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TRADE LIBERALIZATION, PRICE TRANSMISSION AND HOUSEHOLD WELFARE: EVIDENCE FROM CHINA

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Abstract. This paper estimates the welfare effect of trade through the price channel by jointly considering the consumption and income effect. The consumer price data and household survey data of China are used to conduct the empirical analysis. For assessing the consumption effect, the quadratic almost ideal demand system (QUAIDS) model is used to capture the substitution effect of price changes. We find that every household of China is better off due to the reduction of import tariffs, but there is a strongly pro-poor bias. More importantly, ignoring the substitution effect on the consumption side not only underestimates the absolute value of welfare changes but also distorts the distribution of welfare changes. Our results imply the importance of the consumption effect in estimating the welfare gain of households from trade liberalization. Our framework can also be extended to assess consequences of the opening policies of other economies.

Keywords: trade liberalization, household welfare, price transmission, consumption effect, income effect, distributional effect.

JEL Classification: F14, F16, D30, R21.

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1. Introduction

Existing studies have confirmed that international trade significantly affects the well-being of its participants. While most studies have explored the welfare effect of trade via the employment and wage channels (e.g., Amiti & Davis, 2012; Erten et al., 2019; César et al., 2021; Kim & Vogel, 2021; Keller & Utar, 2023), a growing but still limited stream of literature has concentrated on the price channel, especially the expenditure (consumption) channel (e.g., Nicita, 2009; Jaravel & Sager, 2019; Vo & Nguyen, 2021). Focusing on the expenditure channel contributes to better understanding the impact of trade on consumers in different income groups (e.g., Fajgelbaum & Khandelwal, 2016; Han et al., 2016; Jaravel & Lashkari, 2024). Moreover, the large consumption gains from trade may be able to compensate those who suffer from the labor market loss induced by trade exposure (Jaravel & Sager, 2019). Therefore, ignoring the consumption effect of trade will lead to the underestimation of the welfare gain due to opening policies[1], thereby misleading the public and policymakers and ultimately triggering the re-rise of trade protectionism (Waugh, 2019; Chor & Li, 2024).

[1] For example, Zhao et al. (2024) mention that there is a "trade-loss effect" due to the technological progress.

Changes in consumer prices may also affect the equilibrium of factor markets and further impact the factor prices or income of household members, who act as both consumers and factor owners (Nicita, 2009; Artuc et al., 2021). Hence, the earning (income) channel is another essential aspect of the price channel. However, only a few studies explore how trade liberalization impacts the household income through influencing the domestic consumer price, and even fewer have measured the aggregate price effect of trade by combining the welfare changes on the consumption side with that on earning side (Porto, 2006; Nicita, 2009; He, 2019). Therefore, in this paper we develop an empirical framework to estimate the welfare effect of trade through the price channel by jointly considering the consumption effect (i.e., the effect through expenditure channel) and the income effect (i.e., the effect through earning channel). More importantly, we analyze how the welfare changes induced by trade liberalization distribute across income groups and whether the rich or the poor are the main beneficiaries of trade (Galle et al., 2023; Bai et al., 2024).

Most of prior studies use the reduction of import tariff to depict trade liberalization (Aichele & Heiland, 2018; Erten et al., 2019; Fan et al., 2020). Since the beginning of 21st century, the world has witnessed a substantially decrease of import tariffs in China (Fan et al., 2021; Dai et al., 2021). For example, China has reduced its import tariffs more than 7% in the few years after its accession to the World Trade Organization (n.d.) in 2001. The significant change of import tariffs inevitably transmits to domestic consumer price, and further impacts the household welfare. Thus, China provides a good case to assess the resulting welfare gains through price changes due to the import tariff reduction. Therefore, this paper focuses exclusively on trade liberalization that has taken place in China.

We address a number of practical issues in our empirical approach. One issue is that we require a good measure of consumer price to discuss the price effect of trade. Most related studies have used the calculated unit value (i.e., expenditure divided by the quantity of consumption) as the proxy of consumer price based on household survey data (e.g., Attanasio et al., 2013; Bai & Stumpner, 2019). However, the calculated unit value is endogenously determined by the behaviors of consumers[2]. In this case, the estimated elasticities for consumer price, such as tariff pass-through elasticities and demand elasticities, are inevitably biased. To tackle this problem, we exploit the detailed price data sourced from the China Price Information Network (n.d.) maintained by the Price-monitoring Center of the National Development and Reform Commission (n.d.) to conduct our empirical analysis. The consumer price collected by the NDRC in specific locations (e.g., agriculture markets and supermarkets) is more independent of the behavior of individual consumers than the unit value computed from household survey data and therefore alleviates the endogeneity.

Another practical issue is that we require an ideal demand model to estimate the consumption effect of trade. The demand model should meet at least two premises; the first one is that the goods can be substituted by each other as their relative price changes, i.e., the substitution effect. This premise is in line with the pattern of observed responses of consumers to the price change in the real world[3]. Most of the previous studies used first-order ap-

[2] For example, if consumers respond to a price change by adjusting both the quantity and quality of their consumptions, the observed unit value would not reflect the actual variation in the consumer price.

[3] For example, consumers may adjust their consumption baskets as prices change and substitute their purchases for relatively cheaper goods.

proximations to estimate the consumption effect of trade (e.g., Porto, 2006; Han et al., 2016), which did not consider the substitution effect. However, ignoring the substitution effect may cause the mismeasurement of the welfare gain from trade on the consumption side. For example, Baqaee and Burstein (2021) noted that the substitution bias is larger if changes in expenditures caused by income effects or taste shocks are correlated with changes in prices. The second premise is that the income elasticities vary across goods, i.e., the good-specific income effect. This premise matches the stylized fact that there are large differences between the consumption bundles of rich and poor households and there is significant heterogeneity in their marginal propensity to consume goods. More importantly, this premise allows us to study of the distributional effect of trade across income groups.

The almost ideal demand system (AIDS) satisfies the above two premises and can simultaneously capture the substitution effect and the good-specific income effect with the changes of consumer prices. Gaarder (2018) suggested that, compared with the AIDS, the first-order approximation seriously understates the redistributive nature of the value-added tax (VAT) reform. Two recent studies (Fajgelbaum & Khandelwal, 2016; He, 2019) further use the AIDS to measure the unequal gain from trade within a country and across countries. In this paper, we use the quadratic AIDS (QUAIDS), which is an extended version of AIDS, to estimate the consumption effect of trade in China, because QUAIDS can better capture the patterns of observed consumer behavior while being consistent with the predictions of consumer theory than AIDS (Banks et al., 1997; Qu & Chen, 2024).

Based on our empirical approach, the results show that every Chinese household is better off with the reduction of import tariffs after China's WTO accession and that the mean aggregated welfare gain of trade through the price channel is 12.42% of the total expenditure. To be specific, the mean consumption effect is found to be about 8.57%, which is about twice larger than that if the substitution effect was ignored (about 3.05%); the mean income effect is found to be about 3.88%. More importantly, the distributional impact is strongly pro-poor in terms of the consumption effect but significantly pro-rich if the substitution effect was neglected. In addition, the distributional impacts are weakly pro-poor in terms of the income effect and strongly pro-poor in terms of the aggregate price effect. These results together imply the importance of consumption effect in aggregate welfare gain of trade liberalization.

To sum up, we add to the studies on the welfare effect of trade through the price channel in the following ways. First, we contribute to the literature regarding the consumption effect of trade. Most of previous studies use the calculated consumer price and the first-order approximation method to estimate the consumption effect of trade (e.g., Porto, 2006; Marchand, 2012; Han et al., 2016), while we rely on the QUAIDS combined with a novel and large disaggregated price data to estimate the consumption effect of trade. Our approach can better capture the behavioral responses of consumers to price changes (i.e., substitute effect) and more accurately reflect the welfare changes in the consumption side. Second, we add to the literature by discussing the income effect of trade from the perspective of price transmission. Most of existing studies explore the direct effect of tariff reduction on individual income (e.g., Amiti & Davis, 2012; Kis-Katos & Sparrow, 2015; Cheong & Jung, 2021), while we focus on how household income changes as the liberalization-induced consumer price changes. Finally, this study sheds light on better understanding the aggregate welfare ef-

fect of trade through the price channel in China. Although the previous studies estimate the consumption effect (Han et al., 2016) or income effect of China's trade liberalization (Aichele & Heiland, 2018), the aggregate price effect associated with China's WTO accession is still under-explored. We attempt to fill this gap. Moreover, our framework can also be extended to assess consequences of other opening policies, such as the capital account liberalization and technology globalization (Ionescu et al., 2022; Chien et al., 2024).

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 estimates the consumer price change to trade liberalization. Sections 4 and 5 respectively assess the consumption and income effect of trade. Section 6 computes the aggregate price effect of trade. Section 7 concludes.

