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Agricultural Trade and Food Security

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Abstract

In recent years, food insecurity has reached alarming proportions. Moreover, there has also been a growing recognition that international trade may affect the severity of the challenge. Accordingly, the effect of countries' agricultural trade on food security is worth analyzing. However, identifying this impact is challenging due to the endogeneity of agricultural openness. Employing data across roughly 200 countries over 2000-2016 and an instrumental variables strategy, we estimate this causal effect of interest and arrive at a number of novel conclusions. First, the effect of agricultural commerce on food security differs from those of overall and non-agricultural trade. Second, the estimated impacts are often sensitive to the measure of food security employed. Finally, concerns over the endogeneity of openness are relevant.

JEL: C36, F63, Q17

Keywords: Food Security, Agricultural Trade, Instrumental Variables

1 Introduction

As Barrett (2021) (p. 422) highlights, based on the 1996 World Food Summit, food security refers to the state where "all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Now, according to Brenton et al. (2022) (p. 581), "[f]or most countries, food security cannot be guaranteed by domestic production alone." In other words, "trade is vital to global food security" and "this role will become more important as the impact of climate change is increasingly felt in the agriculture sector." Accordingly, analyzing the effect of international agricultural trade on countries' levels of food security is crucial due to a number of reasons.

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First, in 2022, the number of people without access to nutritious, safe, and sufficient food amounted to about 2.4 billion. Moreover, during this time, at least 690 million people faced hunger (FAO et al. 2023). Second, as Brenton et al. (2022) (p. 588) notes, "one of the biggest risks to food security in food-importing countries is the imposition of export restrictions by exporting countries that curtail global supply and increase prices." Hence, if agricultural openness is evidenced to affect food security, "[s]ome form of international agreement may be necessary ... to provide food-insecure countries with the degree of certainty they require to further open their markets to trade." Third, and related to the previous point, if agricultural trade can alleviate the current food crisis, the World Trade Organization's (WTO's) role in ensuring the transparency and openness of agricultural markets is especially important.[1] Finally, the issue also relates to the second Sustainable Development Goal (SDG) adopted by all United Nations Member States.[2]

There are a number of channels by which such trade may affect food security. First, as discussed by Martin (2017) and others, it may raise real income and provide access to a greater variety of nutritious food. Second, agricultural openness may reduce a country's susceptibility to food shortages and price shocks. Third, trade in new plant varieties or agricultural inputs such as seeds may enhance agricultural productivity and thereby food security. At the same time, Marson et al. (2023) argue that agricultural openness may encourage producers to divert output from domestic to international markets. Mary (2019) also notes that increased food supply may adversely affect farm households. Further, as Mary (2019) and Marson et al. (2023) contend, increased agricultural trade may also lead to a substitution towards less nutritious food. Finally, the effect of trade intensity on a country's food stability is also potentially dependent on the policies of its trading partners (e.g., Brenton et al. 2022; Mary 2019).

Despite the stakes involved, analyses pertaining to the effect of agricultural trade on food security are relatively few. In the existing empirical literature, Dithmer and Abdulai (2017) find overall openness to be positively related to measures such as calorie consumption, protein supply, and dietary diversity. Similarly, Krivonos and Kuhn (2019) restrict attention to the post-communist countries of Eastern Europe and Central Asia and highlight how trade can improve access to a diversified food basket. On the contrary, Mary (2019) witnesses food trade openness to increase the prevalence of undernourishment. Focusing on the impact of openness in overall as well as cereals trade, Marson et al. (2023) find trade intensity to reduce the prevalence of undernourishment particularly via commerce in cereals. Given this background, our objective is to examine the causal effect of countries' agricultural trade on food security.

However, estimating such an effect is challenging due to the endogeneity of agricultural openness. For instance, unobserved characteristics such as agricultural export promotion policies, food safety standards,

[1]See https://www.wto.org/english/blogs_e/ddg_jean_marie_paugam_e/blog_jp_28mar23_e.htm.
[2]See https://sdgs.un.org/goals.

agricultural research and development (R&D) spending, and weather variations are potentially related to food security as well as trade (e.g., Aragie et al. 2023; Jin et al. 2024; Hertel et al. 2020; Dallmann 2019). Moreover, reverse causation may be a concern. For example, anticipation of low food security may influence protectionist policies (Dithmer and Abdulai 2017; Mary 2019). In addition, any index of agricultural openness is likely subject to measurement error. According to Gräbner et al. (2021) (p. 88), "not only the definition, but also the measurement of openness has varied considerably over the past three decades and a corresponding lack of consensus on how to best measure economic openness has been widely acknowledged."

In this light, we utilize data across roughly 200 countries over the years 2000 to 2016 and explore the impact of agricultural trade intensity on various indicators of food security. Due to the potential endogeneity of openness, we employ a novel instrumental variables (IV) strategy. Although some of the existing empirical studies allude to such endogeneity, our analysis contributes to this nascent literature. For example, Mary (2019) restricts attention to reverse causation as the sole source of endogeneity of food trade intensity. As noted above, the endogeneity of agricultural openness may be attributable to other factors. For instance, unobservables that are correlated with food security as well as trade may render the latter endogenous. Next, Dithmer and Abdulai (2017) resort to a dynamic panel model and discuss the endogeneity of lagged food security as well as trade intensity. While the authors rely on instruments obtained from lagging independent and dependent variables, Roodman (2009), Reed (2015), and Bellemare et al. (2017) discuss the limitations of such internal instruments. For example, in our context, such an approach would require a country's lagged agricultural openness to be sufficiently correlated with contemporaneous trade and have no direct effect on food security. Moreover, unobserved characteristics such as a country's agricultural R&D expenditure or measurement error in openness would have to be uncorrelated over time.

More recently, Marson et al. (2023) also discuss the endogeneity of trade intensity. Discouraging the use of lagged explanatory variables as internal instruments, the authors utilize trade intensity of the rest of the world as an exclusion restriction for a country's openness to trade. However, it is plausible for such an instrument to be correlated with unobserved determinants of food security. For instance, expectation of reduced openness elsewhere in the world may encourage countries to modify domestic food policies or engage in public stockholding (Gouel 2016; Rudloff et al. 2024).[3] Similarly, although Krivonos and Kuhn (2019) use agricultural trade costs as an instrument for agricultural openness, such costs are derived from a ratio involving intra- and international trade flows. Accordingly, the instrument is likely correlated with crucial unobservables such as domestic transportation infrastructure (Beghin and Schweizer 2021).

