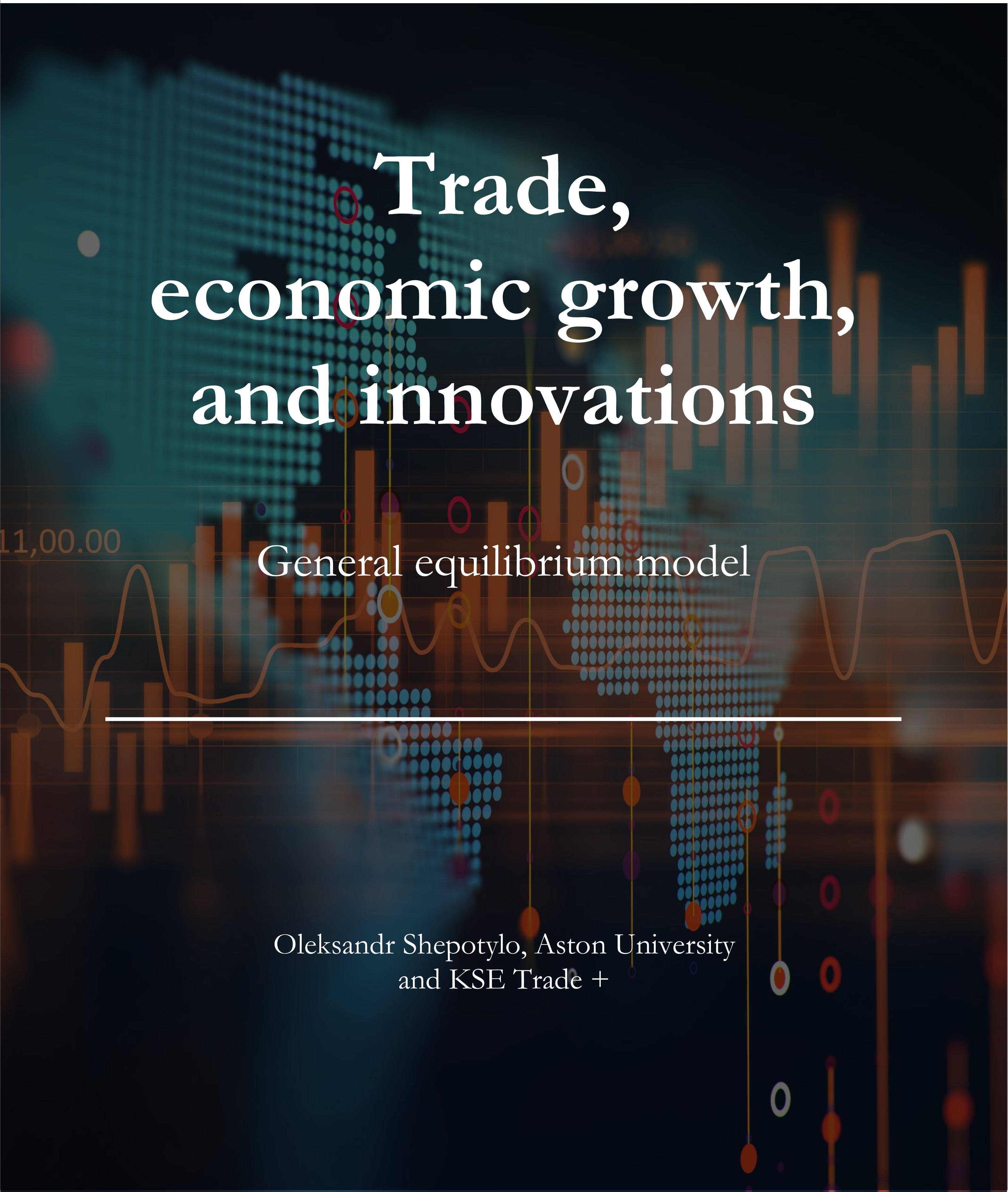
співпраця з німеччиною
DEUTSCHE ZUSAMMENARBEIT

Виконавець:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Trade+ at Kyiv School of Economics

KSE Kyiv School of Economics



Trade, economic growth, and innovations

General equilibrium model

Oleksandr Shepotylo, Aston University
and KSE Trade +

Gratitude

This report was prepared by the Trade+, International Trade Research Center at the Kyiv School of Economics, as an effort to implement the Export Strategy of Ukraine (the "Road Map" for Strategic Trade Development) for 2017-2021.

