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Trade diversion and antidumping effectiveness: insights from a residual demand model

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A residual demand model is developed to predict the likely effects of an antidumping duty in the presence of trade diversion. A key insight is that the ability of an AD duty to increase the welfare of producers in the country imposing the duty hinges on the import supply elasticity for product from non-named sources. The only instance in which this is not true is when supply for product from the named source is perfectly elastic. In this case, the welfare gain to domestic producers is maximised irrespective of the supply elasticity for imports from non-named sources. A comparison of the residual demand model with the Armington model suggests the latter significantly understates both trade diversion and domestic producer gains from the duty.

Key words: antidumping, Armington model, pass-through elasticity, residual demand model, trade diversion, trade policy.

1. Introduction

Antidumping (AD) policy aims to assist domestic producers by raising price in the home market. The primary instrument is a tariff against named exporters. Because a higher price harms consumers and downstream industries in the importing country, economists find little justification for AD policy (Ethier 1982; Blonigen and Prusa 2003; Vandebussche and Zanardi 2010). Yet the policy persists, filings have multiplied, and rulings have become more protectionist. Blonigen (2003) reports that AD cases worldwide increased from only a few in the 1970s to 2200 in the 1990s. According to World Trade Organization statistics, a total of 4757 AD cases were initiated between 1995 and 2014, of which 527 came from the United

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States and 468 from the European Union.[1] In the United States, calculated dumping margins (the difference between price or cost in the foreign market and price in the domestic market) between 1980 and 2000 rose from 15% to over 63%, and the probability of an affirmative ruling rose from 45% to over 60% (Blonigen 2006). A major development in recent years is the growing frequency of AD complaints initiated by nontraditional users such as Argentina, Brazil, China and India (Blonigen and Prusa 2015). Prior to 1995, traditional users, namely Australia, Canada, EU and the USA, accounted for 64% of AD cases worldwide (Wu 2012, p. 74). Since then China and India have become the leading users, accounting for 29% of AD cases compared to 27% for traditional users. Thus, the findings of this study have particular relevance for Australasia.

The purpose of this research is to determine the role that trade diversion plays in AD effectiveness. Trade diversion occurs when decreased imports from the dutied country are offset with increased imports from nondutied countries. In an analysis of 428 AD petitions filed in the United States between 1980 and 1988, Prusa (1996, abstract) found 'there is substantial trade diversion from named to non-named countries and the diversion is greater the larger is the estimated duty'. Similar results were obtained by Brenton (2001) in an analysis of AD actions undertaken by the European Union, and by Park (2009) in an analysis of AD actions undertaken by China. In a study of AD actions by the United States against China, Shen and Fu (2014) found the significance of trade diversion to depend on whether petitions were filed against single or multiple countries and on whether the duties were preliminary or final. For single-country petitions, trade diversion was significant only for preliminary AD duties; for multiple-country petitions trade diversion was significant only for final duties. Preliminary duties are imposed in the first 45 days of the petition if an initial investigation by the U.S. International Trade Commission determines that dumping may have caused material injury (or the threat of material injury) to the domestic industry. The duties become final if subsequent investigation by the U.S. Department of Commerce affirms that dumping occurred (for details, see https://www.usitc.gov/press_room/usad.htm).

Focusing on agricultural products and analysing 105 AD cases filed in the United States between 1980 and 2005, Carter and Gunning-Trant (2010) found trade diversion to be relatively unimportant. Carter and Gunning-Trant (2010, p. 100) summarise their findings by stating 'A relatively low degree of trade diversion means that trade remedy laws are more effective for U.S. agriculture compared to manufacturing'. The extent to which this conclusion can be justified on theoretical grounds is analysed herein using a residual demand model. Goldberg and Knetter (1999) argue that residual

[1] Source: https://www.wto.org/english/tratop_e/adp_e/AD_Sectoral_InitiationsByRepMem.pdf (accessed 14 September 2015). For detailed information on AD filings worldwide, see Bown (2016).

demand models are sufficiently flexible to represent alternative market structures and perceived product differentiation. The residual demand model is similar to the market segmentation model developed by Venables (1985) and extended by Brown and Stern (1989) to analyse tariffs in a situation where the product is homogeneous yet price differs across countries. In this model, firms play a Cournot game and perceived demand is market demand net of the supply of other firms. Domestic firms charge the same price in the home market, but different prices in export markets due to perceived market segmentation.

Following Blonigen and Haynes (2002), our analysis focuses on the pass-through elasticity (PTE), that is the elasticity that indicates the sensitivity of domestic price to the duty. Importantly, we extend Blonigen and Haynes' (2002) analysis by developing an analytical expression for the trade diversion elasticity (TDE), that is the elasticity that indicates the sensitivity of imports from non-named sources to the duty. AD duties are shown to be most effective when supply from the dutied source is relatively elastic, and supply from nondutied sources is relatively inelastic. Relatively elastic supply means most of the duty is borne by consumers in the home market; relatively inelastic supply means potential suppliers cannot adjust exports to any extent to take advantage of higher prices. In this instance, PTE approaches its upper limit of one, and TDE approaches its lower limit of zero.