As discussed below, our identification approach relies on external instruments to attend to concerns over

[3]See https://www.piie.com/commentary/speeches-papers/2024/international-cooperation-food-security-finding-way-forward#_ftn1.

the endogeneity of our openness measures as well as per capita gross domestic product (GDP). For example, some of the exclusion restrictions are based on predicted values obtained from exogenous determinants of bilateral trade. Hence, it seems plausible that they are correlated with the endogenous variables but not the unobserved determinants of food security. While we rely on several sets of instruments and discuss their potential validity, a number of IV specification tests further support our strategy.

Overall, we obtain a number of crucial findings. First, agricultural openness is mostly witnessed to significantly improve food security. In case of our stability indicators, i.e., cereal import dependency and the variability of food supply, the effects are unambiguously favorable. For the food availability measures, while agricultural trade encourages protein supply, the impact on dietary diversity is negative. Our findings complement the results in Mary (2019) and Marson et al. (2023) where food and cereals trade are witnessed to encourage and discourage the prevalence of undernourishment, respectively. Second, the impact of overall trade intensity on food security is relatively ambiguous. While it is evidenced to promote dietary diversity, the corresponding estimates are statistically insignificant. In addition, it reduces protein supply. These results differ from those of Dithmer and Abdulai (2017) who find overall trade to encourage protein supply and dietary diversity. In case of our stability indicators, overall openness increases (decreases) the variability of food supply (cereal import dependency). Third, in some specifications, the effects of agricultural commerce and non-agricultural trade are significantly different. Thus, while examining the effect of trade on food security, it is crucial to distinguish between the roles of agricultural and non-agricultural openness. Fourth, the effects of any measure of trade intensity vary across food security indicators. Finally, our concerns over the endogeneity of trade and income are relevant.

The rest of the paper is organized as follows. Section 2 describes the empirical methodology. Section 3 discusses the data. Section 4 presents the results, while Section 5 concludes.

2 Empirical Methodology

To estimate the effect of agricultural trade intensity on food security, we begin with a specification motivated by Dithmer and Abdulai (2017), Mary (2019), and Marson et al. (2023). Our estimating equation is given by

$$FS_{it} = \beta_1 ATRADE_{it} + \beta_2 \ln{(Y/POP)}_{it} + S_{it}\theta + \varepsilon_{it}. \tag{1}$$

Here, i denotes country, t indicates year, FS is a measure of food security, $ATRADE$ represents agricultural openness, Y depicts (real) GDP, POP denotes population, and S is a vector of observable characteristics. S includes (log) arable land in hectares per person, (log) agricultural productivity in kilograms of cereal yield per hectare, percent of rural population, as well as year- and country-specific dummies. The unobservables are denoted by ε and include all remaining determinants of food security.

As discussed above, $ATRADE$ is potentially endogenous. Moreover, measurement error and unobserved attributes such as food safety standards are also likely to render GDP per capita endogenous. In fact, while exploring the impact of trade on health, environmental quality, and child labor, Levine and Rothman (2006), Frankel and Rose (2005), Chintrakarn and Millimet (2006), McAusland and Millimet (2013), Roy (2017), as well as Edmonds and Pavcnik (2005) express this concern. Accordingly, our IV approach based on Generalized Method of Moments (GMM) attends to the potential endogeneity of both agricultural trade intensity and income.

In keeping with the abovementioned studies analyzing the environmental and health implications of trade, one of our instruments is obtained from a gravity model of trade given by

$$AM_{ijt} = \delta_{it}\delta_{jt} \exp\left(W_{ijt}\eta\right) u_{ijt}. \tag{2}$$

Here, AM_{ijt} is the (real) value of agricultural imports of country i from country j in year t. The vector of observable attributes, W_{ijt}, includes (log) distance between i and j, a binary indicator taking the value one if i and j are contiguous, a dummy variable assuming the value unity if i and j share a common language, and two binary variables denoting whether i (j) has ever been a colony of j (i). While u_{ijt} is an error term, δ_{it} and δ_{jt} are country-by-time fixed effects (Anderson and Van Wincoop (2003)). Following Silva and Tenreyro (2006) and Henderson and Millimet (2008), the gravity model is estimated using a Poisson pseudo-maximum likelihood estimator (Correia et al. 2019; Correia et al. 2020). For any country in a particular year, the predicted values of bilateral trade are then added across trading partners to obtain predicted aggregate agricultural imports and exports. Using such predicted values of agricultural trade, we obtain our instrument. Since we rely on exogenous determinants of bilateral trade to construct the instrument, it seems plausible that this creates exogenous variation in predicted agricultural trade that is correlated with agricultural openness.

As discussed below, in some specifications, we focus on non-agricultural as well as total, i.e., agricultural and non-agricultural, trade. In these instances, we control for the corresponding trade intensity values in 1. Moreover, the related gravity models are estimated using (bilateral) non-agricultural and total trade. The associated instruments are then obtained upon aggregating the predicted values of (bilateral) non-agricultural and total trade across trading partners.

Due to the endogeneity of GDP per capita, we also include the following exclusion restrictions: number of days required to start a business, time needed to enforce a contract, mobile cellular subscriptions per 100 individuals, percentage of population with access to electricity, and percent of working-age population, i.e., age dependency ratio. As noted by Djankov et al. (2006) and Clague et al. (1999), countries' regulations and institutional qualities are related to their growth. Moreover, Edquist et al. (2018) and Ferguson et al. (2000) discuss how the use of electricity and diffusion of mobile broadband affect development. Similarly, Bidisha et al. (2020) highlight the relationship between countries' age dependency ratios and growth rates.