2. Data

2.1. Import tariffs

Import tariffs. The data on import tariffs is sourced from the World Integrated Trade Solution (n.d.). The World Bank maintains the WITS (n.d.), which contains custom information regarding each product with an HS 6-digit code. Data on imported final goods from 1997 to 2011 is adopted in this research. The import tariffs on final goods at the HS 4-digit level are calculated as a simple average of the import tariffs on the 6-digit goods covered in that HS 4-digit (2002 version) group. The import tariffs remained approximately 17% before the end of 2001, but decreased substantially in 2002 because of China's WTO accession; the significant decreasing trend lasted until 2005.

2.2. Consumer prices

The data on consumer prices from 1997 to 2011 is sourced from the CPIN (n.d.) database. This database is collected by the Price-monitoring Center of the NDRC (n.d.), and is the most disaggregated price dataset available in China. The Price-monitoring Center of the NDRC (n.d.) collected price information in 36 large and medium-sized cities before 2003, and about 170 cities and small regions thereafter. All selected price-collecting spots within a city, such as agriculture markets and supermarkets, are required to regularly report their price information. This database mainly contains the name, standard, unit, location of collection, price (purchase price, sale price, etc.), and the time of collection of more than 400 subdivided goods. The goods reported in the database can be classified into more than 10 categories, such as food, daily industrial consumer goods, household services, industrial means production, and fees related to agriculture. In this study, we only focus on the sale prices of food, daily industrial consumer goods (including clothing and household equipment), and household services (including health, transport and communication, education, and housing service) of city residents. Table A1 in the Appendix reports the summary statistics of the price for each category.

To explore the tariff pass-through to the domestic consumer prices, the tariff data is matched with the price data. There are 64 HS 4-digit goods in the matched sample. The detailed data-matching approach is presented in Section 1.2 of the Appendix.

2.3. Household expenditures and income

The data on household expenditures and income is sourced from the Chinese Urban Household Survey (UHS, n.d.) conducted by the National Bureau of Statistics (NBS) of China (Han et al., 2016). The UHS (n.d.) is the official source of data on basic living indicators for urban households in China, which contains two datasets. The first one provides detailed household-level information, such as household characteristics, consumption expenditures and household income. Particularly, the database reports the expenditures of each household on commodities and services. The second one provides the detailed individual-level information within households including the age, gender, educational level, and wage.

A sample from the period of 2002 to 2008 is used to conduct this study[4]. It should be noted that the data of the UHS (n.d.) does not have a panel structure, and thus households cannot be tracked over time.

To estimate the consumption and income effects, the expenditure and income data from the UHS are matched with the price data from the CPIN (n.d.). The detailed matching approach is documented in Section 1.3 of the Appendix. To make the households in the sample more representative, 2002 is considered as the base year and the period ranging from 2003 to 2008 as the estimated period.

3. Trade liberalization and price changes

In this Section, we aim to examine the impact of trade liberalization on the domestic consumer price in China. To do so, we first investigate how import tariffs affect the prices of tradable goods (i.e., pass-through effect) and then discuss how the prices of non-tradable goods respond to the price changes of tradable goods.

3.1. Price changes of tradable goods

The standard tariff pass-through model is estimated to show the effect of import tariffs on the prices of tradable goods as follows:

$$\ln price_{pct} = \beta_1 \ln\left(tariff_{pt} + 1\right) + \beta_2 \ln\left(world\ price_{pt}\right) + \beta_3 \left(\frac{import_{pt}}{GDP_t}\right) + \varphi_{pc} + \varphi_{ct} + \varepsilon_{pct}, \quad (1)$$

where $price_{pct}$ is the consumer price of tradable good p in city c in year t, and $tariff_{pt}$ is the import tariff of that good in the current year. As in previous studies (e.g., Nicita, 2009; Han et al., 2016), we control for the world prices of goods ($world\ price_{pt}$) to capture the effect of fluctuations in the world economy on domestic consumer prices not through the tariff channel. The U.S. export unit value for each HS 4-digit good is used to denote the world price (Han et al., 2016)[5]. In addition, to capture the importance of specific goods in China's import list, the share of imports to GDP for good p, $import_{pt}/GDP_t$, is also controlled for. The product-by-city fixed effects (φ_{pc}) and city-by-year fixed effects ((φ_{ct}) are also included. ε_{pct} is the error term.

[4] While UHS data from 1998 to 2008 is available, the cities and products in the survey data between 2002 and 2008 are more consistent. Therefore, we use the sample during 2002–2008 to conduct our study.

[5] The data from the USITC (n.d.) is used to construct the world prices (Han et al., 2016).

Column (1) of Table 1 presents the baseline of tariff pass-through estimation, which demonstrates the existence of an incomplete tariff pass-through for the domestic consumer price. To be specific, the estimated tariff pass-through elasticity for consumer price is found to be about 8%, which is lower than those reported in previous studies on China and other developing countries (e.g., Nicita, 2009; Han et al., 2016). A possible reason is that the consumer price used in this research is more exogenous to individual consumer behavior and suffers less severe measurement error issue, thereby mitigating the overestimation of the tariff pass-through rate[6].

Table 1. The impact of import tariff on the price of tradable goods

Dep. variable	Ln (price)			
	Full sample	Food	Clothing	Household equipment
	(1)	(2)	(3)	(4)
Ln (tariff+1)	0.0779***	0.0564***	0.884***	0.252***
	(0.00877)	(0.00822)	(0.201)	(0.0269)
Controls	Yes	Yes	Yes	Yes
City-product FEs	Yes	Yes	Yes	Yes
City-year FEs	Yes	Yes	Yes	Yes
Observations	58,275	45,178	4,132	8,958
R-squared	0.976	0.911	0.969	0.871

Notes: *Controls* includes world prices and the share of imports to GDP. Both of the domestic consumer price and world price are deflated to 1997 by using CPI. Robust standard errors are clustered at the city level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In reality, different commodities may experience different pass-through rates because they face inconsistent import penetration or have heterogeneous sensitivities to tariff changes. Ignoring such heterogeneity across commodities within the household's consumption basket may also cause the mismeasurement of the household's welfare gains from trade. To address this concern, the goods are categorized as food, clothing, and household equipment, and these three subsamples are used to re-estimate Eq. (1). The results are presented in Columns (2)–(4) of Table 1. The tariff pass-through rate for food is found to be about 6%, that for clothing is about 88%, and that for household equipment is about 25%. Because a large variation in the pass-through rates is identified across categories, in our later discussion, the pass-through rate of each category is applied in computing the liberalization-induced consumer price changes.

3.2. Price changes of non-tradable goods

To explore the overall mechanism of price transmission in the domestic market, the relationship between the prices of tradable and non-tradable goods also needs to be checked. To do so, we further classify the tradable and non-tradable goods into the following seven product groups: food, clothing, household equipment, health, transport and communication,

[6] We also perform multiple tests to show the robustness of our main finding in Section 2 of the Appendix.

education, and housing service. The first three product groups are tradable goods, and the last four are non-tradable goods. The price of each product group is calculated as the simple average of the prices of products in the corresponding product group. Following previous studies (Porto, 2006; Han et al., 2016), the dynamic panel model is estimated:

$$\ln(price_{ct}^{G}) = \beta_0 \ln(price_{c,t-1}^{G}) + \sum\nolimits_{T} \beta_T \ln(price_{ct}^{T}) + \varphi_c + \varphi_t + \varepsilon_{ct}, \quad (2)$$

where $price_{ct}^{G}$ is the price of non-tradable product group G in city c in year t, and $price_{c,t-1}^{G}$ is the one-year-lagged price of that product group[7]. Moreover, $price_{ct}^{T}$ is the price of tradable product group T in city c in year t[8]. We use the estimation approach developed by Arellano and Bond (1991) to estimate Eq. (2).

Table 2 reports the estimated results for the price elasticities of non-tradable goods. As Porto (2006) argued, there are no theoretical predictions for those complex, general equilibrium relationships. Correlations are not transitive and thus the elasticities in Table 2 can show any sign (Dixit & Norman, 1980). Consequently, the signs and magnitudes of the coefficients on the prices of tradable goods are not analyzed. However, the results reported in Table 2 still indicate that most of the prices of non-tradable goods are significantly affected by that of tradable goods.

Table 2. The impact of price of tradable goods on non-tradable goods

Dep. variable	Ln (price)			
	Health	Transport and communication	Education	Housing service
	(1)	(2)	(3)	(4)
Food	–0.0288	0.0207	0.0360*	–0.0086
	(0.0276)	(0.0236)	(0.0187)	(0.0227)
Clothing	0.139**	–0.109**	0.0297	–0.0055
	(0.0585)	(0.0550)	(0.0360)	(0.0511)
Household equipment	–0.0272	0.386**	–0.145	–0.0502
	(0.186)	(0.187)	(0.0935)	(0.1670)
L. ln (price)	0.6410***	0.7820***	0.6970***	0.5630***
	(0.0838)	(0.0487)	(0.0542)	(0.0520)
Hansen-J test (p value)	1.000	1.000	1.000	1.000
A-B test AR(1) (p value)	0.001	0.000	0.000	0.000
A-B test AR(2) (p value)	0.078	0.356	0.665	0.529
City FEs	yes	yes	yes	yes
Year FEs	yes	yes	yes	yes
Observations	715	1,021	979	1,021

Notes: The dependent (independent) variable is the price of a product group, measured by the simple average of prices of products covered by that product group. First-differenced GMM estimator (AB) is used in all columns. Robust standard errors are clustered at city level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[7] $G \in$ (health, transport and communication, education, housing service).

