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Impacts of Australia's free trade agreements on trade in agricultural products: an aggregative and disaggregative analysis*

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The importance of free trade agreements (FTAs) has been increasing as such agreements help reduce barriers to trade. This paper estimates the agricultural trade creation and export diversion effects of Australia's free trade agreements (FTAs) at the aggregate and disaggregate levels, using the Poisson pseudo-maximum-likelihood (PPML) estimator. It includes 24 of Australia's major trading partner countries comprising FTA and non-FTA members and covers 22 years from 1996 to 2017. The heteroscedasticity robust regression error specification test (RESET) confirms the relevance of PPML over the Ordinary Least Square (OLS) estimator. Results showed that China–Australia, Korea–Australia, Australia–USA and Japan–Australia have larger trade creation effects in the agricultural sector. At the commodity level, variation in trade creation effects is estimated from the different trade agreements. Among the selected commodities, the larger effects were generated in trade in sugar and wine by the implementation of the majority of the trade agreements. Overall, the trade creation was greater than the export diversion of the FTAs. The findings of the study have implications for Australia's future trade agreements.

Key words: agricultural trade, Australia, free trade agreements, gravity model, PPML.

1. Introduction

The growth of economic regionalism in world trade has been rapid, especially during the last three decades with significant progress in regional integration in the most important global economic areas. The number of free trade agreements (FTAs) between countries has increased. For instance, the number of FTAs has risen from 23 in 1988 to 683 in January 2019, of which 469 are in force (WTO 2019). Different views on the role of FTAs have been expressed. Levy (1997) argues that bilateral free trade agreements between countries with similar factor endowments are most likely to have a higher

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chance of increasing utility. This has discouraged further multilateral trade liberalisation. It is probably the reason for the failure to negotiate talks at a multilateral level that led to the increasing number of bilateral FTAs as a compelling alternative to multilateral agreements (Sarker and Jayasinghe 2007).

Australia concluded its first FTA in 2003 with Singapore after the Closer Economic Relations agreement with New Zealand (ANZCER) in 1983. In 2005, Australia signed FTAs with the USA and Thailand. A more significant shift in Australian trade policy strategy occurred with the negotiation of the Australia–United States Free Trade Agreement (Armstrong 2012). Since then, Australia has signed FTAs with Chile (2009), the Association of Southeast Asian Nations (ASEAN) and New Zealand (2010), Malaysia (2013), Korea (2014), Japan (2015), China (2016) and the Trans-Pacific Partnership Agreement (TPP) in 2018 (AIIA 2018; DFAT 2019a). Currently, Australia has eleven FTAs in force covering about two-thirds of Australia's total trade; four FTAs have been concluded but are not in effect and another seven FTAs are under negotiation (Hyde *et al*. 2014; AIIA 2018; DFAT 2019a, 2019b). Details of all three categories of Australia's FTAs are presented in Tables S1 and S2.

FTAs are not always equally beneficial to all parties. For example, an evaluation of the India–ASEAN FTA concluded that ASEAN had benefitted more than India (Bhattacharyya and Mandal 2014). Similarly, India gains more in terms of welfare and real GDP from the FTA between India and Bangladesh (Kim *et al*. 2013). FTAs are beneficial for countries that have a higher priority for elastic tariff goods compared to countries having a preference for inelastic tariff goods (Bhattacharyya and Mandal 2014). An FTA between two countries is also affected by other trade agreements; for example, Australian beef exports to Korea will be reduced drastically after full implementation of the Korean FTA with the USA and Europe (Quansah and Ahn 2017). Tang (2005) studied the North American FTA (NAFTA), ANZCER and ASEAN countries from 1989 to 2000 and concluded that ANZCER and ASEAN had facilitated increased trade among their member countries. In case of trade diversion, the formation of the ANZCER had resulted in trade diversion with non-member countries and ASEAN had also generated a trade increase with non-member countries, whereas the formation of the NAFTA had no significant effect on trade with non-member countries. The trade creation effects of African Regional Trade Agreements have shown some positive impacts on trade, ranging from a 27 per cent to 32 per cent increase in trade (Afesorgbor 2017). The trade liberalisation and technological changes have made way for the development of giant supply chains, which have contributed to an expansion of the international trade more rapidly when compared to the global economic growth in the last five decades (Krist 2013).

The econometric models such as computable general equilibrium (CGE) models and gravity models have been commonly used to analyse the economic impacts of an FTA on the welfare of a trade partner, notably ex ante effects from CGE and ex post effects from gravity models. However, both of these models ignore the social impacts of an FTA (Tejedor 2017). Zero trade observation is a significant issue in gravity analysis. The presence of zero-valued trade flows becomes more relevant in specific goods rather than the volume of overall and sectoral trade between two countries (Sun and Reed 2010; Philippidis *et al*. 2013). Studies have typically dealt with the issue of zero trade value in one of three ways: (i) use some transformation, such as adding a small value to the zero observation (Sandberg *et al*. 2006; Fadeyi *et al*. 2014); (ii) delete the observations with zero trade (Hndi *et al*. 2016); and (iii) use a Tobit model and keep the zero observations (Dee and Gali 2005). Dropping zeros or replacing zeros with small values can lead to substantial bias and influence the estimated results (Hurd 1979; Burger *et al*. 2009; Kim *et al*. 2013).

In the econometric analyses, the omitted variable bias, average trade flows rather than unidirectional and inappropriate deflation of trade flows are the major three mistakes in the gravity literature (Anderson and Van Wincoop 2003; Baldwin and Taglioni 2006). Baier and Bergstrand (2007) reported that omitted variable bias is a primary source of endogeneity when estimating the effects of FTAs in gravity equations using cross-sectional data. The instrumental variable approach can deal with endogeneity; however, it provides poor results if it is not identified correctly (Bascle 2008). The problem of endogeneity has been dealt with by using various fixed effects in a panel data setting with numerous estimation procedures, such as two-stage least squares, Poisson pseudo-maximum-likelihood (PPML) and Tobit (Coulibaly 2004; Dee and Gali 2005; Sun and Reed 2010; Khurana and Nauriyal 2017; Irshad *et al*. 2018). Endogeneity and zero trade observation issues have not been considered in the analyses of trade creation and diversion effects in some studies (Sarker and Jayasinghe 2007; Lambert and McKoy 2009; Mafizur Rahman 2012). Various studies on the effects of FTAs on agricultural trade (Yu *et al*. 2010; Dal Bianco *et al*. 2017; Borodin and Salnikov 2018), do not include trade creation and trade diversion impacts. Similarly, the retrospective effects of FTAs on Australian agricultural trade creation and diversion, at the aggregate (agricultural) and disaggregate (commodity) levels, have not been explored adequately (see Table 1). Therefore, this study estimates Australia's agricultural trade creation and export trade diversion effects from its FTAs at aggregate and disaggregate levels. Yang and Martinez-Zarzoso (2014) suggest that disaggregated data for specific commodities are important, in terms of differences in the trade structures and integration impacts. This study is an important one in the academic context, but it also has important policy implications in relation to future and ongoing FTA negotiations between Australia and other countries. Thus, this study raises the following research questions.