3 Data

The data across roughly 200 countries over the years 2000 to 2016 are obtained from a number of sources. For the food security measures, we rely on the *FAOSTAT* database of the Food and Agriculture Organization (FAO) of the United Nations.[4] As displayed in Table 1, we utilize a number of indicators related to the availability and stability aspects of food security (Izraelov and Silber 2019). While protein supply is expressed in grams per capita per day, dietary diversity denotes the share of dietary energy supply that is not derived from cereals, roots, and tubers. Food supply variability represents annual fluctuations in kilocalories of per capita food supply. Moreover, cereal import dependency captures the percentage of a country's cereal supply that is imported. For some of the indicators, the data are available in the form of three-year averages. In such cases, we consider the earliest time period as the corresponding year. For instance, if dietary diversity is reported as the three-year average from 2004 to 2006, we consider 2004 as the associated year. This allows agricultural openness to have a lagged effect on food security and thus seems reasonable.

The trade data come from the United States International Trade Commission's (USITC's) *International Trade and Production Database for Estimation* (Borchert et al. 2021; Borchert et al. 2022).[5] As Borchert et al. (2021) and Borchert et al. (2022) note, the data are available at a disaggregated level with nearly 30 industries comprising the agricultural sector. Accordingly, in keeping with contributions such as Mary (2019) and Krivonos and Kuhn (2019), agricultural trade intensity for country i in period t is defined as

$$ATRADE_{it} = \frac{AX_{it} + AM_{it}}{AVA_{it}} \tag{3}$$

where AX_{it} and AM_{it} represent i's agricultural exports and imports, respectively; AVA_{it} denotes agricultural value added. Overall openness is obtained from a similar ratio using values of total exports and imports in the numerator, and GDP in the denominator. Non-agricultural trade intensity is analogously calculated as the sum of non-agricultural exports and imports divided by non-agricultural value added. The data on GDP and agricultural value added are obtained from the World Bank's *World Development Indicators* (WDI).

[4]See https://www.fao.org/faostat/en/#home.
[5]See https://www.usitc.gov/data/gravity/itpde.htm.

Table 1 reports the related summary statistics.

For the gravity model, the information on country characteristics are obtained from the *Dynamic Gravity Dataset* provided by the USITC (Gurevich and Herman 2018).[6] Tables 2 and 3 report the estimates pertaining to (bilateral) agricultural and total trade, respectively; the gravity estimates corresponding to non-agricultural trade are provided in Table 4. In case of agricultural (non-agricultural) openness, our instrument is obtained by first aggregating predicted values of bilateral agricultural (non-agricultural) trade across trading partners. Next, the sum of predicted agricultural (non-agricultural) exports and imports is divided by agricultural (non-agricultural) value added. For overall trade intensity, we perform a similar exercise. After aggregating predicted values of total pairwise trade, the sum of predicted overall exports and imports is divided by GDP. The summary statistics corresponding to the predicted values of agricultural, total, and non-agricultural openness are displayed in Table 1.

Finally, the data on GDP per capita, arable land, agricultural productivity, percent of rural population, time needed to start a business or enforce a contract, mobile cellular subscriptions, access to electricity, age dependency ratio, as well as the US GDP deflator to express nominal values in 2010 dollars are obtained from WDI. Table 1 provides the associated summary measures.

4 Results

4.1 Agricultural Trade Intensity

We focus on the impact of agricultural trade intensity in Table 5. Panels A and B correspond to (log) protein supply and dietary diversity as the dependent variables, respectively. Food supply variability and cereal import dependency are the measures of food security in Panels C and D, respectively. Apart from displaying the results obtained using Ordinary Least Squares (OLS), the IV estimates are reported under the columns labeled 'IV Set #1', 'IV Set #2', ..., 'IV Set #5'.[7] While all the instrument sets include predicted agricultural trade intensity as an exclusion restriction, the first four also contain time needed to start a business. Next, access to electricity (age dependency ratio) is included in IV Set #1 (IV Set #2), and the third set contains mobile cellular subscriptions. The time required to enforce a contract is a part of the last two sets with IV Set #5 also including mobile subscriptions. According to Murray (2006) (p. 118), obtaining "similar results from alternative instruments enhances the credibility of instrumental variable estimates."

Across most dependent variables, the OLS specification finds agricultural openness and per capita income to be jointly significant at the $p < 0.01$ level. Moreover, agricultural trade intensity is also individually

[6] https://www.usitc.gov/data/gravity/dgd.htm.

[7] Note, although the results focus on the effect of agricultural openness, the coefficient estimates corresponding to the remaining explanatory variables are available upon request.

statistically significant at least at the $p < 0.05$ level of confidence. While such commerce is positively associated with protein supply, the corresponding correlations with dietary diversity and each of the stability measures in Panels C and D are negative. Nonetheless, we refrain from putting too much stock on the estimates obtained under exogeneity.

Turning to the GMM results, in Panel A, agricultural trade intensity is witnessed to increase protein supply across all specifications. Moreover, the associated coefficient estimates are typically statistically significant at the $p < 0.01$ level of confidence. In terms of the IV specification tests, across all instrument sets, the Kleibergen and Paap (2006) rk statistic rejects the null of underidentification and the Kleibergen-Paap F-statistic is typically large. While the estimates pertaining to IV Sets #1 and #2 reject the exogeneity of agricultural trade intensity and GDP per capita at conventional levels of significance, the Anderson and Rubin (1949) test (robust to weak instruments) typically finds the endogenous regressors to be jointly significant at the $p < 0.01$ level of confidence. In addition, Hansen's J-test of overidentifying restrictions supports the validity of our instruments. Across all instrument groups, a one standard deviation rise in agricultural trade intensity is evidenced to enhance protein supply by roughly 1%.[8] In other words, during 2014, if Chile's agricultural openness increased to that of Luxembourg, a similar effect on protein supply seems reasonable.

Continuing to focus on food availability in Panel B, for all IV sets, the exclusion restrictions perform well in terms of the specification tests and the coefficient estimates remain statistically significant. Based on the estimates, a one standard deviation increase in agricultural trade intensity may reduce dietary diversity by up to 0.44 percentage points.[9] This negative effect is, however, not unreasonable. For instance, Krivonos and Kuhn (2019) witness agricultural trade to negatively impact the share of fruits and vegetables consumed. Similarly, Marson et al. (2023) highlight the possibility of reduced variety for consumption due to higher incentives to export.

