financial services), 2.77 (insurance), 3.39 (transport). These figures indicate that the intranational firm-wise variety of services is highly elastic, i.e., the services can easily be substituted for each other. On the other hand, our estimates for service trade elasticities summarized in Table 4 indicate substantial complementarity in the international variety of services. Our findings seem to accord with our understanding of the elasticity of substitution.

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Appendix 1

Feenstra's method and extensions

Here, we consider estimating γ in equation (9) by way of Feenstra's method to address the endogeneity problem without finding external instruments. Below, we write the main (endogenous) regression equation (9) with obvious notational changes and the corresponding reverse-cause equation.[9]

$$s_{it} = \gamma z_{it} + \mu_{it}, \qquad z_{it} = \rho s_{it} + \nu_{it} \tag{20}$$

Following Feenstra's method, we multiply the zero-mean error terms of the above equations to obtain the following equation:

$$U_{it} = \alpha_1 W_{1it} + \alpha_2 W_{2it} + \xi_{it} \tag{21}$$

where $\xi_{it} = -\mu_{it}\nu_{it}/\gamma$, $W_{1it} = (s_{it})^2$, $W_{2it} = s_{it}z_{it}$, $\alpha_1 = -\rho/\gamma$, $\alpha_2 = (1+\gamma\rho)/\gamma$ and $U_{it} = z_{it}z_{it}$. Then, we take the temporal average of (21) as follows:

$$\langle U_i \rangle = \alpha_1 \langle W_{1i} \rangle + \alpha_2 \langle W_{2i} \rangle + \langle \xi_i \rangle \tag{22}$$

where $\langle U_i \rangle = \sum_{t=1}^{T} U_{it}/T$ and so forth for the full-panel case. Assume that plim $\langle \xi_i \rangle = 0$, in which case we can assert that plim $\langle W_{ni} \rangle \langle \xi_i \rangle = (\text{plim} \langle W_{ni} \rangle)(\text{plim} \langle \xi_i \rangle) = 0$ for $n = 1, 2$, or the consistency of the least squares estimators of regression (22), where we will then be able to solve for $\hat{\gamma}$ and $\hat{\rho}$ by the following formulae:

$$\hat{\gamma} = \frac{-\hat{\alpha}_2 \pm \sqrt{(\hat{\alpha}_2)^2 + 4\hat{\alpha}_1}}{2\hat{\alpha}_1}, \qquad \hat{\rho} = \frac{\hat{\alpha}_2 \mp \sqrt{(\hat{\alpha}_2)^2 + 4\hat{\alpha}_1}}{2} \tag{23}$$

In practice, with unbalanced panel data, Equation (22) is estimated by WLS (weighted least squares) regression, using T_i/v_i as weights where T_i and v_i denote the temporal size and the variance of the residuals of the ith panel, respectively.

Note that our key assumption (i.e., plim $\langle \xi_i \rangle = 0$) is equivalent to the following:

$$\underset{T\to\infty}{\text{plim}} \frac{1}{T} \sum_{t=1}^{T} \mu_{it}\nu_{it} = 0 \tag{24}$$

That is, in Feenstra's method, we assume asymptotic uncorrelation (i.e., independence) between μ_i and ν_i for all i. This is the point from which our second strategy stems. By this assumption, we can use the $\hat{\rho}$ from the first strategy to recover the residual $\hat{\nu}_{it}$, which must be uncorrelated with the error term of the main demand equation μ_{it}, and yet is correlated with the response variable z_{it} by construction. The residual $\hat{\nu}_{it}$ must therefore be a relevant instrument for estimating the main demand equation (9) or (8). We call this instrument ($\hat{\nu}$) the IIV (implicit instrumental variable) of Feenstra's method.

[9] Feenstra's method is designed to provide a consistent estimate of substitution elasticity by way of a demand equation such as that of (4), and thus the reverse-cause equation usually corresponds to a supply equation. Moreover, instead of double-demeaning the variables, Feenstra's method takes time differences and item differences from a reference item to eliminate time- and item-specific effects.

Table 5: Applying Feenstra's method.