Table 1 Synopsis of Australia's trade-related studies in the last ten years (2008–2018)

Author/s and date	Objective	Study period/Data used	Coverage (FTA/total, sectoral and agricultural commodities trade)	Estimation of Trade Creation (TC) and Trade Diversion (TD) effects of FTA	Estimation/ Analytical method
Martin and Anderson (2008)	Discussing the most controversial areas of the agricultural negotiations and market access issues under WTO and proposed unique safeguard mechanism	Review	General/Agricultural	No	Descriptive and review-based analysis
Capling (2008)	Exploring the geopolitical and strategic dimensions for free trade agreements (FTA) concerning the negotiation of Japan and Australia FTA (JAEPA)	Review	JAEPA/ Agri-food trade	No	Review-based analysis
Siriwardana and Yang (2008)	Analysing the economic effects of an Australia–China free trade (ChAFTA) focusing on welfare and sectoral aspects	Global Trade Analysis Project (GTAP) database – version 6	ChAFTA/grains, vegetables, fruits, nuts, animal products, dairy, sugar, beverage, etc	Yes	Computable General Equilibrium (CGE) model
Yu *et al.* (2010)	Examine the impact of the Sino-Australia free trade Agreement talks on China's dairy industry	GTAP Version 7 database in 2004	ChAFTA/grain crops, milk, meat, mining, processed food, textiles, manufacture and others	Yes	GTAP model with different scenarios
Cook *et al.* (2011)	Estimating economic welfare consequences for Australia of allowing quarantine-restricted New Zealand apple imports	30-year time period	ANZCERTA/apple	No	Partial Equilibrium Trade Model (international trade model combine with a stratified dispersal model)
Athukorala and Kohpaiboon (2011)	Examining the impact of the Thailand–Australia Free Trade Agreement (TAFTA)	2000-2010	TAFTA/total trade, food beverage and tobacco	No	Average annual growth rate, descriptive and review-based analysis

Table 1 (*Continued*)

Author/s and date	Objective	Study period/Data used	Coverage (FTA/total, sectoral and agricultural commodities trade)	Estimation of Trade Creation (TC) and Trade Diversion (TD) effects of FTA	Estimation/ Analytical method
Mafizur Rahman (2012)	Identifying Australia's global trade potential	1972-2006/Panel	General/total trade	Yes*	OLS
Sally and Siddique (2014)	Examining the trade creation and diversion effects of TAFTA on bilateral merchandise trade flows	1998 to 2012/Panel	TAFTA/total trade	Yes	OLS, fixed effects
Cho and Yoon (2014)	Analysing the potential sectoral effects of Australia and India FTA	Input–output tables for the year 2005 and combining it with additional data from different sources	Australia–India FTA (not in force)/ seven sectors including mining, fuel, other primary agri-commodities, textile machinery, other manufacture and services	Yes	Applied General Equilibrium Model (AGEM)
Siriwardana (2015)	Examining the economic and environmental impacts of Australia's FTA with Japan and South Korea (KAFTA)	GTAP-E version 8.1 database	JAEPA, KAFTA/ 20 sectors including agriculture, forestry and fishing	Yes	Global Trade Analysis Project-Environmental general equilibrium (GTAP-E) model
Dixon (2015)	Explaining the proliferation of free trade agreements (FTAs) through the theory of efficiency gains and terms-of-trade losses, and discuss gains from Australia's FTA with Japan, Korea and China	Review	ChAFTA, JAEPA, KAFTA/ Agricultural and non-agricultural products	No	Review-based analysis
Barbalet *et al.* (2015)	Analysing the effects of 27 agreements that are of particular importance for Australia on the value of merchandise trade flows	1970-2008/Panel	27 agreements that are of particular significance to Australia including ANZCERTA/total trade	Yes	Poisson estimator

Table 1 (*Continued*)

Author/s and date	Objective	Study period/Data used	Coverage (FTA/total, sectoral and agricultural commodities trade)	Estimation of Trade Creation (TC) and Trade Diversion (TD) effects of FTA	Estimation/ Analytical method
Armstrong (2015)	Assessing the economic impact of the Australia–US free trade agreement	1970-2008/Panel	AUSFTA/total trade	Yes	Productivity Commission model
IIT (2015)	Identifying the potential impact of ChAFTA on the South Australian economy	2000, 2004 and 2009-14/cross section and panel	ChAFTA/total, agricultural and non-agricultural	Yes*	OLS, random effects, fixed effects
Anderson (2016)	Examining the price and trade-distorting policy impacts on producer and consumer prices and value added by farmers in Australia and New Zealand and other regions of the world	Review	General/agricultural	No	Review-based analysis
Xiang *et al.* (2017)	Analysing the economic impacts of the ChAFTA on global coal output, trade, consumption and welfare	2014/cross section	ChAFTA/non-agriculture (coal)	Yes	Global simulation model (GSIM)
Quansah and Ahn (2017)	Analysing the effect of the Korea–Australia Free Trade Agreement (KAFTA)	2012-2015	KAFTA/food beverage, tobacco, rubber	No	Trade Specialization Index (TSI), Grubel-Lloyd (GL)/Intra-Industry Trade (IIT) Index and Contribution to Trade Balance (CTB) Index
Swinbank (2018)	Identifying possible policy options for the future UK–Australia agri-food trade agreement	Review	Future Australia–UK free trade/ agri-food trade	No	Descriptive and review-based analysis

Table 1 (*Continued*)

Author/s and date	Objective	Study period/Data used	Coverage (FTA/total, sectoral and agricultural commodities trade)	Estimation of Trade Creation (TC) and Trade Diversion (TD) effects of FTA	Estimation/ Analytical method
Anderson (2018)	Explaining the reasons to slow emergence for Australia's production and competitive advantage in wine	1843-2017	General/wine	No	Revealed comparative advantage (RCA), descriptive and review-based analysis
Qi and Zhang (2018)	Examining the causes and consequences of delays in ChAFTA negotiation and see how the FTA affects the world economy with a particular reference to New Zealand	2007 and 2011	ChAFTA/ total, grains, meat	yes	Computable General Equilibrium Model (CGM)/ GTAP model
Villalta Puig (2018)	Assessing the drivers and difficulties in the economic relationship between Australia and the EU	Review	Proposed Australia–EU FTA/total, agricultural	No	Review-based analysis
Suder (2018)	Analysis of the business case for FTA between the European Union and Australia	Review	Proposed Australia–EU FTA/agriculture and education sector	No	Descriptive and review-based analysis
Murray (2018)	Examinations of the drivers and obstacles for the development of Australia's relationship with the European Union (EU)	Review	Proposed Australia–EU FTA/general, agricultural	No	Review-based analysis

Note: Yes* means only TC; papers are mainly from the journal database of the Web of Science, Taylor and Francis online, and Wiley online library.

- Are Australia's FTAs beneficial at aggregate (agricultural) and disaggregate (beef, wine, sugar, and edible fruits and nuts) levels?
- Have Australia's FTAs delivered comparable benefits for its beef, wine, sugar, and edible fruit and nut industries?
- Are the benefits generated by Australia's FTAs continuous?

We used a gravity model, a PPML estimator with time and importer fixed effects to address endogeneity of FTAs and zero trade observation issues. Similarly, we also looked at the dynamic effects of FTAs. The rest of the paper is organised as follows. A brief overview of the literature is given in Section two, focusing on theoretical discussion, followed by impacts of trade creation and trade diversion, and finally Australia's trade studies in the ten years 2008–2018. A description of the gravity model is presented in Section three. Section four details the data and sources used in this analysis. The results and discussion are outlined in section five, followed by the conclusion in section six.

2. Literature review

Adam Smith in the 19th century provided the productivity principle of the benefits of trade that explains why classical trade theory is often associated with colonialism (Smith 1776). Ricardo (1817) developed the theory of comparative advantage based on the principle of relative efficiency. It postulates that even if one country can produce all goods more economically than can another country, both countries can derive benefit from trading. The country can obtain welfare gains through specialising in the production of those goods with the lowest opportunity cost (Thirlwall 2000). As specialisation increases, the static gains arise from the reallocation of resources from one sector to another sector (Thirlwall 2000). Poor countries have cheaper labour than capital that provides comparative advantage when exporting goods from labour-intensive production systems (Sapsford and Garikipati 2006). Krist (2013) judged that Ricardo and other early economists founded their theories on trade in goods, but they ignored the trade in factors of production such as labour, capital and technology, which are traded today. Modern trade theory focuses on the dynamic gains of the trade (Helpman and Krugman 1985). These gains typically transform a country's income generation capacity as it capitalises on economies of scale in production and invests more and more in the knowledge economy (Thirlwall 2000).