Proceeding to the stability indicators in Panels C and D, agricultural openness is witnessed to significantly improve food security. While our instruments continue to perform well in terms of the IV specification tests, the exogeneity of our trade and income variables is rejected less frequently than in Panels A and B. Turning to the magnitudes of the coefficient estimates, a one standard deviation rise in agricultural trade intensity is witnessed to reduce the variability of food supply by at least 1.88 kilocalories per capita per day.[10] A related increase in agricultural openness decreases cereal import dependency by up to 4.43 percentage points.[11]

In sum, we find evidence of agricultural trade improving food security. Among our availability measures,

[8] Using the value of standard deviation from Table 1, we obtain $(\exp(0.002 \times 4.943) - 1) \times 100$.
[9] Using the value of standard deviation from Table 1, we calculate -0.09×4.943.
[10] Based on the value of standard deviation in Table 1, we calculate -0.381×4.943.
[11] Using the value of standard deviation from Table 1, we calculate -0.896×4.943.

we uncover a positive effect with respect to protein supply. While such trade is evidenced to reduce dietary diversity, the impact on our stability indicators is unambiguously favorable. Agricultural openness decreases the variability of food supply and makes countries less dependent on imports for cereals. Our findings complement the results in the existing literature. For instance, Mary (2019) and Marson et al. (2023) witnessed food and cereals trade to encourage and discourage the prevalence of undernourishment, respectively. To further assess the robustness of our findings, we turn to the impact of overall openness on food security.

4.2 Trade Intensity

The results corresponding to overall openness are displayed in Table 6. Here, the dependent variables in Panels A-D are identical to those in Table 5. Moreover, each of the five sets of instruments are very similar to the corresponding exclusion restrictions in Table 5; the only exception is the use of (predicted) overall trade intensity instead of agricultural openness.

In case of OLS, the coefficient estimates pertaining to overall openness and per capita income are often jointly significant at the $p < 0.01$ level of confidence. However, the individual effects of trade intensity are mostly statistically insignificant.

Focusing on the IV results in Panel A, across all instrument groups, overall trade intensity is largely witnessed to reduce protein supply. Moreover, the associated coefficient estimates pertaining to IV Sets #1, #2, and #3 are statistically significant at the $p < 0.1$ level of confidence. In addition, trade intensity and (log) GDP per capita are often jointly significant. Further, as in the case of Table 5, the exclusion restrictions continue to perform well with respect to the IV specification tests for underidentification and weak identification. While the overidentification tests further support the validity of our instruments, our concerns over the endogeneity of trade and income are also warranted. Based on the statistically significant coefficient estimates, a one standard deviation rise in openness decreases protein supply by roughly up to 9%.[12] However, this negative effect is not surprising. For example, Krivonos and Kuhn (2019) (p. 1) state: "Due to the complexity of the relationship between trade policy and the nutrition transition, both negative and positive outcomes may arise from different aspects of trade liberalization."

Turning to Panel B, across all IV sets, the specification tests continue to perform well but the coefficient estimates are largely statistically insignificant. Although the trade and income variables are often jointly significant, we typically fail to reject their exogeneity. In case of IV Set #1, a one standard deviation increase in trade intensity is witnessed to encourage dietary diversity by nearly 2 percentage points.[13] It is worth noting that our results in Panels A and B differ from Dithmer and Abdulai (2017) who find overall openness

[12] Using the value of standard deviation from Table 1, we obtain $(\exp(-0.023 \times 4.164) - 1) \times 100$.

[13] Again, using the value of standard deviation from Table 1, we obtain 0.47×4.164.

to promote protein supply and dietary diversity.

The IV results in Panels C and D support the joint significance of openness and income as well as their potential endogeneity. Moreover, the specification tests across all sets of instruments continue to lend credibility to our estimation strategy. However, while the effects of openness are often statistically significant, they are not always witnessed to improve food security. For instance, a one standard deviation increase in overall trade intensity enhances the variability of food supply by nearly up to 26 kilocalories per capita per day. Contrarily, a related increase in openness significantly reduces cereal import dependency by at least about 40 percentage points. Here, it is worth noting that the impacts on our stability measures seem plausible. For example, as Dithmer and Abdulai (2017) (p. 219) highlight, while "an open trade policy can [help] to stabilize domestic food availability," it may also "leave some countries, in which export earnings are critical for ensuring staple food imports, extremely vulnerable to changing market conditions, such as international price fluctuations."

In sum, we find mixed evidence of overall trade improving food security. Based on our availability measures, we uncover a positive but mostly insignificant effect with respect to dietary diversity. However, openness is witnessed to reduce protein supply. Similarly, for the stability indicators, our results are sensitive to the dependent variable employed. While trade reduces dependency on imports for cereals, it increases the variability of food supply.

Thus, agricultural trade is characterized by potentially different implications for food security than overall openness. In case of protein supply, the former has a more favorable effect than overall trade intensity. Although agricultural openness is witnessed to reduce dietary diversity, the corresponding impact of overall trade is often statistically insignificant. Moreover, unlike overall openness, agricultural trade unambiguously benefits food stability. Accordingly, in the trade and food security debate, it is crucial to explore the role of agricultural openness separately. The next set of results further examines the role of agricultural trade after controlling for non-agricultural openness.

4.3 Agricultural and Non-Agricultural Trade Intensities

The results in Table 7 are obtained from an equation such as 1 after accounting for the role of both agricultural and non-agricultural openness. Across the IV sets, the instruments are similar to those in Tables 5 and 6; the only difference corresponds to the use of both (predicted) agricultural and non-agricultural intensities as our trade-based instruments. In addition, Table 7 reports the p-values for the test of equality between the coefficients corresponding to agricultural and non-agricultural openness.