[8] $T \in$ (food, clothing, household equipment).

Overall, we find that trade liberalization significantly decreases the consumer prices of tradable goods, and the reduced consumer prices of tradable goods further influences the prices of non-tradable goods.

4. Consumption effect of trade liberalization

So far, we have estimated the impact of import tariffs on consumer price in Section 3. In this Section, we assess the consumption effect of trade using the estimated elasticities in Section 3 and the parameters of a demand system simultaneously. Specifically, we first introduce a demand model called QUAIDS; we then construct the price indicators of product groups for households to estimate the QUAIDS; finally, we use the estimated parameters from QUAIDS combined with the estimated elasticities in Section 3 to compute the welfare change of each household.

4.1. Consumption effect based on QUAIDS

4.1.1. QUAIDS

The AIDS was first proposed by Deaton and Muellbauer (1980), after which Banks et al. (1997) further developed it by introducing the quadratic term of total expenditure into the demand model (noted as QUAIDS); as a result, the observed consumer behaviors are more consistent with consumer theory. From the setting of the QUAIDS, the equation system for standard expenditure share is as follows:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(p_j) + \beta_i \ln\frac{m}{a(p)} + \frac{\lambda_i}{b(p)}\left(\ln\frac{m}{a(p)}\right)^2, \tag{3}$$

where w_i is the expenditure of product group i of the total expenditure of a household, and p_j is the price of product group j[9]. A series of parameters, γ_{ij}, capture the own-price effect (i.e., $i = j$) and the substitution effect between product groups (i.e., $i \neq j$). Moreover, m is the total expenditure of a household. Both $a(p)$ and $b(p)$ are aggregators of prices. Thus, $m/a(p)$ can be regarded as the real expenditure. The parameters β_i and λ_i capture the good-specific income effect, since they can be used to calculate the elasticity of the expenditure share to the total expenditure for a specific product group[10]. Therefore, the framework of the QUAIDS satisfies the two premises mentioned in Section 1 (i.e., substitution effect and good-specific income effect).

The parameters $a(p)$ and $b(p)$ in Eq. (3) are defined as follows:

$$\ln a(p) = \alpha_0 + \sum_k \alpha_k \ln(p_k) + \frac{1}{2}\sum_k \sum_j \gamma_{kj} \ln(p_k)\ln(p_j), \tag{4}$$

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i}. \tag{5}$$

By taking the partial derivative of Eq. (3) with respect to the income and price, the income and price elasticities can be respectively obtained as follows:

[9] i and $j \in$ (food, clothing, household equipment, health, transport and communication, education, and housing service).

[10] The detailed description of Eq. (3) is shown in Section 3 of the Appendix.

$$\mu_i = \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(p)} \ln\left(\frac{m}{a(p)}\right), \tag{6}$$

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i(\alpha_j + \sum\nolimits_k \gamma_{jk} \ln p_k) - \frac{\lambda_i \beta_j}{b(p)} \ln\left(\frac{m}{a(p)}\right)^2. \tag{7}$$

4.1.2. The prices of product groups for households

To estimate Eq. (3), the household-level expenditure and price data must be used. The expenditures for households are obtained from the UHS (n.d.), whereas the prices of product groups for households are not available directly. Households with different consumption patterns face different prices of product groups. Thus, both the detailed expenditure information of households reported by the UHS (n.d.) and the price information of products collected by the C is used to construct the prices of product groups for households. The weighted average price of a product group for a household is calculated as follows:

$$p_{i(h)} = \sum\nolimits_{r \in i} \omega_{hr} p_r, \tag{8}$$

where p_r is the price of product r within product group i in a year, and ω_{hr} is the weight, which is measured by the expenditure share of product r within product group i for household h. To be specific, ω_{hr} is constructed via the following approach. First, all households are classified into 12 groups according to their income (four quantiles) and the education of household head (primary and middle school or below, high school, and college or above). The expenditure shares of each product within the product group and household group are then computed using the data from 2002. As mentioned in Section 2.3, the estimation period is from 2003 to 2008, and thus this weight is pre-determined and time-invariant; this helps eliminate the impacts of consumer behavior on the weighted prices of the product groups.

4.1.3. Estimation results

In this subsection, the QUAIDS is estimated by using the household-level data from UHS (n.d.) and estimated parameters of Eq. (3) are reported in Table A5 in the Appendix. Because the estimated coefficients in the demand system (Eq. (3)) are difficult to interpret, the implied income and price elasticities are discussed, as reported in Table 3. All the elasticities are found to be at the mean values of the data sample based on Eq. (6) and (7), respectively. The estimated income elasticities are presented in the first column of Table 3; they are all positive, indicating that the demand for all product groups is normal. Moreover, food, housing service, transport and communication, and clothing are necessities with small income elasticities, whereas education, health services, and household equipment are luxuries with large income elasticities. For the estimated price elasticities, only the compensated and uncompensated own-price elasticities are provided in the last two columns of Table 3[11]. As expected, the own-price elasticities are all negative and significant. The relative magnitudes of these elasticities are also intuitive; food and clothing appear to be the least elastic with respect to price, while education and household equipment have the highest elasticities.

[11] The full set of own-price and cross-price elasticities is exhibited in Table A6 in the Appendix.

Table 3. Estimated elasticities

	Income elasticities	Own-price elasticities (compensated)	Own-price elasticities (uncompensated)
	(1)	(2)	(3)
Food	0.6959*** (0.0137)	–0.4442*** (0.0264)	–0.7510*** (0.0293)
Clothing	1.1135*** (0.0185)	–0.7001 *** (0.0208)	–0.8469*** (0.0204)
Household equipment	1.9108** (0.0545)	–1.2396 *** (0.1019)	–1.3352*** (0.1018)
Health	1.7047*** (0.0541)	–0.9959*** (0.0510)	–1.0585*** (0.0510)
Transport and communication	0.9595 *** (0.0105)	–0.9197 *** (0.0216)	–1.0311*** (0.0218)
Education	1.7982 *** (0.0385)	–1.0893*** (0.0633)	–1.2270*** (0.0630)
Housing service	0.9409 *** (0.0207)	–0.8457*** (0.0236)	–0.9849*** (0.0237)

Notes: Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.1.4. Welfare assessment

To get a more precise idea of how the well-being of Chinese households on the consumption side is impacted by trade liberalization, the welfare effect of trade is assessed in this subsection. One measure of the welfare effect is the compensating variation (CV), which is defined as the additional expenditure that consumers need to achieve the same utility levels before the price change or without a policy shock. Therefore, we calculate the CV for each household by taking the following approach.

As shown in Banks et al. (1997), QUAIDS can be derived from an indirect utility function of the following form:

$$\ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1}, \tag{9}$$

where $\lambda(p) = \sum_i \lambda_i \ln p_i$. Thus, for each household in 2008, the observed actual cost or total expenditure (m_{2008}) and counterfactual cost (m^*_{2008}) without trade liberalization effect would satisfy the following Equation:

$$\left\{ \left[\frac{\ln m_{2008} - \ln a(p_{2008})}{b(p_{2008})} \right]^{-1} + \lambda(p_{2008}) \right\}^{-1} = \left\{ \left[\frac{\ln m^*_{2008} - \ln a(p^*_{2008})}{b(p^*_{2008})} \right]^{-1} + \lambda(p^*_{2008}) \right\}^{-1}, \tag{10}$$

where $\ln a(p_{2008})$, $b(p_{2008})$, and $\lambda(p_{2008})$ can be directly calculated based on the observed prices $p_{i,2008}$ and the estimated demand parameters in Eq. (3). Moreover, $a(p^*_{2008})$, $b(p^*_{2008})$, and $\lambda(p^*_{2008})$ should be constructed based on the counterfactual prices $p^*_{i,2008}$ and the demand parameters. The counterfactual prices are obtained as follows. For any product group *i*,

$$p^{*}_{i,2008} = p_{i,2008} - \Delta p_i^{tariff}, \tag{11}$$

where Δp_i^{tariff} is the price change of product group i due to the tariff change from 2001 to 2008. To be specific, for tradable product group T,

$$\Delta p_T^{tariff} = pass\_through_T \times \Delta tariff_{T,2001-2008}, \tag{12}$$

where $pass\_through_T$ is obtained from Table 1, and $\Delta tariff_{T,2001-2008}$ is the tariff change of product group T between 2001 and 2008. For non-tradable goods G,

$$\Delta p_G^{tariff} = \sum\nolimits_T \beta_T \Delta p_T^{tariff}, \tag{13}$$

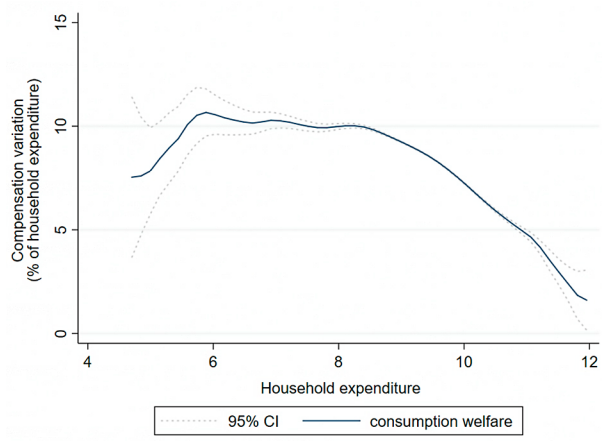
where β_T is obtained from Table 2. In summary, $p^{*}_{i,2008}$ is the price of product group i in 2008 without the effect of trade liberalization.