	FM	IIV			
commodity	$\hat{\sigma}$ (s.e.)	$\hat{\sigma}$ (s.e.)	1F[*1]	overid.[*2]	endog.[*3]
Coffee	5.028 (0.322)	4.523 (0.332)	4877	0.102 (0.750)	1602 (0.000)
Beef	12.885 (1.579)	11.233 (1.874)	61	0.177 (0.674)	299 (0.000)
Blue fish	26.919 (3.321)	19.074 (1.130)	566		1024 (0.000)
Chicken	8.721 (0.666)	4.068 (0.454)	221	0.009 (0.923)	565 (0.000)
Rocks	5.118 (0.308)	3.141 (0.389)	1705	0.252 (0.616)	585 (0.000)
Salmon	4.488 (0.269)	5.283 (0.354)	3321	0.117 (0.732)	953 (0.000)
Wine	83.064 (13.031)	23.395 (3.137)	34	0.173 (0.678)	955 (0.000)
Cotton[*4]					
Beer	17.461 (1.425)	13.092 (1.011)	255	3.707 (0.054)	1508 (0.000)
Crabs	1.498 (0.061)	1.562 (0.063)	1088		112 (0.000)
Shrimps	2.604 (0.080)	1.698 (0.055)	0		0 (0.000)
Flat fish	30.700 (5.020)	1.544 (0.351)	544	2.566 (0.109)	138 (0.000)

[*1] First-stage (Cragg-Donald Wald) F statistic for 2SLS FE estimation. The rule of thumb to reject the hypothesis that the explanatory variable is correlated with the instrument is for this to exceed 10.
[*2] Overidentification test by Sargan statistic. Rejection of the null indicates that the instruments are correlated with the residuals. Blank indicates that a secondary instrument could not be found.
[*3] Endogeneity test by Davidson-MacKinnon F statistic. Rejection of the null indicates that the instrumental variable fixed effects estimator should be employed.
[*4] Estimations resulted in anomalies.

Table 5 summarizes the result obtained by Feenstra's method (FM) and an extension that utilizes the corresponding implicit instrumental variables (IIV). Specifically, our primary IIV is obtained by the following protocol, utilizing the $\hat{\rho}$ from Equation (23):

$$\hat{\nu} = [\ln Z_{it}] - \hat{\rho}[\ln S_{it}] \tag{25}$$

We apply instrumental variable $\hat{\nu}$ and its derivatives onto the explanatory variable $[\ln Z_{it}]$ of Equation (9), whenever they pass the overidentification test. Note that by derivatives of ν_{it}, we mean $\ln \hat{\nu}_{it}$, its forward and backward lags, and its first differences. Ultimately, where the overidentification test statistic is blank, only the primary instrument $\hat{\nu}_{it}$ was applied. As anticipated, both alternative means provide similar results, except for flat fish. The estimated trade elasticities are reiterated in Table 3 (columns FM and IIV).

Appendix 2

Table 6 shows the HS codes eligible for each tangible commodity. The size of sample is $T = 180$ in all cases for the 11 tangible commodities. The size of panel N is restricted to the number of countries that have more than 160 observations out of full 180, except for beef. To secure the strength of our primary instrument, we use data spanning from 2006 to 2020 for chicken, and from 2001 to 2015 for beef and restrict the panel to those with more than 100 observations. For the same purpose we excluded South American wines form the data for wine.

Table 6: Commodities and HS codes.

	HS code				
Beef	0201.10-000	0201.20-000	0201.20-010	0201.20-090	0201.30-010
	0201.30-020	0201.30-030	0201.30-090	0202.10-000	0202.20-000
	0202.20-010	0202.20-090	0202.30-010	0202.30-020	0202.30-030
	0202.30-090				
Beer	2203.00-000				
Blue	0302.44-000	0302.45-000	0302.61-010	0302.64-000	0303.53-100
fish	0303.54-000	0303.55-000	0303.59-110	0303.59-120	0303.71-010
	0303.71-090	0303.74-000	0303.79-021	0303.79-023	0303.79-029
	0303.89-121	0303.89-129			
Chicken	0207.11-000	0207.12-000	0207.13-100	0207.13-200	0207.14-100
	0207.14-210	0207.14-220			
Coffee	0901.11-000				
Crabs	0306.11-200	0306.12-200	0306.14-010	0306.14-020	0306.14-030
	0306.14-040	0306.14-090	0306.24-110	0306.24-121	0306.24-129
	0306.24-130	0306.24-140	0306.24-150	0306.24-190	0306.24-200
	0306.26-300	0306.33-110	0306.33-121	0306.33-129	0306.33-130
	0306.33-140	0306.33-150	0306.33-190	0306.93-900	
Flat	0301.99-220	0302.21-000	0302.23-000	0302.24-000	0302.29-000
fish	0303.31-000	0303.32-000	0303.33-000	0303.34-000	0303.39-000
	0304.43-000	0304.83-000			
Salmon	0302.11-000	0302.12-011	0302.12-019	0302.12-020	0302.13-011
	0302.13-012	0302.13-019	0302.14-000	0302.19-000	0303.11-000
	0303.12-010	0303.12-090	0303.13-000	0303.14-000	0303.19-000
	0303.19-010	0303.19-090	0303.21-000	0303.22-000	0304.29-950
	0304.41-000	0304.42-000	0304.81-000	0304.82-000	0304.89-220
Shrimps	0306.13-000	0306.16-000	0306.16-200	0306.17-000	0306.17-100
	0306.17-200	0306.19-010	0306.19-090	0306.19-100	0306.19-190
	0306.19-200	0306.19-290	0306.23-111	0306.23-119	0306.23-190
	0306.23-200	0306.27-111	0306.27-119	0306.27-190	0306.27-200
	0306.27-300	0306.29-110	0306.29-120	0306.29-190	0306.29-210
	0306.29-220	0306.29-290	0306.36-110	0306.36-190	0306.36-900
	0306.39-100	0306.39-900	0306.95-100	0306.95-900	0306.99-910
	0306.99-990				
Rocks	6801.00-000				
Wine	2204.10-000	2204.21-010	2204.21-020	2204.22-000	2204.29-010
	2204.29-090	2204.30-111	2204.30-119	2204.30-191	2204.30-200