The Center was established at the Kyiv School of Economics as a part of the "Promotion of a Supportive Framework for Trade in Ukraine" project, implemented through the German Federal Company Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by the German Government.

We are grateful to Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH for the opportunity to conduct this research and to contribute to the support of Ukrainian exports.

We express our gratitude to Olena Besedina, Maryna Khorunzha and Natalia Shapoval for reviewing the paper.

1. Introduction

This paper presents a general equilibrium model of the global economy that links economic growth to the developments in labor market, investments, research and development, and trade. It first outlines the model and further develops it in detail, incorporating all those elements into a unified, general equilibrium framework. The model is useful to evaluate how changes in trade costs, including transportation, policy, and institutional costs, impact the global equilibrium. By adding more detailed description of an economy, it is possible to analyze how technological, demographic, and political shocks to that economy influence the long-term growth, trade, and welfare.

Considerable progress in data collection and computational power made it possible to develop models that build up from the micro foundations and microdata towards the relationships at the aggregate macroeconomic level. These models are able to generate predictions on trade and economic growth at the macro level. Unlike the previous generation of computable general equilibrium models, which had a large number of parameters to estimate, the new models are built with only several key parameters in mind.[1] They also rely more on microdata to estimate the key parameters within the model, while CGE models were primarily calibrated using the previous literature.

A pioneering work in this area was Eaton and Kortum (2002), who build on Ricardian model of trade with differences in productivities across firms, driving towards the comparative advantage. Later, the multisector Melitz model of trade with intermediate goods has been quantified by Balistreri, Hillberry, and Rutherford (2011). The real explosion of the new quantitative models of trade has begun with Costinot and Rodríguez-Clare (2015), which was actually called "Trade theory with numbers". It paved the way for new quantitative models that relied on extensive use of data. In particular, the structural gravity model, which accounts for bilateral and multilateral factors affecting trade flows, plays a central role in these stream of literature. The difference between traditional and structural gravity models is related to how multilateral terms (Anderson & Wincoop, 2003) are ignored in the former and are accounted for in the latter. Head & Mayer (2015) have an extensive survey of literature on different methods of estimating the gravity model of trade. They particularly focus on the differences between the traditional and structural gravity models.

Considerable contribution into modelling of structural gravity experiments has been made in works of Anderson, Larch, and Yotov (ALY, 2018, 2019). In particular, ALY 2018 developed a methodology that uses the structural gravity model to estimate the effects of trade policy changes on welfare. ALY 2019 developed a two tier model, where the lower

---

[1] Computable general equilibrium models (CGE) have been extensively used for policy analysis since 1980s. In particular, Francois et al (1996) and Harisson et al. (1997) estimate the impact of the multilateral trade liberalization on welfare. Rutherford and Tarr (2002) build a CGE model for a small open economy. Detailed introduction to CGE models is presented in Dixon and Jorgenson (2013).

layer is the structural gravity model that takes production and input factors as given, while the upper level links output, labor and capital accumulation with prices determined in the global trade equilibrium to estimate the effects of trade policy changes on welfare through trade, investment, and FDI channels.

Other examples of the quantitative approach to trade and development includes research on trade policy determinants and innovation. Ossa (2014) incorporated game theoretical models of trade policy into the quantitative models of trade. More recently, trade theory has been blended with the theory of innovation and economic growth (Acemoglu et al. 2018; Akcigit, 2018). These models emphasize the role of R&D and innovation on productivity and growth. They also study how government policies may influence growth through policies targeting knowledge accumulation through subsidies and tax credits.

2. Background

General equilibrium models of trade (CGE or structural gravity models) explain how trade flows are shaped in the long-run (3-5 years horizon can be considered for planning and policy development). They are designed to predict a long-run equilibrium in the global economy, so they do not deal with daily or monthly fluctuations in the exchange rate, money supply, or interest rates. There is a good reason for this – in the long-run monetary factors and short-term fluctuations (business cycles) have no effect on growth and output. As a result, there is division of economics into macroeconomics of business cycles, which deals with the short-run fluctuations, and theories of economic growth and trade, which study the long-run dynamics and long-run equilibrium.

The new models incorporate structural gravity approach (Costinot and Rodríguez-Clare, 2015; Head and Mayer, 2015). They are used to analyze effects of policy changes (changing tariffs, signing preferential trade agreements, introducing or harmonizing non-tariff measures, liberalizing services etc.) on trade and welfare. Balistreri et al (2011) add firms, incorporating the Melitz model with heterogeneous firms (Melitz, 2003) into the general set up. However, to have a global model requires having the firm level data for all countries, which is unrealistic and computationally challenging to deal with. As a result, we will focus on a model at more aggregate level.