International trade theories make the argument that the intensification of trade between countries may produce increased level of welfare in both countries (Tejedor 2017). The trade agreements refer to specific agreements that are designed to reduce transaction costs in international trade (Bagwell and Staiger 1999). Trade liberalisation and regional integration have begun with the signing of a number of bilateral, multilateral and regional trade agreements after the creation of the General Agreement on Tariffs and Trade

(GATT) in 1947 (Tejedor 2017). Dicaprio and Santos-Paulino (2011) reported that FTAs have the potential to address economic vulnerability in developing country partners. In an FTA, signatory countries aim to remove tariffs across member states, but they maintain independent tariff regimes to non-member countries (Plummer *et al*. 2010), and so partner countries in an FTA receive higher welfare compared to countries without FTA due to adjustment of consumption and production to new prices with a higher level of welfare (Culas and Timsina 2019b). An FTA can create competitive position for partners through providing access to markets, access to improved technology and a free flow of investment (Islam 2004). If a tariff is imposed, there can be a gain in domestic producer surplus but with a reduction in consumer surplus, which can result in a net welfare loss (Economics 2019; Culas and Timsina 2019b). In a nutshell, the benefits flowing from membership of an FTA can be explained by trade creation and trade diversion analysis (Tejedor 2017).

The trade studies focusing on trade creation (TC) and trade diversion (TD) have increased to assess the trade effects from the formation of FTAs among different nations. Viner (1950) introduced the concepts of TC and TD. TC occurs when new trade is created between members due to the reduction of internal trade barriers. TD refers to welfare loss caused by a change in the origin of a product from a non-member, whose resource costs are more economical, compared to a member whose resource costs are higher. Later, Endoh (1999) introduced the concept of export trade diversion, which differs from the definition given by Viner (1950). Endoh represented the concept of trade diversion as concerning each regional institution's exporting activities. Khurana and Nauriyal (2017) adopted the approach introduced by Endoh (1999) and estimated separately the export and the import trade diversion effects of FTAs.

However, few studies have been carried out in the global context focusing on agricultural trade creation and diversion effects of FTAs at aggregate levels (Koo *et al*. 2006; Lambert and McKoy 2009; Vollrath *et al*. 2009; Sun and Reed 2010; Yang and Martinez-Zarzoso 2014) and disaggregate levels (Sarker and Jayasinghe 2007; Ghazalian *et al*. 2011; Fadeyi *et al*. 2014; Hndi *et al*. 2016). Yang and Martinez-Zarzoso (2014) reported the ASEAN–China Free Trade Agreement (ACFTA) has substantial and significant trade creation effects in the case of both agricultural and manufactured goods. The intra-regional trade of maize and beef has been stimulated by the effective implementation of the South African Development Community's FTA (Fadeyi *et al*. 2014). Similarly, Hndi *et al*. (2016) assessed the impacts of this FTA by taking the case of North African countries and reported the positive influences of the FTA on vegetable trade flow, while for the live animal trade, the influence has been negative.

The impacts of FTAs may not always be the same for different commodities; they may vary and may have positive and adverse effects in the same country (Siriwardana 2006; Sarker and Jayasinghe 2007; Siriwardana and Yang 2008; Athukorala and Kohpaiboon 2011; Kim *et al.* 2013; Hndi *et al.* 2016; Qi and Zhang 2018). FTAs can have dynamic effects; mostly, the positive trade creation effects of an FTA can continue over time, but these effects can also completely diminish (Sun and Reed 2010). Unforeseen events and trade-distorting policies are also more prevalent; they can mask or overwhelm the FTA effects (Anderson 2016; Anderson 2018). Plummer *et al.* (2010) have identified long-term cumulative effects (dynamic effects) of FTAs.

We conducted a literature review of Australia's trade-related studies for the ten years 2008 to 2018. These studies have covered ChAFTA, AUSFTA, TAFTA, JAEPA, KAFTA, ANZCERTA and the proposed Australia–EU, Australia–UK and Australia–India trades. However, most of the studies are ex ante focused on ChAFTA, AUSFTA and Australia–EU trades (Siriwardana and Yang 2008; Yu *et al.* 2010; Armstrong 2015; Dixon 2015; IIT 2015; Xiang *et al.* 2017; Qi and Zhang 2018; Suder 2018). Various estimation techniques, from empirical to review-based analyses, were used to identify the impacts of different trade agreements concentrating on merchandise trade. The empirical studies mostly use multisectoral computable general equilibrium (CGE) models to analyse the welfare impacts of FTAs. Many authors did not consider trade creation and diversion effects of Australia's FTAs in their studies (Capling 2008; Athukorala and Kohpaiboon 2011; Quansah and Ahn 2017; Anderson 2018; Murray 2018; Suder 2018; Swinbank 2018; Villalta Puig 2018). Similarly, limited empirical studies have been conducted to analyse trade creation and diversion effects of Australia's FTAs focusing on the agricultural sector and agri-commodities trade. A synopsis of Australia's trade studies during the last ten years is presented in Table 1. The following hypotheses were developed based on relevant theory and arguments from existing literature:

H1: Australia's FTAs have differential effects at aggregate and disaggregate levels.

H2: The trade creation effects of Australia's FTAs are higher than the intra-block export diversion effects both at aggregate and disaggregate levels.

H3: The effects of Australia's FTAs have changed over time.

3. Description of the Gravity model

After its introduction by Tinbergen (1962) and Linneman (1966), the gravity model has been used extensively to analyse trade flows. The basic gravity model, which was introduced by Tinbergen (1962), has the following structure:

$$LnExp_{ij} = \beta_0 + \beta_1 LnY_i + \beta_2 LnY_j + \beta_3 LnDIS_{ij} + \varepsilon_{ij} \quad (1)$$

where the export volume of country i to country j (Exp_{ij}) has a relationship with the GNP in county i (Y_i) and in country j (Y_j). Similarly, the distance between countries i and j (DIS_{ij}) is taken as a proxy for transportation cost. 'Ln' is the natural logarithm, and ε_{ij} is the stochastic error term. We have extended our model after including specific variables listed in Table 2 in Equation (2), meaning the gravity equation can be expressed as:

Table 2 Independent variables and expected signs

Independent variable	Description	Expected Sign
GDP_i	Gross domestic product of the exporting country i (current US dollars)	+
GDP_j	Gross domestic product of the importing country j (current US dollars)	+
DIS_{ij}	Weighted distance between countries i and j (Kilometres)	-
$Popu_i$	Population of exporting country i (number million)	-
$Popu_j$	Population of importing country j (number million)	+
$Area_i$	Area of exporting country i (square Km in thousand)	+
$Area_j$	Area of importing country j (square Km in thousand)	-
$Comol_{ij}$	Dummy variable;=1 if countries i and j have a common official language	+
$ChAFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to China in and after 2016	+
$JAEPA_{ijt}$	Dummy variable;= 1 when export destination belongs to Japan in and after 2015	+
$KAFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to Korea in and after 2014	+
$A\ NZCERTA_{ijt}$	Dummy variable;= 1 when export destination belongs to New Zealand in and after 1996; zero otherwise	+
$SAFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to Singapore in and after 2003	+
$AUSFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to the USA in and after 2005	+
$TAFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to Thailand in and after 2005	+
$ACIFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to Chile in and after 2009	+
$AANZFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to New Zealand and ASEAN countries in and after 2010	+
$MAFTA_{ijt}$	Dummy variable;= 1 when export destination belongs to Malaysia in and after 2013	+
FTA_{it}	Dummy variable;=1 if country j is a non-member of Australia's free trade in time t	+

$$\begin{aligned} LnExp_{ijt} = {} & \beta_0 + \beta_1 LnGDP_{it} + \beta_2 LnGDP_{jt} + \beta_3 LnDIS_{ij} + \beta_4 LnPopu_i \\ & + \beta_5 LnPopu_j + \beta_6 LnArea_i + \beta_7 LnArea_j + \beta_8 Comol_{it} \\ & + \beta_9 ChAFTA_{ijt} + \beta_{10} JAEPA_{ijt} + \beta_{11} KAFTA_{ijt} \\ & + \beta_{12} ANZCERTA_{ijt} + \beta_{13} SAFTA_{ijt} + \beta_{14} AUSFTA_{ijt} \\ & + \beta_{15} TAFTA_{ijt} + \beta_{16} ACIFTA_{ijt} + \beta_{17} AANZFTA_{ijt} \\ & + \beta_{18} MAFTA_{ijt} + \beta_{19} FTA_{it} + \varepsilon_{ijt} \end{aligned} \tag{2}$$

where Exp_{ijt} is exports from country '*i*' to country '*j*'. GDP_i (*j*) are the respective incomes of exporting and importing countries, which is a proxy for the size of the economy. The sub-index i and j refer to the exporter and importer, respectively, and t refers to the year. The estimated coefficient of the distance variable DIS_{ij} is expected to have a negative sign.
The remaining variables included in equation (2) are designed to capture the influence of other factors on trade flows. Recent econometric studies have incorporated the effects of regional trade agreements (RTAs) into the model specification and estimated the models using pre-RTA and post-RTA data through the use of dummy variables (Sarker and Jayasinghe 2007). The FTA_{ijt} variables (β_9 to β_{18}) take the value of 1 in and after their effective date of a regional/bilateral trade agreement if both exporter (*i*) and importer (*j*) in the year (*t*) belong to the regional/bilateral trade agreements, or zero otherwise. We use the term trade creation for additional trade due to both members being in the trade agreement. The FTA_{it} variable (β_{19}) takes the value of 1 if the importer (*j*) is a non-member in Australia's free trade agreements in the year t or zero otherwise. Details of the explanatory variables are presented in Table 2.