Beef Carcasses, cuts, loin, kata, ude, momo, and belly cuts that are fresh, chilled or frozen.
Beer Beer made from malt.
Blue fish Mackerel, Jack & Horse mackerel, sardines, anchovies, pacific saury that are fresh, chilled or frozen.
Chicken Meat, legs, cuts, and offal that are fresh, chilled or frozen.
Coffee Coffee, not roasted, not decaffeinated.
Crabs King, snow, swimming, horsehair, and mitten crabs that are fresh, chilled or frozen.
Flat fish Hirame, halibut, sole, and turbots, and fillets thereof, that are fresh, chilled or frozen.
Salmon Red, silver, pacific, Atlantic & Danube salmon, and salmonidae, that are fresh, chilled or frozen.
Shrimps Shrimps, prawns, ebi, and crustaceans that are fresh, chilled, frozen, or smoked.
Rocks Setts, curbRocks and flagRocks of natural stone.
Wine Wine in various containers and grape must.

Appendix 3

STRI elasticity of import

The OECD Service Trade Restrictiveness Index (STRI) provides comparable information on regulations affecting trade in services across 50 countries and 22 sectors from 2014 (OECD, 2024). Our model presented in Section 2.1 uses exchange rates as the only observable variable to estimate trade elasticities, while other exogenous disturbances are incorporated as part of demand shocks. In this section, we examine how STRI data could contribute in scraping relevant disturbances and raise the efficiency of the elasticity estimation. To illustrate the modifications, let us first decompose the disturbance term ε_{it} of the demand equation (5) into two parts. Below are the modified demand and supply equations:

$$\ln S_{it} = \ln \lambda_i - \gamma \ln Q_t + \gamma (\ln Z_{it} + \ln \pi_{it}) + \epsilon_{it} + \eta \ln R_{it} \tag{26}$$

$$\ln \pi_{it} = \tau + \omega \ln S_{it} + \delta_{it} \tag{6}$$

Here, $\varepsilon_{it} = \epsilon_{it} + \eta \ln R_{it}$ where R_{it} denotes the restrictiveness index (STRI), and η denotes the STRI elasticity of service import (value).[10] According to OECD (2024), the STRIs are composite indices taking values between zero and one, zero representing open market and one a market completely closed to foreign services providers. The weighting scheme for the STRI is derived from online survey collecting binary (yes/no) answers, while measures that have numerical answers are broken down on thresholds to which binary scores are applied. We may therefore be convinced that STRIs have nothing to do with the exchange rates nor with the remaining external demand shocks ϵ_{it}. In a nutshell, we make the following assumption:

Assumption 2. *The supply shocks δ_{it}, demand shocks ϵ_{it}, and (growth rate of) trade restrictiveness* $\ln R_{it}$ *are mutually independent, i.e.,*

$$\operatorname{cov}(\epsilon_{it}, \delta_{it}) = \operatorname{cov}(\epsilon_{it}, \ln R_{it}) = \operatorname{cov}(\delta_{it}, \ln R_{it}) = 0$$

Combining the demand and supply equations (26) and (6), we have the following (modified) equilibrium equation:

$$\ln S_{it} = \phi \ln \lambda_i + \kappa\tau - \kappa \ln Q_t + \kappa \ln Z_{it} + \mu \ln R_{it} + (\phi\epsilon_{it} + \phi\gamma\delta_{it})$$

where $\mu = \frac{\eta}{1-\gamma\omega}$, $\kappa = \frac{\gamma}{1-\gamma\omega}$, and $\phi = \frac{1}{1-\gamma\omega}$. By virtue of Assumptions 1 and 2, the following double-demeaned equilibrium equation must be endogeneity-free:[11]

$$[\ln S_{it}] = \kappa[\ln Z_{it}] + \mu[\ln R_{it}] + [\phi\epsilon_{it} + \phi\gamma\delta_{it}] \tag{27}$$