Trade models fully compatible with the long-run growth models (Solow model, endogenous growth model (Romer, 1986), or a Schumpetrian growth model with innovation and creative destruction (Aghion, Akcigit, and Howitt, 2013) can easily incorporate population growth, technological progress due to investment in innovations and R&D, capital growth due to investment in physical capital and FDI into the structural gravity analysis and compute the impact of policy changes on the future trade flows and economic welfare.

3. Model description

The model incorporates the relationships between the population growth and employment, investment, R&D, and trade into a unified framework. Its starting point is a simplified ALY (2019) with capital accumulation, but without FDI. Instead, we introduce the R&D sector that invest final good to maintain and increase productivity of the economy.

Set up

Consider a world economy consisting of N countries, indexed $i = 1 \dots N$, each producing a unique good[2] using factors of production (labor and capital) and employing certain technology, which varies across countries. Given the existing stock of capital K_{it}, inelastically supplied labor L_{it}, and productivity A_{it}, the variety i is produced according to the following production function

$$Q_{it} = A_{it} K_{it}^{\alpha_K} L_{it}^{\alpha_L}. \tag{1}$$

This model representation makes several assumptions. First, we assume that the economy can be represented by a single production function. It means that all varieties of products that are produced within a country can be aggregated into a single output. The theoretical results have shown that it is possible, under certain restrictions on technology. For more detailed discussion, please see Baqaee and Farhi (2019) on representation of the economy by an aggregate production function. Among other things, they argue that (1) can be viewed not as the structural relationship between outputs and input factors, but as an endogenously formed relationship, that describes how inputs, productivity, and output are linked.

Second, we assume a constant returns to scale technology, described by Cobb-Douglas production function, which has some important limitations. It assumes a constant rate of technical substitution between capital and labor. Moreover, it rules out increasing returns to scale (i.e. due to existence of fixed costs in production) or diminishing return to scale (i.e. due to limited specific resource) for the whole range of factor inputs. These assumptions are however not very restrictive, because the evidence suggest that Cobb Douglas production function is a reasonable approximation of an economy. Moreover, these simplifying assumptions make the model more tractable, without compromising important features of the relationship between the factors of production, technological progress, and output.

---

[2] This is a model of aggregate trade flows. Adding sectors would be a tedious, but quite straightforward task. It is logical to start with the aggregate flows model and expand it to the model with sectors later on.

Labor market

We assume that labor supply evolves over time according to the following law of motion

$$L_{i,t+1} = L_{it}(1 + g_{Li}) \tag{2}$$

where L_{it} is working age population, g_{Li} is population growth. Population growth is computed, using available data over 5-year interval (World Bank Development Indicators). It assumes that the workforce grows exogenously and proportionally to the population growth. The model also allows for unemployment by adding an equation for a long run structural unemployment and adding a law of motion for the unemployment as follows

$$L_{i,t+1}(1 - u_{i,t+1}) = L_{it}(1 + g_{Li})(1 - u_{it}) \tag{2a}$$

and

$$u_{i,t+1} = \bar{u_i} + \rho u_{it} + e_{i,t+1} \tag{2b}$$

In this formulation, we allow for deviation from the long run unemployment $\bar{u_i}$ to follow an autoregressive process with parameter $0 \leq \rho < 1$.

$e_{i,t+1}$ are macroeconomic shocks independent and identically distributed $(0, \sigma_i^2)$.

Capital market

Capital accumulation is driven by the following expression

$$K_{it+1} = K_{it}(1 - \delta_i) + I_{it}^K \tag{3}$$

The next period capital equals capital in the previous period net of depreciation, δ_i plus the current period investment in physical capital, I_{it}^K.

Overall level of investment equals $I_{it} = I_{it}^K + R\&D_{it}$, where investment can be in physical capital or in research and development. It needs to satisfy the following balance condition

$$CA_{it} = TB_{it} = S_{it} - I_{it} \tag{4}$$

We assume that net foreign assets are equal to zero, so current account (CA) is equal to trade balance (TB). Savings (S) in turn is difference between output (Y) and consumption (C) (there is no government in our model), while investment (I) depends on the current real rate of interest (r_{it}):

$$S_{it} = Y_{it} - C_{it} \tag{5}$$

and

$$I_{it} = I_{it}(r_{it}) \tag{6}$$

Often modelers assume balanced trade, which reduces (4) to $S_{it} = I_{it}$. However, it does not capture the current situation well, as the global trade is highly unbalanced. As an alternative, one may assume that the current situation with trade imbalances persists

$$\frac{CA_{it}}{Y_{it}} = const \tag{7}$$

In the current version of the model, we assume no taxes and government spending, but the model can accommodate both taxation and government expenditures.