The residual demand model is applied to an AD duty levied by the United States against imports of catfish from Vietnam. The catfish case is of interest because, notwithstanding Carter and Gunning-Trant's (2010) findings, trade diversion seems to be a large part of the story about how the AD duty affected the market. Prior to the imposition of a 64% AD duty in 2003, U.S. imports of catfish from countries other than Vietnam totalled 1 million pounds, <1% of U.S. consumption.[2] A year later imports from non-named sources had tripled to 3 million pounds and continued to triple in the ensuing years so that by 2006 they totalled 33 million pounds, or 16% of the domestic market (Table 1). That increased imports from non-named sources undermined the duty is hinted at by the fact that despite the duty's size (64%), the U.S. price of catfish in the first three years of the duty increased by <11%. The modest price effect, coupled with the continued erosion in the U.S. producer quantity share from 0.76 in 2003 to 0.24 in 2012 (Table 1), suggests the catfish AD duty was ineffective. A theoretical analysis that illuminates the determinants of trade diversion might help explain this apparent policy failure, and in so doing provide insight into other situations where AD measures might prove futile.

Previous research on the catfish duty includes papers by Kinnucan (2003), Muhammad *et al.* (2010), Nguyen (2010) and Brambilla *et al.* (2012). These studies are consistent in showing the duty did more to harm Vietnamese

[2] For a good overview of the catfish AD duty, see Cong (2010) and Muhammad *et al.* (2010). Cong's article discusses administrative reviews of the duty through 2010.

Table 1 Prices, quantities, quantity shares and value shares for domestic and imported frozen catfish fillets, United States, 1999–2012

Year	Price ($/lb.)*			Quantity (mil. lbs)			Quantity Share†			Value share†		
	P_1	P_2	P_3	Q_1	Q_2	Q_3	k_1	k_2	k_3	S_1	S_2	S_3
1999	2.76	1.96	1.22	120	7	1	0.938	0.055	0.008	0.950	0.040	0.010
2000	2.82	1.66	1.48	120	19	1	0.857	0.136	0.007	0.910	0.090	0.005
2001	2.61	1.39	1.37	115	30	1	0.788	0.205	0.007	0.870	0.120	0.004
2002	2.39	1.45	1.17	131	46	1	0.736	0.258	0.006	0.820	0.180	0.002
2003‡	**2.41**	**1.41**	**1.51**	**125**	**38**	**1**	**0.762**	**0.232**	**0.006**	**0.840**	**0.150**	**0.010**
2004	2.62	1.53	1.68	122	44	3	0.722	0.260	0.018	0.820	0.170	0.010
2005	2.67	1.46	1.52	124	36	10	0.729	0.212	0.059	0.830	0.130	0.040
2006	2.92	1.60	1.74	118	50	33	0.587	0.249	0.164	0.720	0.160	0.120
2007	2.92	1.58	1.81	104	36	40	0.578	0.200	0.222	0.700	0.130	0.170
2008	2.91	1.57	1.76	103	53	44	0.515	0.265	0.220	0.650	0.180	0.170
2009	2.96	1.55	1.72	96	86	42	0.429	0.384	0.188	0.580	0.270	0.150
2010	2.97	1.52	1.79	98	108	28	0.419	0.462	0.120	0.580	0.320	0.100
2011	4.15	1.72	2.63	70	187	15	0.257	0.688	0.055	0.450	0.490	0.060
2012	3.63	1.61	3.30	68	214	6	0.236	0.743	0.021	0.404	0.564	0.032

Note: *1 = U.S., 2 = Vietnam, 3 = Rest of World (primarily China). Vietnam and ROW prices are 'Customs Value', that is price actually paid for merchandise, excluding U.S. import duties.
†The quantity share is defined as $k_i = Q_i/(Q_1 + Q_2 + Q_3)$; the value share is defined as $S_i = P_iQ_i/(P_1Q_1 + P_2Q_2 + P_3Q_3)$.
‡An industry-wide antidumping duty of 63.88% was imposed on June 17 of this year against imports from Vietnam. Sources: Hanson and Sites (2011), NOAH (2011) and USITC (2014).

producers than to benefit U.S. producers. Similar results were obtained by Asche (2001) and by Kinnucan and Myrland (2006) in their studies of AD duties levied by the U.S. on imports of salmon from Norway; by Keithly and Poudel (2008) in their analysis of AD duties levied by the U.S. on imports of shrimp from Asia; and by Xie and Zhang (2014) in their study of AD duties levied by the U.S. on imports of salmon from Chile.[3] This study adds to the literature by (i) developing an expression for the PTE that takes into account trade diversion, but also upward-sloping supply from the named source, (ii) developing an analytical expression for the trade diversion elasticity (TDE) and (iii) extending Warr's (2008) analysis of the PTE based on the Armington (1969) model to the three-good case where one of the imported products enters the importing country duty free. A key finding is that the 'Armington assumption' is apt to cause both trade diversion and duty pass-through to be understated.

The next section describes the model and basic analytical results. We then simulate the model to determine the relative importance of import supply elasticities and market share in AD duty effectiveness. The Armington assumption is then imposed to see how inferences are affected. The paper concludes with a summary of key findings.

[3] Xie and Zhang (2014) estimate residual demand curves for U.S. imports of salmon from Canada and Chile. A key finding is that the Chilean demand curve for the dutied product is flat, which means the entire incidence of the duty is borne by Chilean producers.

2. Model

The basic economics of an AD duty in a partial equilibrium setting can be illustrated with the aid of the following structural model. In this model, we assume the home country's demand for the good in question (Q_{1d}) is satisfied by supply from three sources: domestic production (Q_{1s}), imports from the country in which the AD duty is imposed (Q_2) and imports from other countries (Q_3). The domestic and imported products are perfect substitutes, and the domestic market is integrated with world markets such that the law of one price holds. The home country has buying power in the sense that it faces import supply curves that are upward sloping. Transportation costs are zero, and prices are expressed in the currency of the home country. Farm programs and other government policies that might disrupt market adjustments to the AD duty are ignored.