We estimate Equation (2) using instrumental variables (2SLS) regression with the population and the lagged values of partners' GDP as instruments following Anderson (1979) and Mafizur Rahman (2012):

$$\begin{aligned} LnExp_{ijt} = {} & \beta_0 + \beta_1 LnGDP_{it} + \beta_2 \left(LnGDP_{jt} = LnPopu_j, L_1.LnGDP_{jt} \right) \\ & + \beta_3 LnDIS_{ij} + \beta_4 LnPopu_i + \beta_5 LnArea_i + \beta_6 LnArea_j + \beta_7 Comol_{it} \\ & + \beta_8 ChAFTA_{ijt} + \beta_9 JAEPA_{ijt} + \beta_{10} KAFTA_{ijt} \\ & + \beta_{11} ANZCERTA_{ijt} + \beta_{12} SAFTA_{ijt} + \beta_{13} AUSFTA_{ijt} \\ & + \beta_{14} TAFTA_{ijt} + \beta_{15} ACIFTA_{ijt} + \beta_{16} AANZFTA_{ijt} \\ & + \beta_{17} MAFTA_{ijt} + \beta_{18} FTA_{it} + \varepsilon_{ijt} \end{aligned} \tag{3}$$

The use of log transformation to estimate the gravity model generates an immediate difficulty when the trade value is zero since the log of zero is undefined (Sun and Reed 2010). Due to the problem with log-linear transformation, more attention was given to the use of a PPML estimator (Silva and Tenreyro 2006; Santos Silva and Tenreyro 2011; Martinez-Zarzoso

2013; Fadey *et al*. 2014; Fally 2015; Khurana and Nauriyal 2017; Mahmood and Jongwanich 2018):

$$
\begin{aligned}
Exp_{ijt} = \exp\{&\beta_0 + \beta_1 LnGDP_{it} + \beta_2 LnGDP_{jt} + \beta_3 LnDIS_{ij} + \beta_4 LnPopu_i \\
&+ \beta_5 LnPopu_j + \beta_6 LnArea_i + \beta_7 LnArea_j + \beta_8 Comol_{it} + \beta_9 ChAFTA_{ijt} \\
&+ \beta_{10} JAEPA_{ijt} + \beta_{11} KAFTA_{ijt} + \beta_{12} ANZCERTA_{ijt} + \beta_{13} SAFTA_{ijt} \\
&+ \beta_{14} AUSFTA_{ijt} + \beta_{15} TAFTA_{ijt} + \beta_{16} ACIFTA_{ijt} + \beta_{17} AANZFTA_{ijt} \\
&+ \beta_{18} MAFTA_{ijt} + \beta_{19} FTA_{it} + \varepsilon_{ijt}\}
\end{aligned} \tag{4}
$$

To obtain unbiased results and achieve robustness in the gravity model, several studies have adopted a fixed-effects approach with the PPML method (Dahi and Demir 2013; Mujahid and Kalkuhl 2016; Khurana and Nauriyal 2017; Brodzicki and Uminski 2018; Irshad *et al*. 2018). Therefore, to control the time- and country-specific effects, we estimate one more specification. Equation (2) and (4) with time, importer fixed effects, which adds αt and αj to Equations (5) and (6). Time-fixed effects (αt) capture the shocks that affect global trade flows in a particular year and the time trend in trade. Several studies argued that besides being consistent in the presence of heteroscedasticity, the PPML estimation technique deals with zero trade values of dependent variables in a natural way (Silva and Tenreyro 2006; Santos Silva and Tenreyro 2011; Martinez-Zarzoso 2013). However, various studies (Sun and Reed (2010); Fadeyi *et al*. (2014); Khurana and Nauriyal (2017)) have recommended performing a regression error specification test (RESET) for choosing PPML over OLS. Ramsey (1969) carried out RESET to check for the adequacy of the estimated model. The p-values estimated by OLS and PPML in RESET indicate that the PPML method is suitable (Tables 4, 5, 6, and 7). Moreover, we have also performed data normality, stationary, multicollinearity and heteroscedasticity tests in our analysis (Tables S3 and S4). To overcome the problem of zero value in trade, we have adopted the approach of Fadeyi *et al*. (2014). In this approach, a value of one is added to each observation of the dependent variable before taking the natural logarithm. Thus, the dependent variable becomes $Exp_{ijt}{}^{*} = Exp_{ijt} + 1$. In cases where there is no export value (i.e. where $Exp_{ijt} = 0$), then $Exp_{ijt}{}^{*} = 1$, and $LnExp_{ijt}{}^{*} = Ln(1) = 0$. Moreover, we have taken the natural logarithm of all explanatory variables except dummy variables in our analysis.

4. Data and sources

We have used data on Australian agricultural exports to 24 major destinations with a sample period from 1996 to 2017. The sample countries and their codes are given in the Appendix S1 (Table S5). These countries accounted for at least 85 per cent of Australian agricultural exports (ABARES 2018a). The data for agricultural exports from Australia to these destinations were measured in current US dollars (https://comtrade.un.org/data). We have aggregated data relating to major exportable agricultural commodities (see Table 3), which accounted for at least 75 per cent of agricultural exports from Australia (ABARES 2018a). Data on Gross Domestic Product (GDP), area of exporter and importer countries, and population for exporter and importer countries were sourced from the World Bank Development Indicators (WDI) database (https://datacatalog.worldbank.org). Similarly, data on explanatory variables, namely distance between exporter and importer countries and common official language, were drawn from the CEPII database (http://www.cepii.fr/CEPII/en/bdd_modele/bdd.asp). Data on variables related to FTAs (see Table 2) were generated by the authors based on the effective date of related FTAs given in the Appendix S1 (Table S1).

5. Empirical Results and Discussion

The preliminary results with descriptive statistics are given in Table S6. The results of agricultural trade creation and exports diversion estimated from different specifications are presented in Table 4. The results calculated from Equations (2), (3), (4), (5) and (6) are reported in columns 1 to 5, respectively, which include results without time and individual country dummy variables (pooled OLS, instrumental variables (2SLS) regression and PPML), and with time- and importer-specific effects (OLS and PPML). A positive correlation between the fixed effects and R square value has been observed from a cursory scan of the results. We have tested the endogeneity of GDP using the partners' population and lagged value of partners' GDP as instruments following Anderson (1979) and Mafizur Rahman (2012). The estimated coefficients of the variables from Equation (2) and Equation 3 (columns 1 and 2 in Table 4) do not change significantly. Therefore, GDP is used as an exogenous variable in the estimation. We have performed a Sargan test ($X^2(1) = 0.749873$ and $P = 0.3865$), which confirms that the instruments are correctly specified.