Focusing on Panel A, the OLS and IV models find only agricultural trade intensity to have a favorable effect on protein supply. Moreover, the impact of agricultural openness is witnessed to be significantly different from that of non-agricultural trade. Across all specifications, the trade and income variables are jointly significant. While some of the instrument sets reject the exogeneity of our trade intensity measures and per capita income, the IV specification tests lend credibility to our findings. Based on the GMM estimates, a one standard deviation increase in agricultural (non-agricultural) trade is evidenced to increase (reduce) protein supply by up to 1% (6%).[14]

In case of dietary diversity in Panel B, across our OLS and IV specifications, the effects of agricultural and non-agricultural openness are typically not significantly different. However, the exogeneity of the trade intensities and GDP per capita is often rejected. While the effect of non-agricultural trade intensity is statistically insignificant, agricultural commerce is found to reduce dietary diversity at the $p < 0.01$ level of confidence. In case of IV Set #3, a one standard deviation increase in agricultural openness reduces this measure by 0.42 percentage points.

Turning to the variability of food supply in Panel C, agricultural and non-agricultural trade have significantly different impacts. While the endogenous variables are jointly significant, the exclusion restrictions perform well in terms of the specification tests. Moreover, our concerns pertaining to the endogeneity of the trade and income variables are warranted. Interestingly, only agricultural openness is witnessed to have a favorable effect on our measure of food security. For example, a one standard deviation increase in agricultural (non-agricultural) commerce reduces (increases) the variability of food supply by at least 2.10 (14.31) kilocalories per capita per day.

In case of cereal import dependency, the OLS specification in Panel D fails to reject the null hypothesis of equality between the effects of agricultural and non-agricultural openness. However, across IV Sets #1 and #2, the null of equality is rejected along with the exogeneity of the trade and income variables. Focusing on these estimates, a one standard deviation increase in agricultural trade intensity is witnessed to reduce cereal import dependency by up to 3.88 percentage points. A similar increase in non-agricultural openness has a more pronounced effect of reducing the dependent variable by up to 48.18 percentage points.

Thus, the results in Table 7 further highlight the differential effects of agricultural and non-agricultural trade on food security. Moreover, they indicate that the effect of overall openness is largely attributable to non-agricultural trade. In other words, while exploring the effect of openness on food security, the role of agricultural trade should be examined separately.

[14] Using the values of standard deviation from Table 1, we obtain $(\exp(0.002 \times 4.943) - 1) \times 100$ and $(\exp(-0.011 \times 5.595) - 1) \times 100$.

5 Conclusion

Marson et al. (2023) (p. 300-301) state: "While trade policies are considered strategic to shape national food systems and promote food security, the ultimate impact of trade openness on hunger is still highly debated. Moreover, the empirical evidence is relatively scarce and fragmented if compared to the large literature about the effects of trade on economic growth, poverty, inequality and other aspects of development." Echoing a similar sentiment, Martin (2017) (p. 4) notes that "trade can be a powerful force for improving food security both by raising income and by reducing volatility." Given such concerns, we utilize data across roughly 200 countries over the years 2000 to 2016 and estimate the effect of agricultural trade intensity on a number of indicators of food security. Due to concerns over the endogeneity of our trade and income variables, we employ an IV strategy. Moreover, we analyze the effects of overall openness as well as non-agricultural trade.

We largely witness agricultural openness to significantly improve food security. It unambiguously decreases the variability of food supply as well as cereal import dependency. While agricultural trade intensity is witnessed to reduce dietary diversity, its effect on protein supply is positive. On the contrary, the impact of overall openness on food security is mixed. While there is some evidence in favor of overall trade encouraging dietary diversity, the estimates are imprecise. Moreover, it has a negative effect on protein supply. For our stability indicators, overall openness has a positive and negative impact on the variability of food supply and cereal import dependency, respectively. Upon accounting for the role of non-agricultural trade, the effect of agricultural commerce is uncovered to be significantly different. Accordingly, while analyzing the impact of trade on food security, accounting for the role of agricultural trade is warranted.

Overall, we arrive at a number of broad conclusions. First, the impact of agricultural trade intensity on food security differs from the effects of overall and non-agricultural openness. Second, the effects of any measure of trade intensity differ across food security indicators. Finally, concerns over the endogeneity of such measures of openness are relevant.

References

Anderson, J.E., Van Wincoop, E., 2003. Gravity with gravitas: A solution to the border puzzle. American Economic Review 93, 170–192.

Anderson, T.W., Rubin, H., 1949. Estimation of the parameters of a single equation in a complete system of stochastic equations. The Annals of Mathematical Statistics 20, 46–63.

Aragie, E., Balié, J., Morales, C., Pauw, K., 2023. Synergies and trade-offs between agricultural export promotion and food security: Evidence from african economies. World Development 172, 106368.

Barrett, C.B., 2021. Overcoming global food security challenges through science and solidarity. American Journal of Agricultural Economics 103, 422–447.

Beghin, J.C., Schweizer, H., 2021. Agricultural trade costs. Applied Economic Perspectives and Policy 43, 500–530.

Bellemare, M.F., Masaki, T., Pepinsky, T.B., 2017. Lagged explanatory variables and the estimation of causal effect. The Journal of Politics 79, 949–963.

Bidisha, S.H., Abdullah, S., Siddiqua, S., Islam, M.M., 2020. How does dependency ratio affect economic growth in the long run? evidence from selected asian countries. The Journal of Developing Areas 54.

Borchert, I., Larch, M., Shikher, S., Yotov, Y.V., 2021. The international trade and production database for estimation (itpd-e). International Economics 166, 140–166.

Borchert, I., Larch, M., Shikher, S., Yotov, Y.V., 2022. The international trade and production database for estimation-release 2 .

Brenton, P., Chemutai, V., Pangestu, M., 2022. Trade and food security in a climate change-impacted world. Agricultural Economics 53, 580–591.

Chintrakarn, P., Millimet, D.L., 2006. The environmental consequences of trade: Evidence from subnational trade flows. Journal of Environmental Economics and Management 52, 430–453.

Clague, C., Keefer, P., Knack, S., Olson, M., 1999. Contract-intensive money: Contract enforcement, property rights, and economic performance. Journal of Economic Growth 4, 185–211.

Correia, S., Guimarães, P., Zylkin, T., 2019. Verifying the existence of maximum likelihood estimates for generalized linear models `arXiv:arXiv:1903.01633`.