With these simplifying assumptions, the initial equilibrium can be described by six equations:

$$Q_{1d} = D_M(P) \tag{1}$$

$$Q_{1s} = S_1(P) \tag{2}$$

$$Q_2 = S_2(P_{2s}) \tag{3}$$

$$Q_3 = S_3(P) \tag{4}$$

$$P = P_{2s} \cdot \bar{T}_2 \tag{5}$$

$$Q_{1d} = Q_{1s} + Q_2 + Q_3. \tag{6}$$

Equation (1) is the domestic or 'market' demand curve for the good in question, and Eqns (2) – (4) are supply curves that correspond to domestic production, quantity from the dutied country and quantity from nondutied countries, respectively. The AD duty, $\bar{T}_2 > 1$, is expressed in proportionate or ad valorem form. It places a wedge between the duty-inclusive price paid by consumers in the home country P, and the duty-exclusive price received by sellers in the dutied country P_{2s}. Domestic producers and sellers from nondutied countries respond to P, which is higher than P_{2s}, the price received by sellers from the dutied country.

The model contains six endogenous variables (Q_{1d}, Q_{1s}, Q_2, Q_3, P, P_{2s}) and one exogenous variable, $\bar{T}_2$. Other exogenous variables that affect supply and demand are suppressed.

To derive the effects of the AD duty, we first express the model in proportionate change form by taking the total differential of each equation to yield:

$$Q_{1\mathrm{d}}^{*} = \eta P^{*} \tag{7}$$

$$Q_{1\mathrm{s}}^{*} = \varepsilon_1 P^{*} \tag{8}$$

$$Q_{2}^{*} = \varepsilon_2 P_{2s}^{*} \tag{9}$$

$$Q_{3}^{*} = \varepsilon_3 P^{*} \tag{10}$$

$$P^{*} = P_{2\mathrm{s}}^{*} + \bar{T}_{2}^{*} \tag{11}$$

$$Q_{1d}^{*} = k_1 Q_{1s}^{*} + k_2 Q_{2}^{*} + k_3 Q_{3}^{*} \tag{12}$$

where $X^{*} = \mathrm{d}X/X$. In these equations, $\eta(<0)$ is the domestic demand elasticity for the good in question; $\varepsilon_i(\geq 0)$ i = 1, 2, 3 are supply elasticities corresponding to each source (domestic, dutied and nondutied); $k_1 = Q_{1\mathrm{s}}/Q_{1\mathrm{d}}$ is the domestic quantity share; and $k_i = Q_i/Q_{1\mathrm{d}}$, i = 2, 3 are import quantity shares. The quantity shares sum to one.

2.1 Pass-through elasticity

To derive the PTE, we first derive the residual demand curve for the dutied good by dropping Eqn (9) and solving the remaining equations simultaneously to yield

$$Q_{2}^{*} = \left(\frac{\eta - k_1\varepsilon_1 - k_3\varepsilon_3}{k_2}\right)(\bar{P}_{2\mathrm{s}}^{*} + \bar{T}_{2}^{*}). \tag{13}$$

Under the stated restrictions ($\eta < 0$, $\varepsilon_i \geq 0\,\forall\, i$, $k_i > 0\,\forall\, i$ and $\sum_{i=1}^{3} k_i = 1$), the residual demand curve for Q_2 is downward sloping, and an increase in the duty shifts the curve inward. The curve flattens as domestic demand or supply becomes more price elastic (larger $|\eta|$ or ε_1), and as supply from the nondutied source becomes more price elastic (larger ε_3).

The PTE is derived by setting Eqn (13) equal to Eqn (9) and reusing Eqn (11) to yield

$$\mathrm{PTE} \equiv \frac{P^{*}}{\bar{T}_{2}^{*}} = \frac{\varepsilon_2}{\varepsilon_2 - \eta_2} \leq 1 \tag{14}$$

where $\eta_2 = \left(\frac{\eta - k_1\varepsilon_1 - k_3\varepsilon_3}{k_2}\right) < 0$ is the residual demand elasticity for the dutied good. Eqn (14) reflects the principle that the less elastic side of the market bears the greater incidence of the duty. If supply is perfectly elastic buyers bear the full incidence and PTE = 1 (its upper limit); if supply is perfectly inelastic sellers bear the full incidence and PTE = 0 (its lower limit). An AD duty becomes more effective as demand for the dutied good becomes less price elastic (smaller $|\eta_2|$) and as supply of the dutied good becomes more price elastic (larger ε_2).

2.2 Trade diversion elasticity

The TDE is derived in a similar manner. We first derive the residual demand curve for nondutied imports by dropping Eqn (10) and solving the remaining equations in the model simultaneously to yield

$$Q_3^* = \left(\frac{\eta - k_1\varepsilon_1 - k_2\varepsilon_2}{k_3}\right)\bar{P}^* + \left(\frac{k_2\varepsilon_2}{k_3}\right)\bar{T}_2^*. \tag{15}$$

The residual demand curve for Q_3 is downward sloping, and an increase in the duty shifts the curve to the right. The curve flattens as domestic demand or supply becomes more price elastic (larger $|\eta|$ or ε_1), and as supply from the dutied source becomes more price elastic (larger ε_2). These results parallel the results for the residual demand curve for Q_2.