R&D, FDI and technology

Technology, captured by the total factor productivity (TFP) parameter A_{it} evolves according to the following law of motion

$$A_{i,t+1} = (1 - \delta_{Ai})A_{it} + \gamma T_{it} + A_i + A_t + e_{it}, \tag{8}$$

Current level of knowledge and state of technology that are embedded in TFP, A_{it}, depreciate over time at rate δ_{Ai}. T, representing contribution of knowledge and technology into TFP, depends on the level of investment in innovation and production technology, inflow of technology capital, and investment in human capital and education:

$$T_{it} = F_T(R\&D_{it}, FDI_{it}, EDU_{it}) \tag{9}$$

Level of technology also depends on institutions and government effectiveness in facilitating transaction costs, which adds a fixed component A_i, in addition the overall level of technology is constantly growing, due to knowledge accumulation and technology investments made by other countries, which becomes a common knowledge over time, which adds A_t component.

Demand structure

While some authors introduce a dynamic optimization problem that solves both capital accumulation, R&D, and consumption problem (i.e. Anderson et al., 2019), we make the simplifying assumptions that consumers treat the level of capital, labor and technology as given when solving consumer maximization problem. There is a representative consumer in country j with constant elasticity of substitution (CES) utility function defined as

$$C_j = \left(\sum_i \; C_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{10}$$

where C_{ij} is consumption of variety i and $\sigma > 1$ is elasticity of substitution across varieties. As mentioned before, according to a standard Armington assumption, each country produces a unique variety. We drop time sub-index to simplify notation in the sub-section. The consumer maximizes (10) subject to a budget constraint

$$\sum_i P_{ij} C_{ij} = E_j \tag{11}$$

where P_{ij} is the price of the variety i in the country j, and E_j is aggregate expenditures. Trade is costly – it takes $\tau_{ij} \geq 1$ units of good i to deliver one unit of this good from i to j, with $\tau_{ij} = 1$ only when $i = j$. We assume that the transportation sector is competitive, hence the price of good i in country j is given by $P_{ij} = \tau_{ij} p_i$, where p_i is a 'factory gate' price in i.

Description of global equilibrium

Solving the model yields a structural gravity representation

$$X_{ij} = \frac{Y_i E_j}{Y_w} \left(\frac{\tau_{ij}}{\Omega_i P_j} \right)^{1-\sigma} \tag{12}$$

where X_{ij} is export from country i to country j, $Y_i = \sum_j X_{ij}$ is total income in country i, and $E_j = \sum_i X_{ij}$ is total expenditure in country j.

There are two crucial variables that capture all relevant information about how the world economy influences bilateral trade. These are outward multilateral resistance (ORT)

$$\Omega_i^{1-\sigma} = \sum_j \frac{E_j}{Y_w} \left(\frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \tag{13}$$

which aggregates the state of the global economy relative to the country i producer, and inward multilateral resistance (IRT)

$$P_j^{1-\sigma} = \sum_i \frac{Y_i}{Y_w} \left(\frac{\tau_{ij}}{\Omega_i} \right)^{1-\sigma}. \tag{14}$$

which summarizes configuration of prices and trade costs for country j consumers. Finally, a factory gate price in country i in equilibrium is characterized as follows

$$p_i = \left(\frac{Y_i}{Y_W} \right)^{1/(1-\sigma)} \frac{1}{\Omega_i} \tag{15}$$

4. Estimation methodology and data

Production function

Combining the definition of income and (15), income of country i is given by

$$Y_i = p_i Q_i = Y_W^{\rho-1} \times \frac{1}{\Omega_i^{\rho}} \times Q_i^{\rho} \tag{16}$$

where $\rho = (\sigma - 1)/\sigma$ is a parameter determined by the elasticity of substitution and Y_w is global income. Using (1) and (8), linearizing the technology investment (9), and taking logs of both sides of (16) yields

$$\ln Y_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_{ORT} \ln \Omega\,_{it}^{\sigma-1} + \beta_{R\&D} R\&D + \beta_{FDI} FDI_{it} + \beta_{EUD} EDU_{it} + \mu_t + \mu_i + \epsilon_{it} \tag{17}$$

where $\sigma = -1/\beta_{ORT}$ and $\alpha_f = \beta_f \times (1 + \beta_{ORT}), f = \{L, K\}$.