Various studies have argued for the reliability of PPML estimation over OLS (Silva and Tenreyro 2006; Sun and Reed 2010; Santos Silva and Tenreyro 2011; Khurana and Nauriyal 2017). In our case, PPML has also provided more robust results compared to OLS, so our emphasis would be on the results obtained from PPML estimations. Column 3 in Table 4 presents the results estimated by PPML without the time- and individual country-specific effects. The standard gravity macro variables such as exporter's GDP, importer's GDP and distance are statistically significant and show the expected signs. Other variables such as exporter's population, importer's population, area of importers and common official language show the expected signs but are statistically non-significant. The trade creation variables for AANZFTA, ChAFTA and KAFTA are positive, and they show the positive trade creation effects from those agreements; however, the

Table 3 Description of commodities and their HS (Harmonised System) codes

Commodity	HS codes and description	Mean trade value (US$ million)
Beef	0201: Meat of bovine animals, fresh or chilled	68.0
	0202: Meat of bovine animals, frozen	98.4
Wheat	1001: Wheat and meslin	66.5
Barley	1003: Barley	17.8
Canola	1205: Rape or colza seeds, whether or not broken	12.3
Sugar	1701: Cane or beet sugar and chemically pure sucrose, in solid form	9.9
	1702: Other sugars, including chemically pure lactose, maltose, glucose and fructose, in solid form; sugar syrups not containing added flavouring or colouring matter; artificial honey, whether or not mixed with natural honey; caramel	
	1703: Molasses resulting from the extraction or refining of sugar	
	1704: Sugar confectionery (including white chocolate), not containing cocoa	
Wine	2204: Wine of fresh grapes, including fortified wines	64.4
Wool	5101: Wool, not carded or combed	75.4
Sheep and goat meat	0204: Meat of sheep or goats, fresh, chilled or frozen	38.2
Dairy products	0401: Milk and cream, not concentrated nor containing added sugar or other sweetening matter	62.1
	0402: Milk and cream, concentrated or containing added sugar or other sweetening matter	
	0403: Buttermilk, curdled milk and cream, yogurt, kephir and other fermented or acidified milk and cream, whether or not concentrated or containing added sugar or other sweetening matter or flavoured or containing added fruit	
	0404: Whey, whether or not concentrated or containing added sugar or other sweetening matter; products consisting of natural milk constituents, whether or not containing added sugar or other sweetening matter, not elsewhere	
	0405: Butter and other fats and oils derived from milk; dairy spreads	
	0406: Cheese and curd	
	0407: Birds' eggs, in shell, fresh, preserved or cooked	
	0408: Birds' eggs, not in shell, and egg yolks, fresh, dried, cooked by steaming or by boiling in water, moulded, frozen or otherwise preserved, whether or not containing added sugar or other sweetening matter	
	0409: Natural honey	
	0410: Edible products of animal origin, not elsewhere specified or included	
Edible fruits and nuts	08: Edible fruit and nuts; peel of citrus fruit or melons	21.5
Cotton	52: Cotton	47.1

results are significant only for KAFTA. The export trade diversion variable is significant and negative which means that the agricultural export diversion from Australian free trade agreements from non-members to members is also significant.

Table 4 Estimating the effect of Australia's FTA on agricultural trade creation and Australia's export diversion

Variables	Without fixed effects			With time and importer fixed effects	
	OLS (1)	Instrumental variables (2SLS) regression (2)	PPML (3)	OLS (4)	PPML (5)
DIS_{ij}	−3.098	−2.942	−1.396	−3.280	−2.402
	(0.237)***	(0.249)***	(0.355)***	(0.203)***	(0.809)***
GDP_i	0.131	0.181	0.370	0.173	0.035
	(0.239)	(0.238)	(0.132)***	(0.178)	(0.107)
$GDPj$	1.204	1.142	0.730	1.003	0.920
	(0.064)***	(0.063)***	(0.071)***	(0.053)***	(0.084)***
$Area_j$	−0.100	−0.135	−0.089	NA	NA
	(0.027)***	(0.020)***	(0.075)	NA	NA
$Popu_i$	−3.221	−3.256	−0.592	NA	NA
	(1.435)**	(1.472)**	(0.821)	NA	NA
$Popu_j$	−0.091	NA	0.072	NA	NA
	(0.049)*	NA	(0.129)	NA	NA
$Comol_{ij}$	0.753	0.775	0.270	NA	NA
	(0.100)***	(0.104)***	(0.192)	NA	NA
$AANZFTA_{ijt}$	0.641	0.602	0.127	0.282	0.096
	(0.151)***	(0.152)***	(0.162)	(0.125)**	(0.103)
$ChAFTA_{ijt}$	0.407	0.398	0.159	0.103	0.097
	(0.192)**	(0.190)**	(0.173)	(0.198)	(0.071)
$ACIFTA_{ijt}$	−0.892	−0.883	−1.591	0.985	0.854
	(0.629)	(0.615)	(0.282)***	(0.658)	(0.062)***
$JAEPA_{ijt}$	−0.214	−0.234	−0.065	0.575	0.122
	(0.176)	(0.177)	(0.128)	(0.167)***	(0.065)*
$KAFTA_{ijt}$	0.830	0.835	0.244	0.583	0.264
	(0.145)***	(0.147)***	(0.130)*	(0.174)***	(0.074)***
$SAFTA_{ijt}$	−1.251	−1.267	−0.750	0.184	−0.014
	(0.200)***	(0.200)***	(0.352)**	(0.121)	(0.127)

Table 4 (*Continued*)

Variables	Without fixed effects			With time and importer fixed effects	
	OLS (1)	Instrumental variables (2SLS) regression (2)	PPML (3)	OLS (4)	PPML (5)
$AUSFTA_{ijt}$	−0.151	−0.115	−0.245	0.457	0.178
	(0.186)	(0.170)	(0.234)	(0.166)***	(0.104)*
$TAFTA_{ijt}$	0.442	0.438	−0.133	−0.219	−0.289
	(0.142)***	(0.136)***	(0.173)	(0.114)*	(0.115)**
$MAFTA_{ijt}$	0.213	0.283	−0.071	0.111	0.078
	(0.144)	(0.146)	(0.112)	(0.126)	(0.073)
$ANZCERTA_{ijt}$	−2.812	−2.523	−1.222	NA	NA
	(0.189)***	(0.149)***	(0.526)**	NA	NA
FTA_{it}	−0.357	−0.400	−0.845	NA	NA
	(0.175)**	(0.176)**	(0.238)***	NA	NA
_cons	71.641	69.879	12.994	26.273	15.210
	(20.054)***	(20.891)***	(11.264)	(4.540)***	(6.637)**
Adjusted R^2	0.72	0.72	0.92	0.79	0.96
F statistic	317.59	NA	NA	273.63	NA
N	528	504	528	528	528
$RESET$	$F(1, 507) = 55.62$	NA	$X^2(1) = 0.64$	F(1, 474) = 10.22	$X^2(1) = 0.96$
	Prob> F = 0.0000	NA	Prob> X^2 = 0.4222	Prob> F = 0.0015	Prob> X^2 = 0.3280

Note: NA, not applicable; OLS, Ordinary Least Squares; PPML, pseudo-Poisson maximum likelihood;*$P < 0.1$, **$P < 0.05$, ***$P < 0.01$; robust standard errors reported in parentheses. Variables have more than 10 VIF value were excluded while estimating model.

The use of time, importer and exporter fixed effects has been used extensively in trade analysis (Sun and Reed 2010; Yang and Martinez-Zarzoso 2014; Mujahid and Kalkuhl 2016; Khurana and Nauriyal 2017). We use only the time and importer fixed effects due to a single exporting country. Those variables, which have more than 10 VIF, were excluded from the models in our analysis (Table S4). Due to the better performance of PPML compared to OLS, we are discussing here the results obtained from PPML (see column 5 in Table 4).

The standard errors were clustered by log distance that makes the estimated standard errors robust against possible serial correlation and heteroscedasticity. The standard gravity macro variables show the expected positive signs for income variables and a negative sign for distance. The PPML estimated smaller coefficients compared to OLS for the GDP variables, as reported by Sun and Reed (2010) and for the distance variable as reported by Khurana and Nauriyal (2017). The positive dummy coefficients for AANZFTA, ChAFTA, ACIFTA, JAEPA, KAFTA, AUSFTA and MAFTA imply that trade agreements increase the trade by 10 per cent (US \$69 million), 10 per cent (US \$509 million), 135 per cent (US \$42 million), 13 per cent (US \$310 million), 30 per cent (US \$450 million), 19 per cent (US \$438 million) and 8 per cent (US \$53 million) from the respective agreements. The negative coefficient of other bilateral trade agreements such as TAFTA and SAFTA (see column 5 in Table 4) shows intra-block export diversion of US \$109 million. Siriwardana (2006) reported on the contraction of the agricultural sector in Singapore after trade agreements were signed with Australia. In Asia, Singapore is the most regionally integrated (0.630) country followed by Malaysia (0.614) and Thailand (0.591), which shows that trade diversion might be due to membership of overlapping FTAs. Siriwardana (2006) has argued that Australia's FTAs with countries like Japan, China and Malaysia appear to be more promising given the higher trade barriers that existed before the FTAs were negotiated.