Correia, S., Guimarães, P., Zylkin, T., 2020. Fast Poisson estimation with high-dimensional fixed effects. The Stata Journal 20, 95–115. URL: `https://doi.org/10.1177/1536867X20909691`, doi:10.1177/1536867X20909691, `arXiv:https://doi.org/10.1177/1536867X20909691`.

Dallmann, I., 2019. Weather variations and international trade. Environmental and Resource Economics 72, 155–206.

Dithmer, J., Abdulai, A., 2017. Does trade openness contribute to food security? a dynamic panel analysis. Food Policy 69, 218–230.

Djankov, S., McLiesh, C., Ramalho, R.M., 2006. Regulation and growth. Economics Letters 92, 395–401.

Edmonds, E.V., Pavcnik, N., 2005. The effect of trade liberalization on child labor. Journal of International Economics 65, 401–419.

Edquist, H., Goodridge, P., Haskel, J., Li, X., Lindquist, E., 2018. How important are mobile broadband networks for the global economic development? Information Economics and Policy 45, 16–29.

FAO, IFAD, UNICEF, WFP, WHO, 2023. The state of food security and nutrition in the world 2023: Urbanization, agrifood systems, transformation and healthy diets across the rural-urban continuum .

Ferguson, R., Wilkinson, W., Hill, R., 2000. Electricity use and economic development. Energy policy 28, 923–934.

Frankel, J.A., Rose, A.K., 2005. Is trade good or bad for the environment? sorting out the causality. Review of Economics and Statistics 87, 85–91.

Gouel, C., 2016. Trade policy coordination and food price volatility. American Journal of Agricultural Economics 98, 1018–1037.

Gräbner, C., Heimberger, P., Kapeller, J., Springholz, F., 2021. Understanding economic openness: A review of existing measures. Review of World Economics 157, 87–120.

Gurevich, T., Herman, P., 2018. The dynamic gravity dataset: 1948-2016. US International Trade Commission, Office of Economics Working Paper .

Henderson, D.J., Millimet, D.L., 2008. Is gravity linear? Journal of Applied Econometrics 23, 137–172.

Hertel, T.W., Baldos, U.L., Fuglie, K.O., 2020. Trade in technology: A potential solution to the food security challenges of the 21st century. European Economic Review 127, 103479.

Izraelov, M., Silber, J., 2019. An assessment of the global food security index. Food Security 11, 1135–1152.

Jin, S., Ma, B., Zheng, Y., Jin, X., Wu, W., 2024. Short-term impact of food safety standards on agri-product exports: Evidence from japan's positive list system on chinese vegetable exports. Journal of Agricultural Economics 75, 362–381.

Kleibergen, F., Paap, R., 2006. Generalized reduced rank tests using the singular value decomposition. Journal of Econometrics 133, 97–126.

Krivonos, E., Kuhn, L., 2019. Trade and dietary diversity in eastern europe and central asia. Food Policy 88, 101767.

Levine, D.I., Rothman, D., 2006. Does trade affect child health? Journal of Health Economics 25, 538–554.

Marson, M., Saccone, D., Vallino, E., 2023. Total trade, cereals trade and undernourishment: New empirical evidence for developing countries. Review of World Economics 159, 299–332.

Martin, W., 2017. Agricultural trade and food security .

Mary, S., 2019. Hungry for free trade? food trade and extreme hunger in developing countries. Food Security 11, 461–477.

McAusland, C., Millimet, D.L., 2013. Do national borders matter? intranational trade, international trade, and the environment. Journal of Environmental Economics and Management 65, 411–437.

Murray, M.P., 2006. Avoiding invalid instruments and coping with weak instruments. Journal of Economic Perspectives 20, 111–132.

Reed, W.R., 2015. On the practice of lagging variables to avoid simultaneity. Oxford Bulletin of Economics and Statistics 77, 897–905.

Roodman, D., 2009. A note on the theme of too many instruments. Oxford Bulletin of Economics and Statistics 71, 135–158.

Roy, J., 2017. On the environmental consequences of intra-industry trade. Journal of Environmental Economics and Management 83, 50–67.

Rudloff, B., Mensah, K., Wieck, C., 2024. Geostrategic aspects of policies on food security in the light of recent global tensions–insights from seven countries .

Silva, J.S., Tenreyro, S., 2006. The log of gravity. The Review of Economics and Statistics 88, 641–658.

Table 1. Summary Statistics.

Variable	N	Mean	SD
Measures of Food Security			
Protein Supply	2750	78.835	20.495
(grams per person per day)			
Dietary Diversity	2750	52.695	14.324
(% of dietary energy from non-staple food)			
Per Capita Food Supply Variability	2993	40.385	26.106
(kilocalories per person per day)			
Cereal Import Dependency Ratio	2800	29.651	60.654
(% of cereal supply imported)			
Trade Measures			
Overall Trade Intensity	3202	1.096	4.164
Overall Trade Intensity (Predicted)	3176	1.010	4.255
Agricultural Trade Intensity	3093	1.187	4.943
Agricultural Trade Intensity (Predicted)	2986	1.053	3.846
Non-Agricultural Trade Intensity	3061	1.192	5.595
Non-Agricultural Trade Intensity (Predicted)	2961	1.112	4.959
Controls			
Per Capita GDP (2010 US$)	3176	12989.700	18438.070
Arable Land (hectares per person)	3233	0.214	0.236
Cereal Yield (kilograms per hectare)	2973	3168.329	2792.566
Rural Population (% of population)	3292	43.743	23.227
Time Required to Start a Business (days)	2346	36.134	51.436
Access to Electricity (% of population)	3279	77.568	30.973

Table 2. Gravity Equation Results for Agricultural Trade.

Variable	Coefficient	Standard Error
ln(Distance)	-1.073*	0.012
Common Language	0.341*	0.026
Contiguity	0.399*	0.027
Exporter Ever Colony of Importer	-0.269*	0.045
Importer Ever Colony of Exporter	-0.274*	0.054

‡ $p<0.10$, † $p<0.05$, * $p<0.01$. N=438324. Estimation is performed by a Poisson pseudo-maximum likelihood estimator. Country-by-year dummies are included. Standard errors are heteroskedasticity-robust.

Table 3. Gravity Equation Results for Overall Trade.