Via Eq. (10), m^{*}_{2008} can be solved, and the welfare change (compensating variation) for each household over 2001–2008 can be obtained as follows:

$$Consumption\ welfare_{2001-2008} = \frac{\left(m^{*}_{2008} - m_{2008}\right)}{m_{2008}}. \tag{14}$$

The Figure A2 in the Appendix illustrates the welfare changes based on Eq. (14). We find that all the CV values are found to be positive with a normal distribution, and the mean value is 8.57% of the total expenditure, suggesting that all Chinese households benefit from the process of trade liberalization and a large number of households benefit quite a lot.

The distributional impacts of trade liberalization on the consumption side is further discussed. To show the relationship between per capita expenditure of household and the corresponding CV of household, the nonparametric local linear regression is used. The Figure 1 illustrates the results. As shown in the Figure 1, on average, the CV decreases as the household expenditure increases, and the negative relationship is especially prominent in the



Notes: The result of the nonparametric local liner regression and its 95 percent confidence interval is presented for consumption effect. The *household expenditure* is denoted as the logarithm of per capita expenditure of the household.

Figure 1. Consumption effect of trade liberalization

high expenditure spectrum. The result suggests that the poorer households gain more from trade liberalization than the richer households do. Therefore, the distributional effect of trade liberalization on the consumption side is pro-poor. One possible reason for such a strong pro-poor bias of trade is the substantial differences between the consumption patterns of the poor and the rich. To be specific, poorer households spend relatively more on tradable sectors, which experience a significant decrease in price with import tariff cuts, resulting in largely reduced living costs and substantial welfare gains. In contrast, richer households spend relatively more on non-tradable sectors, such as education and health, which have less response to trade liberalization[12].

4.2. Consumption effect based on first-order approximation

As shown in Eq. (3), the QUAIDS is able to capture the substitute effect. However, most previous studies did not consider the substitution effect, and used first-order approximation to estimate the welfare gain from trade on the consumption side (e.g., Porto, 2006; Nicita, 2009; Han et al., 2016). Particularly, Porto (2006) and Gaarder (2018) noted that if the substitution effect is ignored, the absolute welfare effect would be mismeasured. In this subsection, the CV is re-calculated based on the first-order approximation following the method used by Porto (2006) for comparison with the CV determined based on the QUAIDS.

The specification of first-order approximation is as follows:

$$Consumption\ welfare\ {}^{FOA}_{2001-2008} = -\left(\sum\nolimits_{T} s_{T,2008} \times \Delta p_T{}^{tariff} + \sum\nolimits_{G} s_{G,2008} \times \Delta p_G{}^{tariff}\right), \quad (15)$$

where $s_{T,2008}$ and $s_{G,2008}$ respectively denote the expenditure shares of tradable product group T and non-tradable product group G.

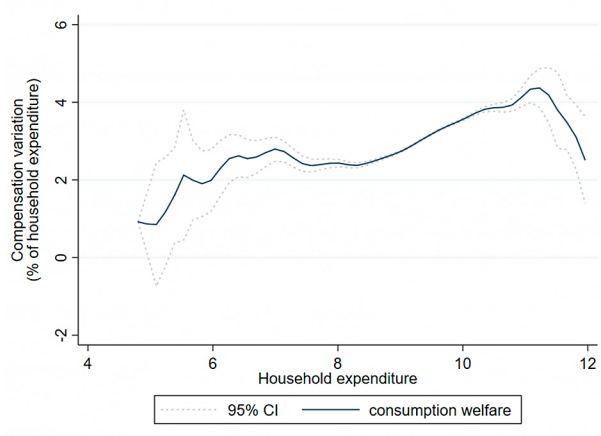
The Figure A4 in the Appendix demonstrates the welfare changes estimated by Eq. (15). We find that although all the households still have positive CVs, the mean is only 3.05% of the total expenditure, which is much less than that in Figure A2 (8.57%). This result suggests that the absolute welfare effect of trade is underestimated using the first-order approximation compared with that from the QUAIDS, consistent with the finding of Gaarder (2018).

The distributional effects of trade liberalization estimated using the first-order approximation is further discussed. The Figure 2 illustrates the relationship between per capita expenditure of household and the corresponding CV of household based on the result of nonparametric local linear estimation. The figure reveals a general pro-rich bias of trade. These findings are consistent with those of Porto (2006) and Nicita (2009), but opposite to those in the Figure 1[13].

To sum up, the results in this subsection imply that ignoring the substitution effect when we measure CVs on the consumption side not only underestimates the absolute value of welfare changes but also distorts the distribution of welfare changes.

[12] The corresponding robustness check is in the Figure A3 in the Appendix.

[13] The corresponding robustness check is in the Figure A5 in the Appendix.



Notes: The result of nonparametric local liner regression and its 95 percent confidence interval is presented for consumption effect. The *household expenditure* is denoted as the logarithm of per capita expenditure of the household.

Figure 2. Consumption effect of trade liberalization estimated by the first-order approximation

5. Income effect of trade liberalization

As the import tariff changes pass through to the domestic consumer price, the labor market also fall out of equilibrium, resulting in changes in the labor price. Therefore, in this Section, we further explore the welfare change in the earning side due the liberalization-induced consumer price change (i.e., income effect). For a household, because individuals within the household have different characteristics, such as different educational backgrounds, their incomes may face different shocks arising from trade liberalization. Thus, the income effect for the household as a whole is unobvious. To study the income effect for the household, we first examine how the change of consumer price induced by trade liberalization leads to the change of individual wage. And, we do so based on the estimated tariff-pass through elasticities in Section 3.1. Then, we determine the sign and magnitude of the income effect for each household and further discuss what kinds of households benefit more from trade.

5.1. The effect of consumer price on individual wage

In this subsection, we first estimate the income-tariff elasticities and then use it and the estimated tariff-pass through elasticities (price-tariff elasticities) to calculate the income-price elasticities.

5.1.1. Income-tariff elasticity

To estimate the income-tariff elasticity, we need to match the individual income data with the import tariff data. Thus, we calculate the import tariff for the city in which workers locate. The city-level import tariff is constructed as follows:

$$tariff_{ct} = \sum\nolimits_{i \in \Omega_c} \frac{employment_{ic,2002}}{employment_{c,2002}} \times tariff_{it}\,, \tag{16}$$

where $employment_{ic,2002}$ is the employment of industry i in city c in year 2002[14]. $employment_{c,2002}$ is the total employment of city c in the base year. $tariff_{it}$ is the import tariff of industry i that is calculated as the simple average of import tariffs of products covered by a given industry.

The effect of import tariff on individual wage is estimated as follows:

$$\ln wage_{ijct} = \beta_1 \ln(tariff_{ct}) + Controls_{ijct/jct}\gamma + \varphi_c + \varphi_t + \varepsilon_{ijct}, \quad (17)$$

where $\ln wage_{ijct}$ is the wage of individual i in household j in city c in year t. We also control for the characteristics of individuals and households, which are all included in $Controls_{ijct/jct}$. Moreover, φ_c and φ_t denote the city and year fixed effects, respectively. β_1 is our interest which captures the income-tariff elasticity.

To estimate Eq. (17), we use the individual data of the UHS during 2003–2008. Because the educational attainment of a worker largely determines his/her skill and different-skilled workers may have different response to trade liberalization (Dix-Carneiro & Traiberman, 2023; Yang, 2024), we attempt to use the educational attainment as a proxy for the worker's skill to explore the heterogeneous income-tariff elasticities. Specifically, education is divided into three levels, that is, primary and middle school or below, high school, and college or above. We estimate the income-tariff elasticities for each educational attainment group based on Eq. (17).

The estimation results are reported in Table 4. The results show that the import tariff has no significant effect on the wage of workers with primary and middle school or below education, while it has a significantly negative impact on the wage of workers with the high school or above education. These results indicate that the highly skilled workers benefit from the reduction of import tariffs and that the wage inequality between low-skilled and high-skilled workers will increase as the import tariff decreases. Our finding is consistent with the result of previous studies that trade liberalizations contribute to the inequality by raising the returns to education (Han et al., 2012; Lee, 2020).