The results in Table 4 assume that the impacts of the FTAs do not vary with time. However, Sun and Reed (2010) have argued that FTA effects change over time. Therefore, we have also analysed the dynamic counterpart of column 5 in Table 4 by generating the interaction of several FTA variables at five-year intervals from 1996 to 2015 (2000, 2005, 2010, 2015) and 2017, the last year of data, which is presented in Table 5. An F-test confirms the existence of time-varying FTA effects by rejecting the null hypothesis of no time-varying FTA effects. The results showed consistent positive trade creation effects from ChAFTA, JAEPA and KAFTA after signing the agreements. ABARES (2018a) reported that Australia had exported about 70 per cent of total agricultural products to China, Korea, Japan, ASEAN countries and the USA in 2016–2017. Compared to 2006–2007, Australian agricultural export to China increased by 100 per cent in 2016–2017 (ABARES 2018a).

Table 5 Estimating the dynamic effects of FTA on Agricultural TC and AED using PPML

Variables	Coefficient and standard error	Variables	Coefficient and standard error
AANZFTA year 2010	−0.128 (0.146)	SAFTA year 2010	0.260 (0.133)*
AANZFTA year 2015	0.086 (0.079)	SAFTA year 2015	−0.123 (0.069)*
AANZFTA year 2017	0.005 (0.210)	SAFTA year 2017	−0.266 (0.110)**
ChAFTA year 2017	0.125 (0.181)	AUSFTA year 2005	0.184 (0.080)**
ACIFTA year 2010	0.029 (0.063)	AUSFTA year 2010	−0.084 (0.066)
ACIFTA year 2015	−2.237 (0.054)***	AUSFTA year 2015	0.523 (0.064)***
ACIFTA year 2017	−3.857 (0.179)***	AUSFTA year 2017	0.085 (0.180)
JAEPA year 2015	0.200 (0.113)*	TAFTA year 2005	−0.032 (0.081)
JAEPA year 2017	0.181 (0.208)	TAFTA year 2010	0.114 (0.134)
KAFTA year 2015	0.327 (0.056)***	TAFTA year 2015	−0.298 (0.070)***
KAFTA year 2017	0.005 (0.181)	TAFTA year 2017	−0.392 (0.110)***
ANZCERTA year 2000	−0.031 (0.102)	MAFTA year 2015	0.112 (0.066)*
ANZCERTA year 2005	−0.193 (0.078)**	MAFTA year 2017	−0.092 (0.108)
ANZCERTA year 2010	0.282 (0.133)**	Adjusted R−squared N	0.96 528
ANZCERTA year 2015	0.144 (0.071)**	RESET	$X^2(1) = 0.20$ Prob> $X^2 = 0.6531$
ANZCERTA year 2017	0.093 (0.110)	NA	NA
SAFTA year 2005	0.062 (0.082)	NA	NA

Note: NA, not applicable; PPML, pseudo-Poisson maximum likelihood with time- and country-specific fixed effects;*$P < 0.1$, **$P < 0.05$, *** $p < 0.01$; robust standard errors reported which are clustered by log distance, and only the coefficients for FTA variables are included because they are the focus of our interest; TC, trade creation, AED, Australia's export diversion.

AANZFTA and ANZCERTA had a negative coefficient in the initial years; however, it has had positive trade creation effects in later years. Armstrong (2015) carried out a study on the economic impacts of the Australia–US free trade agreement (AUSFTA) and reported a reduction in trade between Australia and the United States from 2005 to 2012. Our study shows AUSFTA created agricultural trade in 2005, but it diminished in 2010 as reported by Armstrong (2015), then increased again in later years. MAFTA had significant positive trade creation effects in the year 2015, but it diminished in the year 2017. Similarly, ACIFTA, SAFTA and TAFTA had positive trade creation effects in 2010; however, they diminished in later years.

Different studies have suggested analysing the impacts of FTAs for specific commodities along with their trade creation and diversion effects would provide better insights into the effects of operationalisation of the agreements (IIT 2015; Khurana and Nauriyal 2017; Quansah and Ahn 2017; Culas and Timsina 2019a). We have estimated the effects of different FTAs on trade creation and export diversion for selected Australian agricultural commodities—the results are presented in Table 6. The positive dummy coefficients for ChAFTA, ACIFTA, JAEPA and TAFTA in trade in beef imply that agreements increased trade by 72 per cent (US $408 million), 90 per cent (US $27 million), 15 per cent (US $219 million) and 92 per cent (US $24 million). The negative coefficient of other trade agreements (see column 1 in Table 6) shows intra-block export diversion of US $663 million. In the case of sugar, the positive dummy coefficients for AANZFTA, ACIFTA, KAFTA, SAFTA, AUSFTA, TAFTA and ANZCERTA imply that these agreements increased trade by 72 per cent (US $15 million), 175 per cent (US $ less than 1 million), 164 per cent (US $45 million), 242 per cent (US $144 million), 115 per cent (US $23 million), 880 per cent (US $15 million) and 213 per cent (US $96 million). The negative coefficient of other trade agreements (see column 2 in Table 6) shows intra-block export diversion of US $4 million. Similarly, the positive dummy coefficients for almost all trade agreements in wine (see column 3 in Table 6) imply that agreements increase trade by US $599 million. The negative coefficient of AANZFTA shows intra-block export diversion of US $2 million. In the case of EFN, the positive dummy coefficients for ChAFTA, ACIFTA, JAEPA, KAFTA, TAFTA and ANZCERTA imply that trade agreements increase trade by 44 per cent (US $108 million), 175 per cent (US $ less than 1 million), 119 per cent (US $109 million), 201 per cent (US $38 million), 218 per cent (US $61 million) and 76 per cent (US $24 million) from the respective agreements. The negative coefficient of other trade agreements (see column 4 in Table 6) shows intra-block export diversion of US $67 million. Overall, the trade creation was greater than the intra-block export diversion of the FTAs for all agricultural products.

We have also analysed the dynamic counterpart of Table 6 by generating the interactions of several FTA variables at five-year intervals from 1996 to 2015 (2000, 2005, 2010, 2015) and 2017, the last year of data, which is presented in Table 7. The heteroscedasticity robust RESET test confirmed the appropriateness of PPML, which is given at the bottom of Table 7. The effects of FTAs on trade in beef showed mixed results. Results showed AANZFTA and ACIFTA had negative trade creation effects in 2015, while it was positive in 2010. KAFTA had negative trade creation effects in both 2015 and 2017, while JAEPA had negative trade creation effects in 2015, which turned to be positive in 2017. ChAFTA had positive trade creation effects in 2017. Qi and Zhang (2018) analysed the economic impacts of the China–Australia FTA using a general equilibrium analysis and estimated that Australian beef exports to China will grow at the rate of 5 per cent per year

Table 6 Estimating the effect of FTAs on agricultural products trade creation and export diversion: PPML with time- and country-specific fixed effects