Variable	Coefficient	Standard Error
ln(Distance)	-0.828*	0.007
Common Language	0.270*	0.014
Contiguity	0.319*	0.016
Exporter Ever Colony of Importer	-0.031	0.024
Importer Ever Colony of Exporter	0.094*	0.027

‡ p<0.10, † p<0.05, * p<0.01. N=619740. Estimation is performed by a Poisson pseudo-maximum likelihood estimator. Country-by-year dummies are included. Standard errors are heteroskedasticity-robust.

Table 4. Gravity Equation Results for Non-Agricultural Trade.

Variable	Coefficient	Standard Error
ln(Distance)	-0.828*	0.007
Common Language	0.274*	0.014
Contiguity	0.310*	0.016
Exporter Ever Colony of Importer	-0.022	0.025
Importer Ever Colony of Exporter	0.095*	0.027

‡ p<0.10, † p<0.05, * p<0.01. N=617382. Estimation is performed by a Poisson pseudo-maximum likelihood estimator. Country-by-year dummies are included. Standard errors are heteroskedasticity-robust.

Table 5. Impact of Agricultural Trade Intensity on Food Security.

	OLS	IV Set #1	IV Set #2	IV Set #3	IV Set #4	IV Set #5
Panel A. log(Protein Supply)						
Agricultural Trade Intensity	0.002*	0.002†	0.002*	0.002*	0.002*	0.002*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		29.776	14.067	55.646	19.683	63.758
Overid Test		0.531	0.667	0.951	0.934	0.373
Endogeneity		0.001	0.053	0.353	0.185	0.270
Joint Sign. Endog.	0.000	0.000	0.000	0.000	0.002	0.000
N	2560	1881	1870	1879	1882	1879
Panel B. Dietary Diversity						
Agricultural Trade Intensity	-0.068*	-0.073*	-0.080*	-0.084*	-0.085*	-0.090*
	(0.014)	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		29.776	14.067	55.646	16.298	63.758
Overid Test		0.245	0.169	0.146	0.129	0.874
Endogeneity		0.024	0.060	0.032	0.025	0.009
Joint Sign. Endog.	0.000	0.001	0.000	0.000	0.000	0.000
N	2560	1881	1870	1879	1882	1879
Panel C. Per Capita Food Supply Variability						
Agricultural Trade Intensity	-0.599*	-0.450*	-0.632*	-0.381†	-0.459*	-0.401†
	(0.124)	(0.165)	(0.186)	(0.171)	(0.170)	(0.167)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		30.716	9.597	53.965	18.756	65.552
Overid Test		0.312	0.898	0.170	0.327	0.392
Endogeneity		0.290	0.000	0.751	0.479	0.772
Joint Sign. Endog.	0.000	0.072	0.000	0.204	0.152	0.262
N	2712	2005	1994	2002	2006	2002
Panel D. Cereal Import Dependency Ratio						
Agricultural Trade Intensity	-0.222†	-0.603*	-0.896*	-0.351‡	-0.409‡	-0.373‡
	(0.110)	(0.217)	(0.312)	(0.205)	(0.212)	(0.205)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		30.854	10.806	53.078	18.582	63.777
Overid Test		0.990	0.462	0.237	0.355	0.565
Endogeneity		0.000	0.000	0.538	0.390	0.502
Joint Sign. Endog.	0.019	0.000	0.000	0.209	0.184	0.269
N	2647	1952	1941	1949	1953	1949

‡ p<0.10, † p<0.05, * p<0.01. Standard errors in parentheses are heteroskedasticity-robust. Agricultural trade intensity and log (per capita GDP) are instrumented for using predicted agricultural trade intensity and variables such as the number of days required to start a business, time needed to enforce a contract, mobile cellular subscriptions per 100 individuals, the percentage of population with access to electricity, and the percent of working-age population. Underid Test reports the p-value of the Kleibergen-Paap (2006) rk statistic with rejection implying identification. F-stat reports the Kleibergen-Paap F statistic for weak identification. Overid Test displays the p-value of Hansen J statistic with rejection implying invalid instruments. Endogeneity reports the p-value of endogeneity test of the endogenous regressors. Joint Sign. Endog. displays the p-value of Anderson-Rubin (1949) chi-square test of endogenous regressors. Other covariates include: (log) arable land, (log) agricultural productivity, percent of rural population, as well as year- and country-specific dummies. See text for further details.

Table 6. Impact of Trade Intensity on Food Security.

	OLS	IV Set #1	IV Set #2	IV Set #3	IV Set #4	IV Set #5
Panel A. log(Protein Supply)						
Trade Intensity	-0.005	-0.023*	-0.017*	-0.010‡	-0.004	-0.009
	(0.006)	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		29.200	15.577	34.510	11.508	42.945
Overid Test		0.451	0.518	0.736	0.938	0.135
Endogeneity		0.004	0.067	0.749	0.190	0.527
Joint Sign. Endog.	0.000	0.000	0.000	0.000	0.364	0.000
N	2606	1956	1945	1954	1957	1954
Panel B. Dietary Diversity						
Trade Intensity	-0.114	0.470†	0.086	0.079	0.190	-0.012
	(0.191)	(0.234)	(0.211)	(0.212)	(0.255)	(0.224)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		29.200	15.577	34.510	11.508	42.945
Overid Test		0.232	0.121	0.106	0.135	0.279
Endogeneity		0.116	0.733	0.253	0.830	0.176
Joint Sign. Endog.	0.000	0.048	0.000	0.000	0.005	0.000
N	2606	1956	1945	1954	1957	1954
Panel C. Per Capita Food Supply Variability						
Trade Intensity	-0.360	4.182†	1.317	6.182*	2.586	5.585*
	(1.631)	(1.793)	(2.164)	(2.170)	(2.216)	(2.036)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		30.521	10.774	36.265	13.240	46.631
Overid Test		0.454	0.936	0.173	0.759	0.035
Endogeneity		0.001	0.000	0.003	0.000	0.003
Joint Sign. Endog.	0.917	0.002	0.000	0.009	0.004	0.004
N	2762	2081	2070	2078	2082	2036
Panel D. Cereal Import Dependency Ratio						
Trade Intensity	-9.252*	-13.786*	-18.397*	-9.515†	-10.738†	-9.533†
	(3.332)	(3.657)	(4.213)	(4.250)	(4.299)	(4.216)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		30.800	11.490	34.816	13.166	44.689
Overid Test		0.938	0.539	0.275	0.416	0.558
Endogeneity		0.000	0.000	0.657	0.482	0.697
Joint Sign. Endog.	0.007	0.000	0.000	0.118	0.114	0.172
N	2691	2022	2011	2019	2023	2019