Table 4. The effect of import tariff on individual wage

Dep. variable	Ln(wage)		
	Primary and middle school or below	High school	College or above
	(1)	(2)	(3)
Ln(tariff)	–0.111	–0.213**	–0.167**
	(0.115)	(0.108)	(0.0702)
Controls	Yes	Yes	Yes
City FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Observations	133,087	115,945	109,220
R-squared	0.658	0.167	0.137

Notes: The wage is discounted to 1997 by using the CPI. *Controls* includes the characteristics of individuals and households. The robust standard errors are clustered at the city level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[14] The industry classification is based on the China Industrial Classification (CIC), and the employment data is from the Annual Survey of Industrial Firms (ASIF) database (Shandong University of Finance and Economic Library, 2023).

5.1.2. Income-price elasticity

Since we have estimated the income-tariff elasticities and tariff-pass through elasticities (price-tariff elasticities), we calculate the income-price elasticities as follows:

$$\frac{d\ln wage^E}{d\ln price_T} = \frac{d\ln wage^E}{d\ln tariff} \div \frac{d\ln price_T}{d\ln tariff}, \tag{18}$$

where $E \in$ (primary and middle school or below, high school, college or above), $T \in$ (food, clothing, household equipment), $\frac{d\ln wage^E}{d\ln tariff}$ denotes a group of the income-tariff elasticities estimated in Table 4, and $\frac{d\ln price_T}{d\ln tariff}$ denotes a group of price-tariff elasticities estimated in Table 1. Thus, $\frac{d\ln wage^E}{d\ln price_T}$ is a group of income-price elasticities that capture the changes in individual wage as a result of changes in consumer price induced by trade liberalization. The calculated income-price elasticities based on Eq. (18) are listed in Table 5.

Table 5. Income-price elasticities

	Primary and middle school or below	High school	College or above
Food	–1.968	–3.777	–2.961
Clothing	–0.126	–0.241	–0.189
Household equipment	–0.440	–0.845	–0.668

Notes: The table reports the income-price elasticities calculated based on Eq. (18).

5.2. Welfare measurement

In this subsection, the elasticities reported in Table 5 along with the information on consumer price changes are used to estimate the income effect of trade liberalization through the price channel. We obtain the income change of each individual as follows[15]:

$$\Delta wage_i = wage_i \times \sum\nolimits_T \gamma_T^E \left(\frac{\Delta p_T{}^{tariff}}{p_T} \right), \tag{19}$$

where $E \in$ (primary and middle school or below, high school, college or above), $T \in$ (food, clothing, household equipment), $wage_i$ is the wage of individual i in 2008, and $\Delta p_T{}^{tariff}$ is the liberalization-induced price change of tradable product group T during 2001–2008 (see Section 4). γ_T^E includes a group of the income-price elasticities listed in Table 5.

Because the contribution of each individual within the household can be observed, the aggregate change of income for each household is computed as follows:

$$\Delta household\ income = \sum\nolimits_{i=1}^{S} s_{i,2008} \times \Delta wage_i, \tag{20}$$

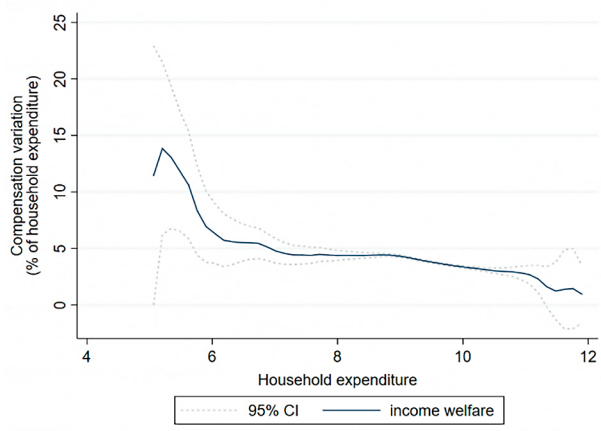
where $s_{i,2008}$ is the wage share of individual i in the household, and S is the household size. Therefore, the income effect of trade measured by the CV is as follows:

$$Income\ welfare_{2001-2008} = \frac{\Delta household\ income}{total\ expenditure}, \tag{21}$$

[15] The detailed approach for deriving Eq. (19) is listed in Section 6 of the Appendix.

The Figure A6 in the Appendix illustrates the welfare changes based on Eq. (21). As the Figure A6 shows, all households are found to be better off after China's WTO accession and the mean CV is 3.88% of the household expenditure, but only about 30% of households achieves that value or higher.

The distributional effect of trade liberalization in the earning side is further discussed. The relationship between per capita expenditure of household and the corresponding CV of household based on the result of nonparametric local linear estimation is illustrated in the Figure 3. The Figure 3 shows that the poorer households experience a slightly higher gain from trade than richer households do[16].



Notes: The result of nonparametric local liner regression and its 95 percent confidence interval are presented for the income effect. The *household expenditure* is denoted as the logarithm of per capita expenditure of the household.

Figure 3. Income effect of trade liberalization

6. Aggregate price effect of trade liberalization

In this Section, we calculate the aggregate price effect based on the results of Section 4 and 5. The aggregate price effect is measured as the sum of the consumption and income effects, as follows:

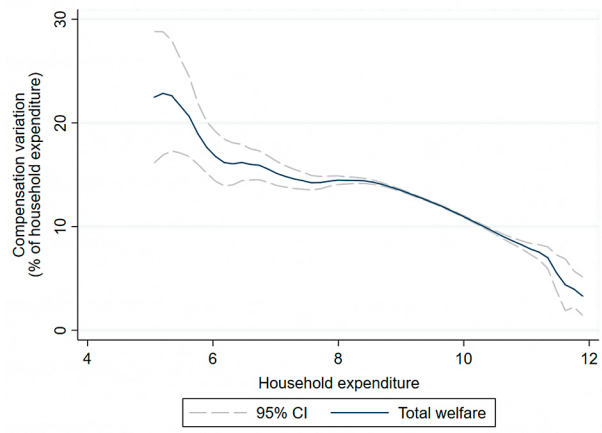
$$Total\,welfare_{2001-2008} = Consumption\ welfare_{2001-2008} + Income\ welfare_{2001-2008}. \quad (22)$$

The Figure A8 in the Appendix illustrates the welfare changes based on Eq. (22). We find that the mean of the CV is 12.42% of the household expenditure. More importantly, for about 86% of households, the consumption effect is larger than the income effect, and the average gap is 4.66% of the household expenditure; this suggests that the consumption effect has dominated the income effect in most Chinese households.

The distributional impact of aggregate welfare changes is shown in the Figure 4, which shows a significant pro-poor bias of trade[17]. In addition, the distributional impact of the ag-

[16] The corresponding robustness check is in the Figure A7 in the Appendix.

[17] The corresponding robustness check is in the Figure A9 in the Appendix.



Notes: The result of nonparametric local liner regression and its 95 percent confidence interval are presented for the aggregate price effect. The *household expenditure* is denoted as the logarithm of per capita expenditure of the household.

Figure 4. Aggregate price effect of trade liberalization

gregate price effect is similar to that of the consumption effect, suggesting the importance of the consumption effect in estimating the welfare gains of heterogeneous consumers due to trade liberalization. In practice, the recent substantial increase in the living quality and the large decrease in absolute poverty in China are mainly attributed to the consumption effect of trade.

7. Conclusions

Some individuals and groups have recently preached against globalization, as they believe that globalization or opening policies damage their interests and make them worse off. To shed light on the real welfare effect of globalization, in this paper we provide a feasible empirical framework to measure the aggregate price effect of trade liberalization, which attracts limited attention in the existing literature.

The discussion begins with the price transmission mechanism. It is found that there is a significant positive tariff pass-through effect for tradable goods. The price transmission from tradable goods to non-tradable goods is also analyzed. Then, price changes are linked with household consumption and income to assess the welfare effect of trade liberalization. We find that all households experience a welfare gain, via both the expenditure and earning channels, after China's WTO accession, and identify a highly pro-poor distribution of the aggregate price effect. In addition, the consumption effect is found to play a dominant role in the aggregate welfare change of most households, implying that the consumption effect is essential in discussing the welfare gain of trade liberalization in China.

In the past two decades, the world, especially China, has witnessed a trend of decreasing poverty and increasing living quality. This study provides a possible explanation for the achievement from the perspective of commodity trade and price transmission. The empirical framework developed in this study could be easily applied to discuss the welfare effect of trade in other countries or other liberalization episodes.

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Author contributions

Teng Zhang was responsible for the investigation, methodology and writing-original draft. Dai Zhou was responsible for the data curation and software. Shu Xu was responsible for the formal analysis and validation. Zhiwei Xu was responsible for the conceptualization, writing-review and editing.

Disclosure statement

There's no financial or personal interest or belief that could affect our objectivity.

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APPENDIX

1. Data description

1.1. Price data

Table A1 reports the summary statistics of the price for each category.