Setting Eqn (15) equal to Eqn (10) and reusing Eqn (10) yields the TDE

$$\mathrm{TDE} \equiv \frac{Q_3^*}{\bar{T}_2^*} = \frac{k_2\varepsilon_2\varepsilon_3}{k_3(\varepsilon_3 - \eta_3)} \geq 0 \tag{16}$$

where $\eta_3 = \left(\frac{\eta - k_1\varepsilon_1 - k_2\varepsilon_2}{k_3}\right) < 0$ is the residual demand elasticity for the nondutied good. Eqn (16) appears to be new to the literature. It shows that trade diversion hinges on the elasticities of import supply. If $\varepsilon_2 = 0$ or $\varepsilon_3 = 0$ then TDE = 0 and there is no trade diversion. ($\varepsilon_3 = 0$ implies exporters from nondutied countries are unable to respond to price changes in the home market; $\varepsilon_2 = 0$ implies the full incidence of the duty is borne by sellers in the dutied country (PTE = 0) and thus there is no price rise in the home market to induce trade diversion). If supply from the dutied source is perfectly elastic, then TDE = ε_3 and trade diversion depends strictly on the size of ε_3.[4]

If supply from nondutied sources is perfectly elastic, then TDE = $\frac{k_2\varepsilon_2}{k_3}$ and trade diversion depends strictly on import shares and ε_2. But in this instance, trade diversion is irrelevant as PTE = 0, which means the duty is ineffective. The reason is that ε_3 and η_2 are related. Specifically, $\eta_2 = \left(\frac{\eta - k_1\varepsilon_1 - k_3\varepsilon_3}{k_2}\right) \to -\infty$ as $\varepsilon_3 \to \infty$. A clockwise rotation in the supply curve for product from nondutied sources causes a counterclockwise rotation in the demand curve

[4] To see this, substitute the expression for η_3 into Eqn (16) to yield TDE $= \frac{k_2\varepsilon_2\varepsilon_3}{k_1\varepsilon_1 + k_2\varepsilon_2 + k_3\varepsilon_3 - \eta}$. Taking the limit of this expression as $\varepsilon_2 \to \infty$ yields TDE $= \varepsilon_3$.

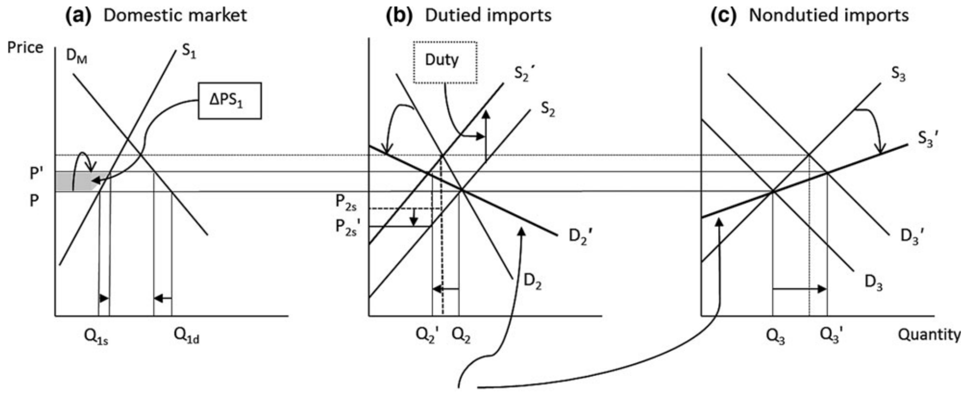

Figure 1 Effects of an antidumping duty on domestic producer surplus (PS1) when supply from non-dutied sources becomes more price elastic. A flatter supply curve for non-dutied imports implies a flatter demand curve for dutied imports, which implies less price enhancement and thus reduced duty effectiveness.

for product from the dutied source (see Figure 1). In the limit where the supply curve for Q_3 is flat, the demand curve for Q_2 is flat. In this instance, the entire incidence of the duty is shifted to producers in the named country, which means price enhancement is nil (since $\eta_2 \rightarrow -\infty$ as $\varepsilon_3 \rightarrow \infty$, which means $\text{PTE} = \frac{\varepsilon_2}{\varepsilon_2 - \eta_2} \rightarrow 0$ as $\varepsilon_3 \rightarrow \infty$).

The conclusion that PTE $\rightarrow 0$ as $\varepsilon_3 \rightarrow \infty$ is predicated on the assumption that $\varepsilon_2 < \infty$. What if the supply curves for Q_2 and Q_3 both are flat? In this instance, $\text{PTE} = \frac{\varepsilon_2}{\varepsilon_2 - \eta_2} = 1$ and the moderating role of ε_3 on AD duty effectiveness (through its effect on η_2) is nullified. This is shown in Table 2, which presents the PTE and TDE for selected values of model parameters. As $\varepsilon_3 \rightarrow \infty$ the PTE approaches zero. The only instance in which this is not true is when ε_2 and ε_3 approach infinity simultaneously, in which case PTE = 1 (compare row 25 with rows 5, 10, 15 and 20). Thus, except in the special case where the importing country is 'small' in the sense that it faces a perfectly elastic supply curve for product from the named source, the supply elasticity for product from non-named sources is critical to understanding the role that trade diversion plays in AD duty effectiveness.

3. Application

The most important principle to be deduced from the foregoing analysis is that an AD duty is most effective when supply from the dutied source is perfectly elastic. In this instance, the full incidence of the duty is borne by consumers in the importing country, which means producer surplus in the importing country increases by its maximum amount. This is true regardless of the size of trade diversion. It is only when the supply curve for named imports is upward sloping that trade diversion undermines duty effectiveness.