‡ $p<0.10$, † $p<0.05$, * $p<0.01$. Standard errors in parentheses are heteroskedasticity-robust. Trade intensity and log (per capita GDP) are instrumented for using predicted trade intensity and variables such as the number of days required to start a business, time needed to enforce a contract, mobile cellular subscriptions per 100 individuals, the percentage of population with access to electricity, and the percent of working-age population. Underid Test reports the p-value of the Kleibergen-Paap (2006) rk statistic with rejection implying identification. F-stat reports the Kleibergen-Paap F statistic for weak identification. Overid Test displays the p-value of Hansen J statistic with rejection implying invalid instruments. Endogeneity reports the p-value of endogeneity test of the endogenous regressors. Joint Sign. Endog. displays the p-value of Anderson-Rubin (1949) chi-square test of endogenous regressors. Other covariates include: (log) arable land, (log) agricultural productivity, percent of rural population, as well as year- and country-specific dummies. See text for further details.

Table 7. Impact of Agricultural and Non-agricultural Trade Intensity on Food Security.

	OLS	IV Set #1	IV Set #2	IV Set #3	IV Set #4	IV Set #5
Panel A. log(Protein Supply)						
Agricultural Trade Intensity	0.002*	0.002*	0.002*	0.002*	0.002*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Non-Agricultural Trade Intensity	-0.008*	-0.011*	-0.009*	-0.006†	-0.005‡	-0.006†
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		22.318	10.860	41.851	11.859	47.795
Overid Test		0.531	0.655	0.933	0.956	0.396
Endogeneity		0.001	0.073	0.509	0.266	0.394
Joint Sign. Endog.	0.000	0.000	0.000	0.000	0.005	0.000
Test Agricultural = Non-Agricultural	0.000	0.000	0.000	0.005	0.019	0.007
N	2556	1881	1870	1879	1882	1879
Panel B. Dietary Diversity						
Agricultural Trade Intensity	-0.067*	-0.075*	-0.080*	-0.085*	-0.085*	-0.090*
	(0.014)	(0.022)	(0.023)	(0.024)	(0.023)	(0.024)
Non-agricultural Trade Intensity	-0.056	0.117	0.037	0.107	-0.002	0.039
	(0.055)	(0.114)	(0.120)	(0.111)	(0.129)	(0.117)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		22.318	10.860	41.851	11.859	47.795
Overid Test		0.245	0.170	0.148	0.129	0.880
Endogeneity		0.031	0.127	0.047	0.058	0.018
Joint Sign. Endog.	0.000	0.001	0.000	0.000	0.000	0.000
Test Agricultural = Non-Agricultural	0.852	0.100	0.345	0.096	0.531	0.286
N	2556	1881	1870	1879	1882	1879
Panel C. Per Capita Food Supply Variability						
Agricultural Trade Intensity	-0.622*	-0.486*	-0.666*	-0.424†	-0.496*	-0.443†
	(0.125)	(0.162)	(0.186)	(0.167)	(0.166)	(0.164)
Non-agricultural Trade Intensity	1.338*	3.803*	2.557†	4.128*	3.991*	4.113*
	(0.399)	(1.148)	(1.235)	(1.369)	(1.382)	(1.370)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		23.012	7.410	40.682	13.614	49.393
Overid Test		0.325	0.891	0.157	0.291	0.427
Endogeneity		0.009	0.000	0.014	0.005	0.017
Joint Sign. Endog.	0.000	0.001	0.000	0.004	0.002	0.006
Test Agricultural = Non-Agricultural	0.000	0.000	0.009	0.001	0.001	0.001
N	2708	2005	1994	2002	2006	2002
Panel D. Cereal Import Dependency Ratio						
Agricultural Trade Intensity	-0.202‡	-0.544†	-0.784*	-0.291	-0.353‡	-0.320
	(0.112)	(0.215)	(0.290)	(0.210)	(0.214)	(0.210)
Non-agricultural Trade Intensity	-0.878	-6.111†	-8.612†	-5.356‡	-5.769‡	-5.051
	(0.921)	(2.997)	(3.794)	(3.239)	(3.286)	(3.229)
Underid Test		0.000	0.000	0.000	0.000	0.000
F-stat		23.134	8.330	40.025	13.495	48.058
Overid Test		0.979	0.453	0.269	0.420	0.523
Endogeneity		0.000	0.000	0.196	0.178	0.208
Joint Sign. Endog.	0.018	0.000	0.000	0.090	0.085	0.113
Test Agricultural = Non-Agricultural	0.479	0.067	0.041	0.125	0.104	0.151
N	2643	1952	1941	1949	1953	1949

‡ p<0.10, † p<0.05, * p<0.01. Standard errors in parentheses are heteroskedasticity-robust. Agricultural trade intensity and log (per capita GDP) are instrumented for using predicted agricultural trade intensity and variables such as the number of days required to start a business, time needed to enforce a contract, mobile cellular subscriptions per 100 individuals, the percentage of population with access to electricity, and the percent of working-age population. Underid Test reports the p-value of the Kleibergen-Paap (2006) rk statistic with rejection implying identification. F-stat reports the Kleibergen-Paap F statistic for weak identification. Overid Test displays the p-value of Hansen J statistic with rejection implying invalid instruments. Endogeneity reports the p-value of endogeneity test of the endogenous regressors. Joint Sign. Endog. displays the p-value of Anderson-Rubin (1949) chi-square test of endogenous regressors. The p-values are reported for the test of equality between the coefficients on the agricultural and non-agricultural trade intensity measures. Other covariates include: (log) arable land, (log) agricultural productivity, percent of rural population, as well as year- and country-specific dummies. See text for further details.