Table A1. The summary statistics of sale price

Product group	Obs.	Mean	Sd. dev	Min	Max
Food	45,840	1.29	1.35	–1.52	8.78
Clothing	4,155	3.92	0.83	1.97	6.37
Household equipment	9,143	7.24	0.69	4.84	9.05
Health	1,038	2.15	2.28	–1.61	7.60
Transport and communication	1,206	0.38	2.19	–3.22	8.29
Education	1,213	6.14	1.44	2.71	9.16
Housing service	1,206	0.66	1.47	-2.30	5.87

Notes: The price is discounted to 1997 by using CPI. Logarithm of price is reported in the table.

1.2. The matching of price data with the tariff data

To explore the tariff pass-through to the domestic consumer prices, the tariff data needs to be matched with the price data. The following approach is taken to match these datasets. First, for each good in the CPIC database, its corresponding HS 4-digit code is found by using the HS 4-digit classification (2002 version). Table A2 in the Appendix provides an example of the correspondence between CPIC goods and 4-digit HS codes. The simple average of the prices of products in that HS 4-digit group is then calculated. Finally, the two databases are matched based on the HS 4-digit code and year. There are 64 HS 4-digit goods in the matched sample.

Table A2. Corresponds between CPIC good categories and 4-digit HS goods (an example)

Goods in CPIC	HS (2002 version)	Product group
Cabbage	0704	Food
Fresh beef	0201	Food
Wheat flour	1101	Food
Men's Shirt	6105	Clothing
Men's underpants	6107	Clothing
Men's T-shirt	6109	Clothing
Refrigerator	8418	Household equipment
Air conditioner	8415	Household equipment
Washing machine	8450	Household equipment

1.3. The matching of household survey data with the price data

To estimate the consumption and income effects, the expenditure and income data from the UHS needs to be matched with the price data from the CPIC.

The expenditure data of UHS reports the expenditures of each household on commodities and services; to be specific, commodities mainly include food, clothing, and household equipment, and services mainly include health services, transport and communication, education and amusement, housing service, and housing rent. The expenditure data is at the "city-household-product" level while the price data is at the "city-product" level. These two databases are thus matched as follows. For each HS 4-digit product in the CPIC, its corresponding product name in the UHS is first identified. The two databases are then matched by using the city code and product name. Table A3 in the Appendix provides the matched sample. It should be noted that, before 2003, there are only 19 large cities in the matched sample, and, after that, there are about 70 matched cities. To make the households in the sample more representative, 2002 is considered as the base year and the period ranging from 2003 to 2008 as the estimated period.

Because the income data used in this paper is at the "city-household-individual" level, we simply merge the income data and price data using the city code.

Table A3. Matched data

Year	Observation (city-household-product level)	Number of cities	Number of products (goods)	In which: tradable goods / non-tradable goods
2002	419,345	19	55	38/17
2003	696,806	72	56	37/19
2004	627,757	68	40	28/12
2005	661,065	68	41	28/13
2006	918,213	71	51	34/17
2007	865,664	69	45	28/17
2008	973,687	72	45	28/17

2. Robustness checks of tariff pass-through effect

To test the robustness of our main finding and the validity of our empirical specification, additional estimations are reported in Table A4. As reported in Column (1), a weighted regression, rather than the simple ordinary least squares (OLS) regression, is used to re-estimate Eq. (1) in the manuscript. If the goods are the main imports in China, the change of their tariffs may exert much stronger impact on consumer prices. Therefore, the import value of each product in 1997 is used as the weight of tariffs for that product to conduct the weighted regression. Column (1) reports a similar result as that reported in Column (1) of Table 1 in the manuscript, suggesting the robustness of our main result.

As presented in Column (2) of Table A4, the robust standard errors are clustered at the HS 4-digit product-by-year level, rather than the city level, to check whether the main result is dependent on the specification of robust standard errors. The result in Column (2) still shows a significant tariff pass-through elasticity.

Table A4. Robustness checks

Dep. variable	Ln(price)			
	Weighted regression	Alternative standard errors	Sample before 2008	DID estimation
	(1)	(2)	(3)	(4)
Ln (tariff+1)	0.0777***	0.0779**	0.0501***	
	(0.00894)	(0.0364)	(0.00815)	
Ln (tariff2001+1) × post2001				–0.196***
				(0.0204)
Controls	Yes	Yes	Yes	Yes
City-product FEs	Yes	Yes	Yes	Yes
City-year FEs	Yes	Yes	Yes	Yes
Constant	2.137***	2.002***	2.348***	2.760***
	(0.0332)	(0.193)	(0.0286)	(0.0512)
Observations	58,275	58,275	43,489	57,172
R-squared	0.977	0.976	0.976	0.976

Notes: World price and imports to GDP are controlled in all columns. Robust standard errors are clustered at the city level in Columns (1), (3) and (4) and at the HS 4-digit product by year level in Column (2) in parentheses. *** p < 0.01, ** p < 0.05, * p<0.1.

As exhibited in Column (3) of Table A4, the sample is limited in the period of 1997–2008 to eliminate the impact of the global economic crisis that spread to China in later 2008. The result reported in the column is consistent with that reported in Column (1) of Table 1 in the manuscript, suggesting that our main result is not driven by the sample choice.

Thus far, the endogenous problem is not considered in estimations. One possible source of endogeneity is that the omitted variables may affect both trade policies and consumer prices. The identification problem is tackled by exploiting the presence of large variations in tariff reductions across products due to China's WTO accession in the end of 2001, which has been treated as an exogenous shock in previous studies (Fan et al., 2015; Bloom et al., 2016; Liu & Qiu, 2016). As utilized in the existing literature, a difference-in-difference (DID) estimation strategy is adopted. Specifically, the treatment group is defined as products subjected to large tariff cuts due to China's WTO accession, and the control group is defined as goods subjected to smaller tariff cuts. Because the goods facing high tariffs before China's WTO accession experienced large tariff reductions thereafter (see Figure A1), the tariffs in 2001, i.e., the pre-determined tariffs, are used to denote the tariff reduction due to China's WTO accession.

Thus, our DID specification is as follows:

$$\ln(price_{pct}) = \beta_1 \ln(tariff2001_p + 1) \times post2001_t + controls_{pt}\gamma + \varphi_{pc} + \varphi_{ct} + \varepsilon_{pct}, \quad (A1)$$

where $tariff2001_p$ is the import tariff on product p in 2001. Moreover, $post2001_t$ denotes the period of post-WTO accession, and is equal to one if t > 2001; otherwise, it is equal to zero. If there is a positive tariff pass-through elasticity for consumer prices, it is expected that the prices will have significantly decreased after Chain's WTO accession due to the dramatic decrease of import tariffs.

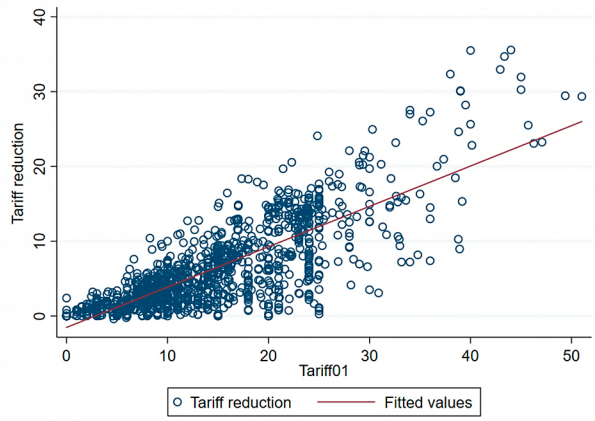


Figure A1. The relationship between tariff in 2001 and tariff reduction due to China's WTO accession

The result reported in the last column of Table A4 reveals a significant and negative coefficient of the interaction term of Eq. (A1), suggesting that tariff reductions lead to a decline in consumer prices[18]. The result is consistent with our expectation. Overall, the main result is robust, and the empirical specification is valid.

3. The description of Eq. (3) in the manuscript

$a(p)$ can be regarded as the cost of a subsistence basket of goods, and $b(p)$ captures the relative price of high-income elastic goods. Moreover, there are three sets of restrictions implied by the theory of utility maximization, which are defined as follows.

$$\begin{aligned}
&\textit{Adding-up}: \sum\nolimits_{i=1}\alpha_i = 1;\ \sum\nolimits_{i=1}\gamma_{ij} = 0 \ \text{ for } \forall j;\ \sum\nolimits_{i=1}\beta_i = 0;\ \sum\nolimits_{i=1}\lambda_i = 0;\\
&\textit{Homogenous}: \sum\nolimits_{j=1}\gamma_{ij} = 0 \ \text{ for } \forall i;\\
&\textit{Symmetry}: \ \gamma_{ij} = \gamma_{ji}.
\end{aligned} \tag{A2}$$

Following Attanasio et al. (2013), we also assume that for product group i, the intercept α_i in Eq. (3) in the manuscript meets the following Equation:

$$\alpha_i = \alpha_{0i} + \sum\nolimits_{n=1}^{N}\alpha_{ni} z_n, \tag{A3}$$

where z_n represents the n-th demographic characteristic, such as household size, the number of children and the number of the aged in the household. Attanasio et al. (2013) further noted that the homogeneity implies the additional restrictions, $\sum\nolimits_{i=1}\alpha_{0i} = 1$ and $\sum\nolimits_{i=1}\alpha_{ni} = 0$.