Table 2 Pass-through elasticity (PTE) and trade diversion elasticity (TDE) for selected values of model parameters

Row	Model parameters							Implied residual demand elasticities		PTE	TDE
	k_1	k_2	k_3	η	ε_1	ε_2	ε_3	η_2	η_3		
1	0.33	0.33	0.34	−1	0.5	1	1	−4.6	−4.4	0.180	0.180
2	0.33	0.33	0.34	−1	0.5	1	5	−8.7	−4.4	0.103	0.516
3	0.33	0.33	0.34	−1	0.5	1	10	−14	−4.4	0.067	0.674
4	0.33	0.33	0.34	−1	0.5	1	100	−107	−4.4	0.009	0.930
5	0.33	0.33	0.34	−1	0.5	1	∞	−∞	−4.4	0.000	0.971
6	0.33	0.33	0.34	−1	0.5	5	1	−4.6	−8.3	0.523	0.523
7	0.33	0.33	0.34	−1	0.5	5	5	−8.7	−8.3	0.365	1.83
8	0.33	0.33	0.34	−1	0.5	5	10	−14	−8.3	0.265	2.65
9	0.33	0.33	0.34	−1	0.5	5	100	−107	−8.3	0.045	4.48
10	0.33	0.33	0.34	−1	0.5	5	∞	−∞	−8.3	0.000	4.85
11	0.33	0.33	0.34	−1	0.5	10	1	−4.6	−13.1	0.687	0.69
12	0.33	0.33	0.34	−1	0.5	10	5	−8.7	−13.1	0.535	2.68
13	0.33	0.33	0.34	−1	0.5	10	10	−14	−13.1	0.420	4.20
14	0.33	0.33	0.34	−1	0.5	10	100	−107	−13.1	0.086	8.58
15	0.33	0.33	0.34	−1	0.5	10	∞	−∞	−13.1	0.000	9.71
16	0.33	0.33	0.34	−1	0.5	100	1	−4.6	−100	0.956	0.96
17	0.33	0.33	0.34	−1	0.5	100	5	−8.7	−100	0.920	4.60
18	0.33	0.33	0.34	−1	0.5	100	10	−14	−100	0.878	8.78
19	0.33	0.33	0.34	−1	0.5	100	100	−107	−100	0.484	48.4
20	0.33	0.33	0.34	−1	0.5	100	∞	−∞	−100	0.000	97.1
21	0.33	0.33	0.34	−1	0.5	∞	1	−4.6	−∞	1.000	1.00
22	0.33	0.33	0.34	−1	0.5	∞	5	−8.7	−∞	1.000	5.00
23	0.33	0.33	0.34	−1	0.5	∞	10	−14	−∞	1.000	10.0
24	0.33	0.33	0.34	−1	0.5	∞	100	−107	−∞	1.000	100
25	0.33	0.33	0.34	−1	0.5	∞	∞	−∞	−∞	1.000	∞

Note: Shaded values underscore the point that PTE = 1 and is invariant to the supply elasticity for good 3 when the supply elasticity for good 2 is infinite.

To gain quantitative insight into the importance of trade diversion for AD effectiveness, we simulated Eqns (14) and (16) for alternative values of ε_2 and ε_3 as shown in Table 3. In these simulations we set the market demand elasticity to $\eta = -1.42$ and the domestic supply elasticity to $\varepsilon_1 = 1.05$. These estimates are consistent with values used by Kinnucan (2003) and by Muhammad *et al.* (2010) in their analyses of the catfish AD duty. The demand elasticity is consistent with estimates provided by Singh *et al.* (2014, Table 4) based on scanner data. The market shares are set alternatively to $k = \{0.74, 0.23, 0.03\}$ and $k' = \{0.30, 0.63, 0.07\}$ to assess the importance of these parameters in AD duty effectiveness. The k and k' series correspond to average market shares for catfish for the 2003–05 and 2010–12 periods, respectively, provided in Table 1.

For the considered parameter values, the TDE is larger than the PTE whenever $\varepsilon_3 > \varepsilon_2$ (Table 3). The only instance in which this is not true is when $\varepsilon_2 = 0$, in which case TDE = PTE = 0 and the duty is ineffective. A large TDE is not incompatible with a large PTE. For example, if import supplies

Table 3 Trade diversion and pass-through elasticities from the residual demand model for alternative values of the supply elasticities for product from dutied (ε_2) and non-dutied (ε_3) sources

ε_3	$\varepsilon_2 = 0$		$\varepsilon_2 = 1$		$\varepsilon_2 = 5$		$\varepsilon_2 = 10$		$\varepsilon_2 = 100$		$\varepsilon_2 = \infty$	
	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE
Part A (k_1 = 0.74, k_2 = 0.23 and k_3 = 0.03)												
0	0	0	0	0.097	0	0.348	0	0.517	0	0.914	0	1
1	0	0	0.095	0.095	0.345	0.345	0.514	0.514	0.913	0.913	1	1
5	0	0	0.457	0.091	1.67	0.335	2.51	0.501	4.55	0.910	5	1
10	0	0	0.867	0.087	3.22	0.322	4.87	0.487	9.05	0.905	10	1
100	0	0	4.52	0.045	19.2	0.192	32.2	0.322	82.6	0.826	100	1
Infinity	0	0	8.53	0	42.6	0	85.1	0	851	0	∞	1
Part B (k_1 = 0.30, k_2 = 0.63 and k_3 = 0.07)												
0	0	0	0	0.266	0	0.645	0	0.784	0	0.973	0	1
1	0	0	0.259	0.259	0.636	0.636	0.778	0.778	0.972	0.972	1	1
5	0	0	1.170	0.234	3.02	0.604	3.77	0.753	4.841	0.968	5	1
10	0	0	2.09	0.209	5.69	0.569	7.25	0.725	9.64	0.963	10	1
100	0	0	7.09	0.071	27.6	0.276	43.3	0.433	88.4	0.884	100	1
Infinity	0	0	9.67	0	48.4	0	96.7	0	967	0	∞	1