Variables	Beef	Sugar	Wine	Edible fruits and nuts (EFN)
$AANZFTA_{ijt}$	−0.155	0.544	−0.089	−0.341
	(0.165)	(0.410)	(0.256)	(0.215)
$ChAFTA_{ijt}$	0.540	−0.463	0.570	0.364
	(0.178)***	(0.330)	(0.231)***	(0.137)***
$ACIFTA_{ijt}$	0.640	1.013	1.224	1.011
	(0.127)***	(0.332)***	(0.258)***	(0.157)***
$JAEPA_{ijt}$	0.142	−1.104	0.198	0.784
	(0.073)*	(0.328)***	(0.312)	(0.205)***
$KAFTA_{ijt}$	−0.220	0.969	0.448	1.101
	(0.122)*	(0.292)***	(0.167)***	(0.128)***
$SAFTA_{ijt}$	−0.329	1.230	0.424	−0.857
	(0.154)**	(0.320)***	(0.189)**	(0.194)***
$AUSFTA_{ijt}$	−0.452	0.765	0.209	−0.512
	(0.123)***	(0.362)**	(0.158)	(0.142)***
$TAFTA_{ijt}$	0.652	2.282	0.624	1.158
	(0.131)***	(0.449)***	(0.140)***	(0.191)***
$MAFTA_{ijt}$	−0.335	−2.294	0.777	−0.598
	(0.133)**	(0.329)***	(0.207)***	(0.227)***
$ANZCERTA_{ijt}$	−2.513	1.141	NA	0.564
	(0.769)***	(0.364)**	NA	(0.664)
Adjusted R^2	0.96	0.65	0.96	0.91
N	528	528	528	528
$RESET$	$X^2(1) = 1.62$ Prob> $X^2 = 0.2035$	$X^2(1) = 2.90$ Prob> $X^2 = 0.0886$	$X^2(1) = 0.14$ Prob> $X^2 = 0.7131$	$X^2(1) = 1.45$ Prob> $X^2 = 0.2288$

Note: NA, not applicable; PPML, pseudo-Poisson maximum likelihood. $^*P < 0.1$, $^{**}P < 0.05$, $^{***}P < 0.01$; robust standard errors reported in parentheses. Only the coefficients for FTA variables are included because they are the focus of our interest.

between 2018–19 and 2022–23, while Australian beef exports to the Republic of Korea were predicted to decline by 7 per cent in 2017–18 (ABARES 2018a). SAFTA had negative trade creation effects in 2005, but the effects turned positive in 2010, although these positive effects disappeared in later years. TAFTA showed negative trade creation effects in earlier years, then positive trade creation effects in 2015 and 2017. ANZCERTA had positive trade creation effects in 2000, and no positive trade creation effects in 2005 and 2010, but positive effects again in 2015. MAFTA showed positive trade creation effects in all years after signing trade agreements, whereas AUSFTA showed different results after signing an agreement in 2005. ABARES (2018b) has reported that Japan, the USA, Korea, China and Indonesia were the top five export markets for Australian beef and veal in 2016–17, while the export quantity to the USA in that year was 45 per cent less than the quantity exported in 2004-05.

The results indicated that ChAFTA, SAFTA, ACIFTA and KAFTA, TAFTA, AUSFTA and ANZCERTA had positive trade creation effects in a consistent manner in the trade of sugar. Other agreements like AANZFTA

Table 7 Estimating the dynamic effect of FTAs on agricultural products trade creation and export diversion: PPML with time- and country-specific fixed effects

Variables	Beef	Sugar	Wine	EFN
AANZFTA year 2010	0.007	−0.681	−0.037	−0.757
	(0.088)	(0.805)	(0.096)	(0.137)***
AANZFTA year 2015	−0.564	−0.191	0.066	−0.713
	(0.223)**	(0.814)	(0.307)	(0.235)***
AANZFTA year 2017	0.222	0.944	0.096	0.383
	(0.305)	(0.822)	(0.392)	(0.398)
ChAFTA year 2017	0.639	0.146	0.546	0.376
	(0.270)**	(0.635)	(0.220)***	(0.134)***
ACIFTA year 2010	0.016		1.282	−2.212
	(0.078)		(0.092)***	(0.104)***
ACIFTA year 2015	−3.612	1.806	0.871	−2.783
	(0.214)***	(0.346)***	(0.197)***	(0.156)***
ACIFTA year 2017		2.370	0.856	0.031
		(0.604)***	(0.226)***	(0.167)
JAEPA year 2015	−0.518	−2.939	0.276	0.127
	(0.227)**	(0.801)***	(0.499)	(0.243)
JAEPA year 2017	0.317	0.715	0.333	1.587
	(0.310)	(0.801)	(0.461)	(0.394)***
KAFTA year 2015	−0.328	0.335	0.286	0.912
	(0.220)	(0.335)	(0.205)	(0.158)***
KAFTA year 2017	−0.156	1.713	0.349	0.968
	(0.297)	(0.592)***	(0.219)	(0.167)***
ANZCERTA year 2000	0.735	0.139	0.712	−0.049
	(0.205)***	(0.376)	(0.272)***	(0.155)
ANZCERTA year 2005	−0.762	1.148	0.064	0.115
	(0.126)***	(0.323)***	(0.072)	(0.094)
ANZCERTA year 2010	−0.205	1.500	−0.151	1.148
	(0.039)***	(0.753)**	(0.057)***	(0.087)***
ANZCERTA year 2015	0.486	0.906	−0.317	0.407
	(0.049)***	(0.733)	(0.232)	(0.174)**
ANZCERTA year 2017	−0.036	0.455	−0.378	0.426
	(0.076)	(0.550)	(0.285)	(0.361)
SAFTA year 2005	−0.423	1.239	0.108	−0.004
	(0.142)***	(0.320)***	(0.184)	(0.110)
SAFTA year 2010	0.091	1.920	−0.104	0.378
	(0.039)**	(0.749)**	(0.040)***	(0.088)***
SAFTA year 2015	−0.126	1.039	0.013	0.004
	(0.046)***	(0.735)	(0.210)	(0.171)
SAFTA year 2017	−0.248	0.669	0.165	−0.895
	(0.076)***	(0.550)	(0.278)	(0.361)**
AUSFTA year 2005	−0.138	0.774	0.191	0.420
	(0.130)	(0.329)**	(0.062)***	(0.089)***
AUSFTA year 2010	−0.372	0.249	0.115	−0.028
	(0.078)***	(0.305)	(0.034)***	(0.115)
AUSFTA year 2015	−0.002	0.628	−0.215	−0.502
	(0.215)	(0.338)*	(0.213)	(0.157)***
AUSFTA year 2017	−0.041	1.169	0.281	−0.577
	(0.294)	(0.589)**	(0.196)	(0.164)***
TAFTA year 2005	−0.537	0.959	−0.149	−0.257
	(0.136)***	(0.323)***	(0.158)	(0.105)**
TAFTA year 2010	−0.188	0.910	0.044	1.169
	(0.040)***	(0.751)	(0.040)	(0.090)***

Table 7 (*Continued*)

Variables	Beef	Sugar	Wine	EFN
TAFTA year 2015	0.563	0.911	0.090	0.726
	(0.047)***	(0.736)	(0.218)	(0.172)***
TAFTA year 2017	0.451	2.216	0.208	−0.084
	(0.075)***	(0.550)***	(0.278)	(0.362)
MAFTA year 2015	0.218	−1.337	0.542	−0.400
	(0.047)***	(0.739)*	(0.219)**	(0.173)**
MAFTA year 2017	0.043	−2.530	0.418	−0.992
	(0.078)	(0.551)***	(0.290)	(0.360)***
Adjusted R-squared	0.96	0.52	0.96	0.88
RESET	$X^2(1) = 1.40$	$X^2(1) = 0.05$	$X^2(1) = 0.14$	$X^2(1) = 0.39$
	Prob>	Prob>	Prob>	Prob>
	$X^2 = 0.2359$	$X^2 = 0.8196$	$X^2 = 0.7131$	$X^2 = 0.5337$

Note: PPML, pseudo-Poisson maximum likelihood. *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$; robust standard errors reported which are clustered by log distance. Only the coefficients for FTA variables are included because they are the focus of our interest.

and JAEPA showed negative effects in earlier years but positive trade creation effects in later years. ABARES (2018b) supported our findings as they reported that Korea, Indonesia, Japan, China, Malaysia and the USA were the primary destinations for Australian sugar exports in 2016-17. Siriwardana (2006) conducted an economic evaluation of Australia's involvement in FTAs and concluded that the sugar industry was the outright winner in Australia from AUSFTA, SAFTA and TAFTA. The analysis shows no trade creation from MAFTA for any of the years. Although Malaysia is one of the major export destinations for Australian sugar, its exports declined by 51 per cent in 2015 and 76 per cent in 2017 compared to 2010 (ABARES 2018b).