[18] The tariff pass-through rate reported in Column (4) of Table A4 is larger than that in Column (1) of Table 1 in the manuscript. Because there is a large drop in tariffs in the post-WTO accession period, the average treatment effect of this policy shock is inevitably higher than the year-by-year effect.

4. Estimating results of demand model

The QUAIDS is estimated by using the household-level data from UHS and estimated parameters of Eq. (3) in the manuscript are reported in Table A5.

Table A5. Demand system parameter estimations

Product group	Food	Clothing	Household equipment	Health	Transport and communication	Education	Housing service
Food	0.0212* (0.0109)	–0.0206*** (0.0040)	–0.0040 (0.00581)	0.0214*** (0.0048)	–0.0081* (0.0047)	0.0244*** (0.0080)	–0.0343*** (0.0050)
Clothing	–0.0206*** (0.0040)	0.0217*** (0.0027)	0.0214*** (0.00257)	–0.0008 (0.00230)	0.0029 (0.00231)	–0.00930*** (0.0031)	–0.0153*** (0.0033)
Household equipment	–0.0040 (0.0058)	0.0214*** (0.0026)	–0.0178*** (0.00510)	–0.0189*** (0.00425)	–0.0057 (0.00383)	–0.00207 (0.0033)	0.0272*** (0.00459)
Health	0.0214*** (0.0048)	–0.0008 (0.0023)	–0.0189*** (0.00425)	–0.0023 (0.0024)	0.00254 (0.0024)	–0.00914*** (0.0028)	0.0072*** (0.0025)
Transport and communication	–0.0081* (0.0047)	0.0029 (0.0023)	–0.0057 (0.00383)	0.00254 (0.0024)	–0.0056** (0.0024)	0.00742** (0.0031)	0.0065** (0.0026)
Education	0.0244*** (0.0078)	–0.0093*** (0.0031)	–0.0021 (0.00326)	–0.0091*** (0.0028)	0.0074** (0.0031)	–0.0195*** (0.0050)	0.0082*** (0.0029)
Housing service	–0.0343*** (0.0046)	–0.0153*** (0.0033)	0.0272*** (0.00459)	0.0072*** (0.0025)	0.0065** (0.0026)	0.00823*** (0.0029)	0.0006 (0.0035)
Ln(expenditure)	–0.0066 (0.0104)	0.0225*** (0.0047)	–0.0023 (0.00438)	–0.0034 (0.0036)	0.0371*** (0.0082)	–0.0391*** (0.0092)	–0.0082 (0.0075)
Ln(expenditure) square	–0.0186*** (0.0014)	0.0013** (0.0007)	0.0066*** (0.000603)	0.0036*** (0.0006)	–0.0049*** (0.0013)	0.0118*** (0.0012)	0.0003 (0.0013)

Notes: The expenditure elasticities with respect to prices of product groups are reported. The weighted-average price of product group for each household is used, and the weight is defined as the expenditure share of goods within the product group and household group. Demographic variables, including household size, the number of children below 12-years old, the number of elderly above 75-years old, household headed by male (dummy), and household head with age above 45-years (dummy), are also included in the estimation. There are 102,640 observations over six waves of household surveys in the estimations. The robust standard errors are clustered at the city level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The full set of own-price and cross-price elasticities is exhibited in Table A6.

Table A6. Estimated price elasticities

Product group	Food	Clothing	Household equipment	Health	Transport and communication	Education	Housing service
Compensated							
Food	–0.4442*** (0.0264)	0.0772*** (0.0090)	0.0184 (0.0137)	0.0727*** (0.0107)	0.1000*** (0.0102)	0.1015*** (0.0178)	0.0745*** (0.0099)
Clothing	0.2594*** (0.0302)	–0.7001*** (0.0208)	0.2206*** (0.0192)	0.0356** (0.0173)	0.1392*** (0.0170)	0.0160 (0.0228)	0.0294 (0.0243)
Household equipment	0.1606 (0.1210)	0.5832*** (0.0502)	–1.2396 *** (0.1019)	–0.3045*** (0.0840)	–0.0055 (0.0801)	0.1271* (0.0677)	0.6787*** (0.0971)
Health	0.8694*** (0.1294)	0.1291** (0.0620)	–0.4138*** (0.1139)	–0.9959*** (0.0510)	0.1796*** (0.0634)	–0.1015 (0.0761)	0.3331*** (0.0655)
Transport and communication	0.3780*** (0.0399)	0.1582*** (0.0195)	–0.0018 (0.0338)	0.0571*** (0.0202)	–0.9197 *** (0.0216)	0.1283*** (0.0266)	0.1999*** (0.0212)
Education	0.5863*** (0.1035)	0.0284 (0.0398)	0.0820* (0.0446)	–0.0498 (0.0356)	0.1936*** (0.0390)	–1.0893*** (0.0633)	0.2489*** (0.0339)
Housing service	0.2223*** (0.0300)	0.0260 (0.0219)	0.2292*** (0.0319)	0.0826*** (0.0165)	0.1570*** (0.0166)	0.1285*** (0.0179)	–0.8457*** (0.0236)
Uncompensated							
Food	–0.7510*** (0.0293)	–0.0146* (0.0087)	–0.0164 (0.0135)	0.0472*** (0.0106)	0.0192* (0.0098)	0.0482*** (0.0180)	–0.0285*** (0.0101)
Clothing	–0.2314*** (0.0316)	–0.8469*** (0.0204)	0.1649*** (0.0194)	–0.0053 (0.0174)	0.0099 (0.0173)	–0.0692*** (0.0230)	–0.1354*** (0.0236)
Household equipment	–0.6816*** (0.1286)	0.3312*** (0.0487)	–1.3352*** (0.1018)	–0.3746*** (0.0843)	–0.2274*** (0.0826)	–0.0191 (0.0682)	0.3960*** (0.0929)
Health	0.1180 (0.1292)	–0.0958 (0.0620)	–0.4990*** (0.1151)	–1.0585*** (0.0510)	–0.0183 (0.0631)	–0.2320*** (0.0752)	0.0808 (0.0660)
Transport and communication	–0.0450 (0.0405)	0.0316 (0.0198)	–0.0498 (0.0338)	0.0219 (0.0203)	–1.0311*** (0.0218)	0.0548** (0.0264)	0.0580*** (0.0209)
Education	–0.2063* (0.1077)	–0.2087*** (0.0414)	–0.0080 (0.0439)	–0.1158*** (0.0361)	–0.0152 (0.0371)	–1.2270*** (0.0630)	–0.0172 (0.0349)
Housing service	–0.1924*** (0.0296)	–0.0980*** (0.0235)	0.1822*** (0.0313)	0.0481*** (0.0167)	0.0478*** (0.0170)	0.0565*** (0.0185)	–0.9849*** (0.0237)

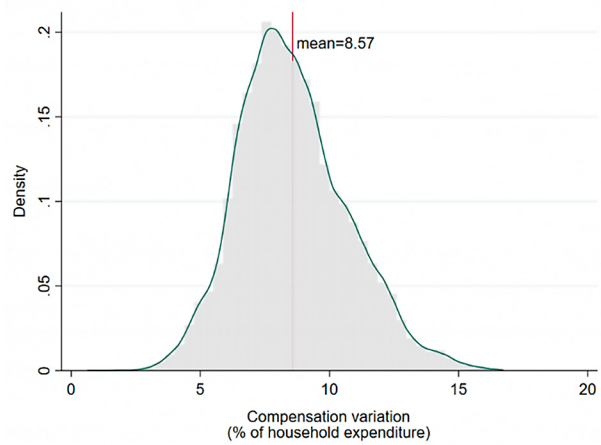
Notes: Standdrd errors are in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

5. Welfare changes on the consumption side

5.1. QUAIDS method

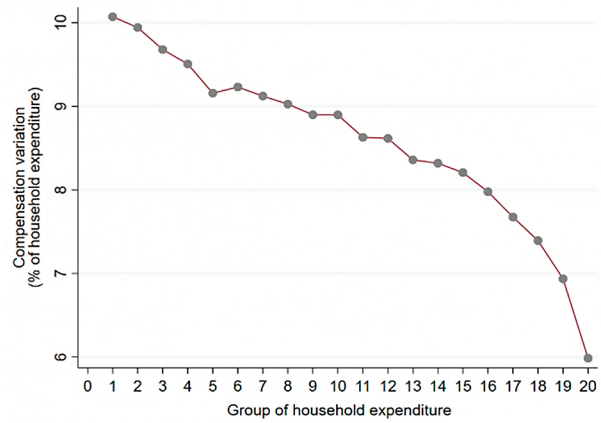
The Figure A2 illustrates the welfare changes based on Eq. (14) in the manuscript.

To mitigate the impact of extreme values of CVs and make our finding more intuitive, we also divide all households into 20 groups according to their per capita expenditure to show the distribution of consumption effect. The results illustrated in the Figure A3 are consistent with that in the Figure 1 in the manuscript.