Normalization of price at $t = \theta$, i.e., $(\ln Z_{i\theta} + \ln \pi_{i\theta}) = 0$, renders the following:

$$\begin{aligned} \ln S_{i\theta} &= \ln \lambda_i - \gamma \ln Q_\theta + \epsilon_{i\theta} + \eta \ln R_{i\theta} \\ -\ln Z_{i\theta} &= \tau + \omega \ln S_{i\theta} + \delta_{i\theta} \end{aligned} \tag{28}$$

Then, we know that regression (28) is endogeneity-free, in light of the following expansion:

$$\operatorname{cov}(\ln S_{i\theta}, \delta_{i\theta}) = \operatorname{cov}(\ln \lambda_i - \gamma \ln Q_\theta + \epsilon_{i\theta} + \eta \ln R_{i\theta}, \delta_{i\theta}) = 0$$

[10] This is possible on the ground that $[\ln S_{it}] = [\ln V_{it} - \ln \sum_{i=1}^{N} V_{it}] = [\ln V_{it}]$.

[11] Moreover, the multivariate regression (27) must be multicollinearity-free.

Table 7: Estimation of trade elasticity and STRI elasticity of import.

	SUR		Equation (28)[*2]	Equation (27)	
ID	$\hat{\sigma}$ (s.e.)[*1]	$\hat{\eta}$ (s.e.)[*1]	$\hat{\omega}$ (s.e.)	$\hat{\kappa}$ (s.e.)	$\hat{\mu}$ (s.e.)
2)	1.229 (0.200)	0.077 (0.412)	−0.136 (0.299)	−0.237 (0.213)	0.080 (0.427)
3)	1.148 (0.204)	−0.760 (0.291)	0.436 (0.200)	−0.139 (0.181)	−0.714 (0.274)
5)	1.394 (0.332)	−0.078 (0.338)	0.587 (0.155)	−0.320 (0.218)	−0.063 (0.275)
6)	1.831 (0.377)	−0.581 (0.886)	0.328 (0.167)	−0.653 (0.225)	−0.456 (0.713)
7)	1.019 (0.128)	−0.815 (0.604)	0.535 (0.288)	−0.018 (0.125)	−0.807 (0.612)

[*1] Delta method standard errors.
[*2] The point of normalization was selected at the final year, 2020. The estimates for constant are suppresed.

which holds true by Assumption 2 and the nonrandomness of λ_i. The trade elasticity σ and the STRI elasticity of service import η are therefore identified by the estimates of regressions (27) and (28) in the following manner:

$$\hat{\sigma} = 1 - \frac{\hat{\kappa}}{1 + \hat{\kappa}\hat{\omega}}, \qquad \hat{\eta} = \frac{\hat{\mu}}{1 + \hat{\kappa}\hat{\omega}}$$

Since the error terms of regressions (27) and (28) seem to be correlated, we use SUR to efficiently estimate the elasticities σ and η.

We draw STRI data from OECD (2024). Selecting Japan as the partner country, yearly values of STRI were drawn for all service sectors available. There we found equivalent sectors of STRI data in WTO's services imports data, for 2) Construction (Construction), 3) Financial services (Commercial banking), 5) Insurance and pension services (Insurance), 6) Telecommunications, computer, and information services (Telecom, and Computer), 7) Transport (Air transport, Maritime transport, Road freight transport, and Rail freight transport). However, we could not find relevant sectors for 1) Commercial services, 4) Goods-related services, and 8) Travel. We therefore performed SUR to estimate the trade elasticity and the STRI elasticity of import at the same time, for services of ID numbers 2), 3), 5), 6), and 7). The results are summarized in Table 7.

The estimates for trade elasticity are different from those reported in Table 4, mainly due to different time range of observations (2014–2020) and to the range of countries covered in the STRI database. As for the estimates for STRI elasticity of service import, we found statistical significance (with correct sign) for 3) Financial services where the STRI of Commercial banking sector was applied. While statistically insignificant, the STRI elasticity of import for 2) Construction has an opposite sign rather than what we can anticipate from our intuition that trade restrictions should have negative effects to import values. The peculiarity of Construction sector can also be recognized in its mode structure studied in Eurostat (2024) with a 90% share of Mode 3 (commercial presence) and a 10% share of Mode 4 (movement of natural persons).[12]

[12] Mode 3 (commercial presence): mode of supply by a service supplier of one country, through a commercial presence in the territory of another country. Mode 4 (movement of natural persons): mode of supply by a service supplier of one country, through the presence of natural persons of that country in the territory of any other country.

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