The results showed that ChAFTA, ACIFTA, JAEPA, KAFTA and MAFTA have positive trade creation effects in a consistent manner on wine trade after the agreements were signed. Siriwardana and Yang (2008) estimated the sectoral economic effects of an Australia and China FTA using different scenarios and reported a 50 per cent gain on the Australian beverage trade. China has increased wine imports significantly, with Australia the third-largest exporter to China, worth $269 million in 2014–15 (Culas and Timsina 2019a). AANZFTA produced negative trade creation effects in 2010, but positive effects were reported in 2015 and 2017. Similarly, TAFTA had negative trade creation effects in 2005, but positive effects were reported in later years. ANZCERTA showed positive trade creation effects in 2000 and 2005, but no effects in later years. With the exception of 2010 for SAFTA and 2015 for AUSFTA, both agreements have shown positive trade creation effects. China, the United States, the United Kingdom, Canada and Hong Kong were the top five markets for Australian wine exports in 2016–17. China's share represents about 25 per cent of the total wine export value of $595 million (ABARES 2018b). There has also been an increasing volume of wine exports to Japan, Singapore, Malaysia and Italy in recent years (ABARES 2018b). Among different agreements, ChAFTA, KAFTA and JAEPA showed positive trade creation effects after signing the agreements for the trade of edible fruits and nuts (EFN). AANZFTA and ACIFTA had negative trade creation effects in 2010 and 2015, but positive effects were reported in 2017. AUSFTA showed positive trade creation effects in 2005 but no such effects in later years. SAFTA and TAFTA had negative trade creation effects in 2005, which turned positive in 2010 and 2015, but had no effects in 2017. ANZCERTA showed negative trade creation effects in earlier years, but positive effects in and after 2010. MAFTA had no trade creation effects in EFN in both 2015 and 2017.

FTAs often produce a gradual reduction in tariffs over time rather than eliminating trade barriers immediately. This means that there is typically a lag in the generation of trade creation effects after agreements are signed (Frankel 1997; Magee 2008). But if tariffs are eliminated immediately and quotas are given for certain commodities, the trade creation effects for such commodities will be realised immediately. For example, Hyde, Gunning-Trant *et al.* (2014) reported that the KAFTA will generate positive trade creation effects in wine and sugar as tariffs on wine will be eliminated immediately and duty-free quotas are given to Australian sugar imports. Sun and Reed (2010) reported that a new FTA might encourage businesses to ramp up their exporting platform and reach out to third-party countries early, but then as the FTA transition continues, member countries become better markets, and the export creation turns to export diversion. The FTA effects may change over time if one of the members enters agreements with other countries or blocks into the new trade agreements. For instance, Australia's beef will remain less competitive against US beef in the Korean market during the implementation of KAFTA because tariffs on US beef will be phased out earlier than on Australian beef under the Korea–US free trade agreement (KORUS) (Hyde, Gunning-Trant *et al.* 2014). Moreover, Korean consumers have shown preference for beef from the USA and Europe. If this consumer preference continues, Australian beef imports may fall drastically by 2030 because by that time there will be a full implementation of the Korean FTA with the USA and Europe (Quansah and Ahn 2017).

Several studies have shown the importance of value chain integration and the relative benefits of FTAs between Australia and entities such as the United Kingdom, India and EU (Cho and Yoon 2014; Suder 2018; Swinbank 2018). Mega-regional trade agreements in Asia can produce substantial economic benefits to Asian countries, but the political economies of such countries might be challenging (Shepherd 2019). Various studies have shown positive effects of regional integration in trade, foreign direct investment (FDI) and economic welfare (DeRosa and Govindan 1996; Kreinin and Plummer 2008; Pomfret and Sourdin 2009; Geldi 2012; Shepherd 2019). The countries that are economically stable, have a large domestic market and are in regional blocks are attracting more Australian FDI, which possibly benefits Australia by indirectly fostering a stronger regional market for its exports (Sharma and Bandara 2010). South-East Asia shows particularly strong integration in trade and investment and the free movement of people. China and Japan, the world's second- and third-largest economies, rank sixth and ninth, respectively, in the regional integration index in Asia. However, they show low scores for trade and investment integration, 0.377 for China and 0.376 for Japan, reflecting relatively small shares of intra-regional trade (Huh and Park 2018). It seems that Australia is receiving relatively greater benefits from FTAs with China and Japan, because these countries have a relatively low level of regional trade and investment integration with other countries.

Although ASEAN–China free trade area (ACFTA) has great economic and trade potential, its performance is weaker than other well-developed regional trade agreements (Yang and Martinez-Zarzoso 2014). After entering into the Comprehensive and Progressive Trans-Pacific Partnership (CPTPP) agreement, Australia will get benefits from Japan because Japan's beef tariff will be reduced to 9 per cent, whereas other countries without an FTA with Japan will face a 38.9 per cent tariff (Dean 2019). Balistreri and Tarr (2019) reported substantial welfare gains from deep regional integration. To achieve a deeper economic integration between FTA members, an agreement should not only focus on tariff barriers but should give priority to product competitiveness, improvements in production efficiency and structures of trade complementarities (Yang and Martinez-Zarzoso 2014). Australia would benefit more from the CPTPP through boosting the value chain integration of particular sectors and commodities (Dean 2019). Shepherd (2019) carried out a simulation for trade in agricultural products from different mega-regional trades and reported beneficial impacts on Australian agricultural product exports.

6. Conclusion

The paper estimates the trade creation and export diversion effects of the Australia's FTAs with respect to its agricultural sector as well as different agricultural commodities using a PPML estimator. It includes 24 countries comprising FTA members and non-members and covers 22 years from 1996 to 2017. The heteroscedasticity robust RESET test confirms the relevance of PPML in the gravity analysis. It helps to avoid problems from using the logarithmic specification in the presence of heteroscedasticity and allows zero trade observations in the analysis.

The results of estimated regressions are consistent with the findings of a standard gravity model. The results showed that the coefficients of standard gravity macro variables such as GDP and distance are in expected signs. However, the coefficient of importer GDP is reported higher than exporter. The dummy coefficients for AANZFTA, ChAFTA, ACIFTA, JAEPA, KAFTA, AUSFTA and MAFTA show that a value of US $1,871 million has been created in Australian agricultural export from different FTAs. The F-test indicates that the FTA effect varies over time as suggested by Sun and Reed (2010). The results showed consistent positive trade creation effects from ChAFTA, JAEPA and KAFTA once implemented.

AANZFTA and ANZCERTA had negative coefficients in the initial years; however, they had positive trade creation effects in later years. Our study shows AUSFTA generated new agricultural trade in 2005, but none in 2010; however, it created positive trade effects in later years. MAFTA and ANZCERTA have had mixed effects; they had significant positive trade creation effects in earlier years, but none in 2017. ACIFTA, SAFTA and TAFTA had positive trade creation effects in 2010, but no such effects in later years. The study also shows the variation in the dynamic effects of FTAs for different agricultural commodities. However, substantial effects have been generated in the trade of sugar and wine among the selected commodities by the implementation of the majority of the trade agreements.

Overall, trade creation was greater than intra-block export diversion both at aggregate and disaggregate levels, so the FTAs signed by Australia were beneficial to the country. Australia has planned to have more than 80 per cent of its total trade with FTA partner countries by 2020. It concluded the CPTPP agreement in December 2018 and several other regional agreements (Table S2) are under negotiation. Since Australia is already benefiting from its own liberal trade policies and many trade agreements, additional trade and output gains especially in the agriculture and mining sectors will be generated from deep regional integration (Petri and Plummer 2018). Therefore, deep regional integration and mega-regional trade agreements can be used as a strategy for sustained growth and inclusive development of the Australian economy in the future. Further, examining the impacts of the FTAs, including greater number of exporters at both sectoral and commodity levels (considering both included and major excluded commodities in the free trade agreements), would be relevant for further research to address the issues of multilateral trade resistances (MTRs), as pointed out by Anderson and Van Wincoop (2003) in their trade analysis.

Data availability statement

The data that support the findings of this study are openly available in Comtrade database (https://comtrade.un.org/data) World Bank Development Indicators (WDI) database (https://datacatalog.worldbank.org) and CEPII database (http://www.cepii.fr/CEPII/en/bdd_modele/bdd.asp).

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Supporting Information

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

Appendix S1 Source: Hyde et al. (2014); ATIC (2019) and DFAT (2019).