Note: The TDE and PTE are computed by simulating text Eqns (14) and (16) with $\eta = -1.42$ and $\varepsilon_1 = 1.05$. The k_i are average quantity shares for 2003–05 (Part A) and 2010–12 (Part B) computed from Table 1. For details, see text. The shaded area indicates the values for TDE and PTE consistent with the observed effects of the duty. See text for explanation.

from dutied and nondutied sources are equally elastic at $\varepsilon_2 = \varepsilon_3 = 100$, the TDE ranges from 83 to 88 depending on market share, and the PTE ranges from 0.83 to 0.88. Despite the fact that the TDE is 100 times larger than the PTE, nearly all of the duty (between 83 and 88 per cent) appears as a rise in domestic (home) price. Reducing the import supply elasticities to $\varepsilon_2 = \varepsilon_3 = 5$ causes the PTE to decline to between 0.34 and 0.60 and the TDE to decline to between 1.67 and 3.02, but the inference still holds. That is, trade diversion *per se* – or, more precisely, its elasticity – is not a reliable indicator of AD duty effectiveness.

Import supply elasticities tend towards zero or infinity depending on international price linkages and export share. To see this, consider the expression for the supply elasticity for imports from the named source[5]

$$\varepsilon_2 = \gamma_2\left(\frac{\varepsilon_2^{\mathrm{d}} Q_2^{\mathrm{s}} - \eta_2^{\mathrm{d}} Q_2^{\mathrm{d}} - \eta_2^{\mathrm{row}} Q_2^{\mathrm{row}}}{Q_2^{x}}\right) \tag{17}$$

where $\varepsilon_2^{\mathrm{d}}$ and η_2^{d} are supply and demand elasticities for the named product within the country subject to the duty; η_2^{row} is the export demand elasticity that the named country faces from rest-of-world demanders, that is

[5] A similar expression for the supply elasticity for imports from non-named sources can be obtained by setting the subscripts in Eqn (17) to 3 rather than 2 and adjusting the definitions given for the variables and parameters accordingly. See Kinnucan (2003) for a derivation of Eqn (17) and Bredahl *et al.* (1979) for a discussion of the transmission elasticity.

demanders exclusive of the country imposing the duty; Q_2^{s} and Q_2^{d} are the levels of production and consumption for the named product within the named country; Q_2^{row} is the level of exports to rest-of-world demanders; Q_2^{x} is the level of exports to the country imposing the duty; and $\gamma_2 = (\partial P_2/\partial P)(P/P_2)$ is the international price transmission elasticity as defined by Bredahl *et al.* (1979). In our partial equilibrium model $\gamma_2 \in [0, 1]$, with the lower limit arising when there are policies that insulate domestic prices from external price shocks, or when time is too short for domestic prices to adjust to such shocks. In either instance, $\varepsilon_2 = 0$ and imports from the named country to the country imposing the duty are unresponsive to price.[6] If $\gamma_2 > 0$, Eqn (17) tends to infinity as $Q_2^{\mathrm{x}} \to 0$, the small trader case.

The market share of the dutied good is an important determinant of duty effectiveness (compare parts A and B of Table 3). This is especially true in instances where supply from the dutied source is relatively unresponsive to price. For example, when $\varepsilon_2 = \varepsilon_3 = 1$ replacing $k' = \{0.74, 0.23, 0.03\}$with the updated series $k' = \{0.30, 0.63, 0.07\}$ causes the PTE to increase from 0.095 to 0.259; the corresponding increase when $\varepsilon_2 = \varepsilon_3 = 10$ is from 0.487 to 0.725. The TDE also rises with the market share of the dutied good, but the rise does not undermine the basic conclusion that an AD duty is more effective when the market share of the dutied good is large than when it is small. The reason for this, as noted by Kinnucan (2003), is that the demand for the dutied good becomes less price elastic as $k_2 \to 1$ (recall $\eta_2 = \left(\frac{\eta - k_1\varepsilon_1 - k_3\varepsilon_3}{k_2}\right)$), which means more of the incidence of the duty is shifted to domestic consumers.

The PTE rises with ε_2 and falls with ε_3. The only situation where this is not true is when supply from the dutied source is perfectly elastic, in which case PTE attains its upper limit of 1 and the effectiveness of the duty is maximised. PTE falls with ε_3 because demand for the product from the dutied source becomes more elastic as supply from nondutied sources becomes more elastic, as shown in Figure 1. As the demand curve for Q_2 flattens in response to a flattening of the supply curve for Q_3, price enhancement decreases, as does the welfare gain to domestic producers, which is equal to the shaded area in Panel A of Figure 1.

How might the results in Table 3 help explain the data in Table 1? The U.S. price of catfish in 2002, the year prior to the duty, was \$2.39 per pound. When the 64% industrywide duty was implemented in 2003, the U.S. price rose to \$2.41 per pound and continued to rise over the next two years to \$2.67 per pound for a total increase of 10.8%. If one takes three years as the appropriate time horizon for the duty to have its full effect, the implied PTE is 0.17. Over the same period, imports from non-named countries increased from 1 million pounds to 10 million pounds, or 900%. This increase implies a

[6] For an example of perfectly inelastic import supply, see Carter and Mohapatra's (2013) analysis of the AD duty imposed by the United States on imports of orange juice from Brazil.