Notes: The density of CVs are reported based on Eq. (14). There are 22,678 households in 2008.

Figure A2. Welfare change on the consumption side



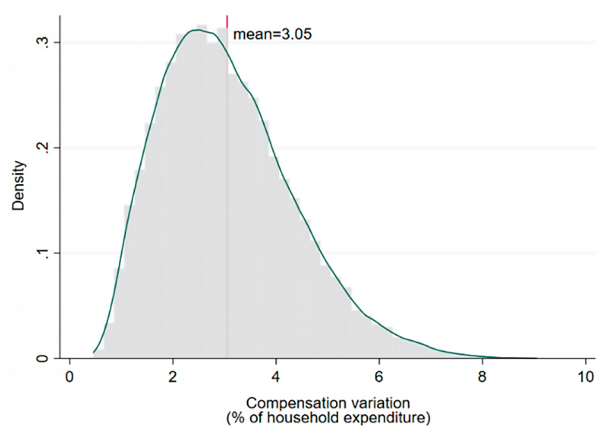
Notes: The figure displays the average CV of each group based on Eq. (14). There are 22,678 households in 2008, and all households are divided into 20 groups according to their per capita expenditure.

Figure A3. Consumption effect of trade liberalization (across 20 groups)

5.2. First-order approximation method

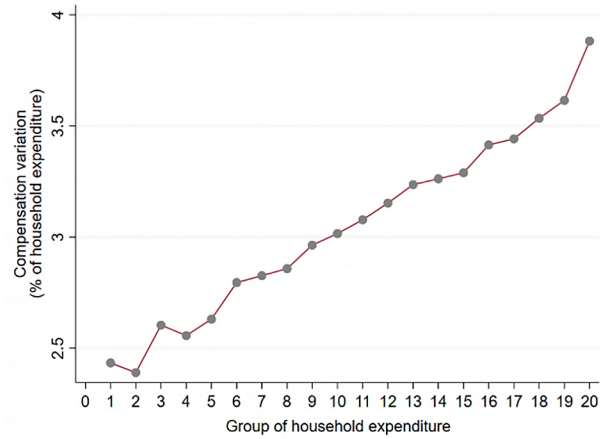
The Figure A4 demonstrates the welfare changes estimated by Eq. (15) in the manuscript.

In the Figure A5, we also divide all households into 20 groups according to their per capita expenditure and obtain the consistent result with that in the Figure 2 in the manuscript.



Notes: The density of CVs are reported based on Eq. (15). There are 22,678 households in 2008.

Figure A4. Welfare change estimated by the first-order approximation on the consumption side



Notes: The figure displays the average CV of each group based on Eq. (15). There are 22,678 households in 2008, and all households are divided into 20 groups according to their per capita expenditure.

Figure A5. Consumption effect of trade liberalization estimated by the first-order approximation (across 20 groups)

6. Welfare change on the earning side

The Eq. (19) in the manuscript is derived as follows.

$$d\ln wage_i = \sum\nolimits_T \gamma_T^E d\ln p_T, \tag{A4}$$

$$\Rightarrow dwage_i / wage_i = \sum\nolimits_T \gamma_T^E (dp_T / p_T).$$

Therefore, the income change due to the liberalization-induced consumer price change for an individual is as follows:

$$dwage_i / wage_i = \sum\nolimits_T \gamma_T^E (dp_T{}^{tariff} / p_T), \tag{A5}$$

$$\Rightarrow \Delta wage_i / wage_i = \sum\nolimits_T \gamma_T^E (\Delta p_T{}^{tariff} / p_T),$$

$$\Rightarrow \Delta wage_i = wage_i \times \sum\nolimits_T \gamma_T^E (\Delta p_T^{tariff} / p_T),$$

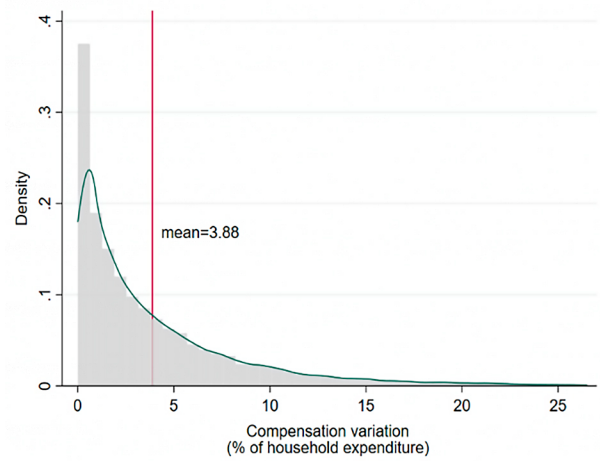
$E \in$ (primary and middle school or below, high school, and college or above),

$T \in$ (food, clothing, household equipment),

where $wage_i$ is the wage of individual i in 2008. Δp_T^{tariff} is the price change of tradable product group T induced by trade liberalization during 2001–2008, which is defined in Section 4 in the manuscript. γ_T^E includes a series of income-price elasticities listed in Table 5 in the manuscript.

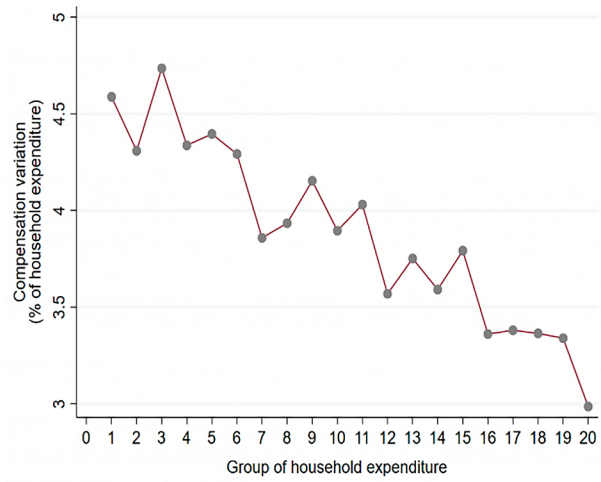
The Figure A6 illustrates the welfare changes based on Eq. (21) in the manuscript.

In the Figure A7, we also divide all households into 20 groups according to their per capita expenditure and obtain the consistent result with that in the Figure 3 in the manuscript.



Notes: The density of CVs are reported based on Eq. (21). There are 22,395 households in 2008.

Figure A6. Welfare change on the earning side



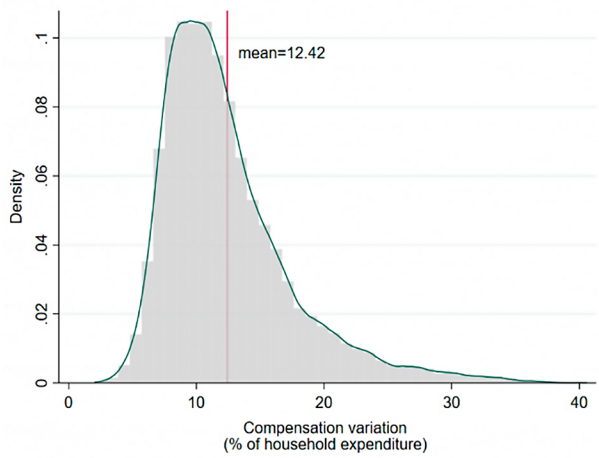
Notes: The figure displays the average CV of each group based on Eq. (21). There are 22,395 households in 2008, and all households are divided into 20 groups according to their per capita expenditure.

Figure A7. Income effect of trade liberalization (across 20 groups)

7. Aggregate welfare change

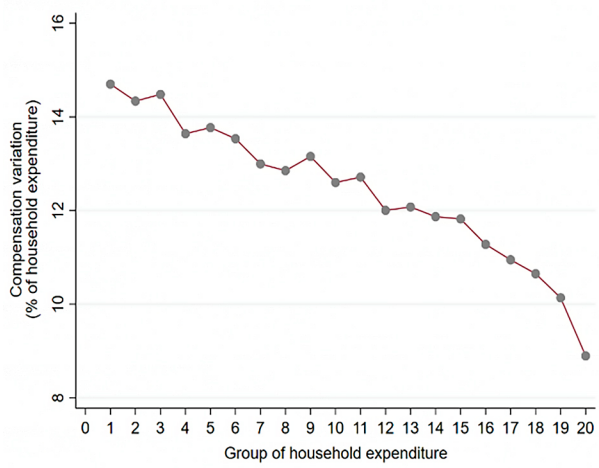
The Figure A8 illustrates the welfare changes based on Eq. (22) in the manuscript.

In the Figure A9, we also divide all households into 20 groups according to their per capita expenditure and obtain the consistent result with that in the Figure 4 in the manuscript.



Notes: The density of CVs are reported based on Eq. (22). There are 22,395 households in 2008.

Figure A8. Aggregate price effect



Notes: The figure displays the average CV of each group based on Eq. (22). There are 22,395 households in 2008, and all households are divided into 20 groups according to their per capita expenditure.

Figure A9. Aggregate price effect of trade liberalization (across 20 groups)