TDE of 14.1. A highly elastic TDE combined with a highly inelastic PTE is consistent with a situation where supply for non-named imports is highly elastic in relation to supply for named imports. Referring to Table 3, Part A (the part that refers to market shares for 2003–05), a PTE of 0.17 suggests $1 < \varepsilon_2 < 5$ and a TDE of 14.1 suggests $10 < \varepsilon_3 < 100$. Although these estimates are crude, they underscore the potential importance of import supply elasticities for explaining and predicting the market consequences of AD duties.

The removal of the catfish AD duty is apt to cause greater pain for U.S. producers than the gain they experienced from duty implementation. The basis for this inference is the market-share effect. Despite the duty, Vietnam's market share between 2003–05 and 2010–12 increased from 23% to 63%. According to Table 3, when $\varepsilon_2 < 5$ an increase in market share of this magnitude would cause the PTE to increase by a factor of two or three. Consequently, the price reduction associated with duty removal might be two to three times larger than the price increase associated with duty emplacement.

4. Armington representation

How would results change if demand responses to price were constrained to conform to Armington's (1969) assumptions? To answer the question, we replaced the market demand equation [Eqn (7)] with the source-specific demand equations

$$Q_i^* = \eta_{i1} P_1^* + \eta_{i2} P_2^* + \eta_{i3} P_3^* \quad i = 1, 2, 3 \tag{18}$$

where Q_i are quantities of catfish consumed in the United States from the three sources (1 = domestic, 2 = Vietnam and 3 = Rest of World) that now are assumed to be differentiated by place of production. The P_i 's in Eqn (18) are the prices paid by domestic buyers for the three products, and the η_{ij} are source-specific demand elasticities.

The supply and tax-wedge equations are identical to those in the original model except for a slight redefinition of variables to reflect the fact that the prices of each product now are distinct:

$$Q_i^* = \varepsilon_i P_i^* \quad i = 1, 3 \tag{19a}$$

$$Q_2^* = \varepsilon_2 P_{2s}^* \tag{19b}$$

$$P_2{}^* = P_{2s}^* + \bar{T}_2^*. \tag{20}$$

The modified model consists of seven equations in seven endogenous variables (four prices and three quantities) and one exogenous variable (the AD duty). As with the residual demand model, other exogenous variables that shift the supply and demand curves are suppressed.

The model is completed by imposing the Armington restrictions (see Appendix S1 for derivation):

$$\begin{bmatrix} \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{bmatrix} = \begin{bmatrix} S_1\eta - (1-S_1)\sigma & S_2(\sigma+\eta) & S_3(\sigma+\eta) \\ S_1(\sigma+\eta) & S_2\eta - (1-S_2)\sigma & S_3(\sigma+\eta) \\ S_1(\sigma+\eta) & S_2(\sigma+\eta) & S_3\eta - (1-S_3)\sigma \end{bmatrix}. \tag{21}$$

The nine demand elasticities are computed from three parameters: the overall demand elasticity for the product group η; the Armington elasticity of substitution σ; and the value share for each product $S_i = \frac{P_i Q_i}{\sum_{i=1}^{3} P_i Q_i}$.

Numerical values for TDE and PTE implied by Eqns (18) – (21) were obtained by simulating the model using the same elasticity values as was used for the residual demand model.[7] Specifically, η is set to -1.42, ε_1 is set to 1.05, and ε_2 and ε_3 are set to alternative values between zero and infinity. The substitution elasticity σ, which is unique to the Armington model, is set to 5. According to Warr (2008, p. 502–503), most empirical applications of the Armington model use a substitution elasticity of between 2 and 5. Hence, our computed PTEs are properly interpreted as *upper-bound* estimates relative to a typical application. The quantity shares k = {0.74, 0.23, 0.03} and k' = {0.30, 0.63, 0.07} are replaced with their corresponding value shares S = {0.83, 0.15, 0.02} and S'={0.48, 0.46, 0.06} to conform to Eqn (21).

Results suggest the Armington model understates both trade diversion and price enhancement relative to a residual demand model (Table 4). For the considered parameter values, the TDE ranges from zero to 2.29 and the PTE ranges from zero to 0.38. The corresponding ranges based on the residual demand model are TDE $\in$ [0, ∞] and PTE $\in$ [0, 1]. Focusing on Part A of Table 4, the part relevant to the first three years of the catfish AD duty, the TDE has an upper limit of 1.06 and the PTE has an upper limit of 0.174. The latter estimate is consistent with the implied PTE of 0.17 based on observed price and quantity changes for 2003–05. The TDE estimate of 1.06, however, is significantly below the implied TDE of 14.1. For $\varepsilon_2 \in [1, 5]$ and $\varepsilon_3 \in [10, 100]$, limits suggested by the residual demand model, TDE is bounded on the interval [0.14, 0.56] and PTE is bounded on the interval [0.036, 0.098] (Table 4, Part A). In this instance, TDE and PTE both are substantially below the results obtained from the residual demand model. This finding supports Vansickle *et al.*'s (2003, p. 285) contention that Armington-based models understate the impact of dumping on domestic producers.

[7] Analytical expressions for PTE and TDE for the Armington model with three products are too complex to be intelligible and thus are not presented. For an expression for the two-good case in which import supply is assumed to be perfectly elastic, see Warr (2008).

Table 4 Trade diversion and pass-through elasticities from the Armington model for alternative values of the import supply elasticities ε_2 and ε_3

ε_3	$\varepsilon_2 = 0$		$\varepsilon_2 = 1$		$\varepsilon_2 = 5$		$\varepsilon_2 = 10$		$\varepsilon_2 = 100$		$\varepsilon_2 = \infty$	
	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE	TDE	PTE
PART A (S_1 = 0.83, S_2 = 0.15 and S_3 = 0.02)												
0	0	0	0	0.037	0	0.101	0	0.129	0	0.173	0	0.179
1	0	0	0.037	0.036	0.101	0.100	0.129	0.128	0.173	0.172	0.180	0.179
5	0	0	0.109	0.036	0.300	0.099	0.384	0.127	0.515	0.170	0.535	0.177
10	0	0	0.144	0.036	0.397	0.099	0.510	0.126	0.683	0.169	0.710	0.176
100	0	0	0.204	0.035	0.563	0.098	0.722	0.125	0.968	0.168	1.01	0.175
Infinity	0	0	0.213	0.035	0.590	0.098	0.757	0.125	1.02	0.168	1.06	0.174
PART B (S_1 = 0.48, S_2 = 0.46 and S_3 = 0.06)												
0	0	0	0	0.113	0	0.267	0	0.322	0	0.394	0.000	0.404
1	0	0	0.112	0.111	0.265	0.263	0.320	0.317	0.392	0.389	0.403	0.399
5	0	0	0.325	0.107	0.773	0.256	0.934	0.309	1.15	0.380	1.18	0.390
10	0	0	0.425	0.105	1.02	0.252	1.23	0.305	1.52	0.376	1.56	0.386
100	0	0	0.589	0.102	1.42	0.246	1.72	0.298	2.13	0.369	2.18	0.379
Infinity	0	0	0.616	0.102	1.48	0.245	1.80	0.297	2.23	0.368	2.29	0.378

Note: The TDE and PTE are computed by simulating text Eqns (18) –(21) with $\eta = -1.42$, $\varepsilon_1 = 1.05$ and $\sigma = 5$. The S_i are average value shares for 2003–05 (Part A) and 2010–12 (Part B) computed from Table 1. For details, see text. The shaded area indicates the empirically relevant region for the import supply elasticities suggested by residual demand model. See text for explanation.

Would a more generous specification of substitution possibilities correct the apparent downward bias in the Armington estimates? To address the question, we re-simulated the model for alternative values of σ ranging from 5 to infinity. In these simulations, the market-share parameters are set to their 2003–05 levels, and ε_2 is set alternatively to 3 and 9, empirically relevant limits suggested by the residual demand model. The ε_3 parameter is permitted to vary along its entire range from zero to infinity. Results (not shown to conserve space) indicate σ would have to be increased to at least 100 to produce an estimate of TDE consistent with its 'observed' value of 14. But in this instance, the PTE is 0.27, which is significantly above its observed value of 0.17. The Armington model is capable of producing an accurate prediction of trade diversion, but at the expense of overstating price enhancement.

5. Concluding comments

The results of this study suggest import supply elasticities are not to be overlooked as important determinants of the effectiveness of antidumping duties. If the dutied product is homogenous across supply sources, an AD duty is most effective when import supply from the named country is perfectly elastic. In this instance, price in the domestic (home) market rises by the full amount of the duty. And this is true regardless of the supply elasticity for product from non-named countries. If import supply from the named country is not perfectly elastic, the effectiveness of an AD duty declines with the supply elasticity for product from non-named countries. In this instance, if supply from non-named countries is perfectly elastic, an AD duty is ineffective, as then trade diversion is complete, that is the contraction in imports from the named country is exactly matched by expansion of imports from non-named countries, resulting in no change in the levy-inclusive price. Without price enhancement, the welfare gain to domestic producers from an AD duty is nil.

If products are differentiated by place of production, as in the Armington framework, the same principles apply, except now domestic producers can gain even if supply from non-named countries is perfectly elastic. The reason is that a duty-induced increase in the price of the product from the named country increases the demand for the domestic product irrespective of the effect of the duty on the price of products imported from non-named countries. That is, irrespective of the amount of trade diversion that might occur. With an increase in demand for the domestic good, domestic price increases (given upward-sloping domestic supply), as does domestic producer welfare. Still, for commonly used values of the elasticity of substitution, our simulations suggest the Armington model understates both trade diversion and price enhancement.

The catfish AD duty did little to prevent the erosion of the U.S. producer share of the domestic market. An *ex ante* analysis predicted this result, citing a small market share for product from Vietnam as the chief reason (Kinnucan 2003). Our *ex post* analysis suggests the real culprit is trade diversion associated with a highly elastic supply response from non-named countries. To the extent a highly elastic supply response from non-named countries can be generalised to other products in or outside of the agricultural/fisheries sector, AD duties are not apt to be an effective instrument of protection. A careful assessment of supply conditions prior to an AD petition should be helpful in avoiding cases where a duty is unlikely to benefit domestic producers.

A limitation of the present analysis is that substitution effects are limited to the market for catfish. In reality, catfish competes in the larger market for finfish, most notably tilapia, whiting, cod and flounder (Norman-López and Asche 2008; Singh *et al.* 2014). Extending the analysis to a general equilibrium setting in which the full array of substitution effects and the attendant supply responses are permitted to affect the equilibrium could yield additional insight. In the meantime, the elucidation of the role of supply elasticities as a determinant of AD duty effectiveness should be useful in predicting and explaining the efficacy of this policy instrument.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Derivation of the armington restrictions.