Parameters of the production function (17) are estimated using a panel data available at Penn World Tables (PWT9.2) data on nominal output, capital and labor, where the production function parameters are treated as estimated coefficients.[3] Estimates of the ORT, $\ln \Omega\,_{it}^{\sigma-1}$, are taken from the structural gravity estimation, described in the next section. Data on FDI, R&D investments, and investments in education are taken from the World Bank Development Indicators.

Structural gravity model estimation and counterfactual scenarios

We parametrize trade costs as follows

$$\tau^{1-\sigma}{}_{ij} = exp\ \left(\gamma_{dist} \ln\left(\lambda_{ij} \times dist_{ij}\right) + \gamma_{MFN}\ ln\ \left(1 + MFN_{ij}\right) + \gamma_{NTM}\ ln\ (1 + NTM_{ij}) + \gamma_{PTA} PTA_{ij} + Z_{ij}\gamma_Z\right) + u_{ij} \tag{18}$$

Trade costs increase with distance and are also influenced by the transport infrastructure parameter, λ_{ij}. Tariffs (MFN) and non-tariff barriers (NTM) are elements of trade policy that governments have at their disposal. Preferential trade agreements (PTA) facilitate trade by lowering tariff and non-tariff barriers, reducing trade policy uncertainty, and giving countries more opportunities to develop long value chains and just-in-time production processes. Other factors affecting trade costs, such as a common border,

---

[3] Alternatively, the production function can be calibrated using macroeconomic data on wages w, returns to capital r and nominal output PQ, where P is the aggregate price deflator, using the national account data by applying the following formulae: $\widehat{\alpha_L} = wL/PQ$ and $\widehat{\alpha_K} = rK/PQ$, and treating productivity as the residual factor $\widehat{A_{it}} = Q_{it}/(K_{it}^{\widehat{\alpha_K}} L_{it}^{\widehat{\alpha_L}})$.

cultural proximity, language barriers, commonality of legal systems, and a colonial past, are all part of Z_{ij}. Finally, the error term u_{ij} is assumed to be uncorrelated with the above-mentioned variables.

Conditional general equilibrium welfare effects

We evaluate how changes in trade costs and trade policies, ceteris paribus, influence global equilibrium trade flows and welfare. For conditional general equilibrium (Head and Mayer, 2014; Anderson et al., 2018), we keep production and expenditure constant and assume that a vector of trade costs changes due to an exogenous shock from τ to τ'.

Following Anderson et al. (2018), we evaluate inward and outward multilateral terms before and after the shock by applying the Poisson Pseudo Maximum Likelihood estimator (PPML) (see Silva and Tenreyro, 2006). Our estimated model is given by

$$X_{ij} = exp \begin{pmatrix} \gamma_{dist} \ln(\lambda_{ij} \times dist_{ij}) + \gamma_{MFN} \ln(1 + MFN_{ij}) + \\ \gamma_{NTM} ln\,(1 + NTM_{ij})\ + \gamma_{PTA} PTA_{ij} + Z_{ij}\gamma_Z + \chi_i + \xi_j \end{pmatrix} + u_{ij} \tag{19}$$

At the second stage, we modify our policy variables to λ'_{ij}, MFN'_{ij}, NTM'_{ij}, and PTA'_{ij} to reflect changes in the policy scenario and re-estimate the model. We constrain the coefficients of policy and control variables to be equal to our estimated coefficients from the previous stage.

$$X_{ij} = exp \begin{pmatrix} \hat{\gamma}_{dist}\ ln\,(\lambda'_{ij} \times dist_{ij})\ + \hat{\gamma}_{MFN}\ ln\ (1 + MFN'_{ij})\ + \\ \hat{\gamma}_{NTM}\ ln\,(1 + NTM'_{ij})\ + \hat{\gamma}_{PTA} PTA'_{ij} + Z_{ij}\hat{\gamma}_Z + \chi'_i + \xi'_j \end{pmatrix} + u'_{ij} \tag{20}$$

Using the result by Fally (2015)[4], and given the set of $\{\hat{\xi}_j\}$, $\{\hat{\chi}_i\}$, $\{\widehat{\xi'}_j\}$, and $\{\hat{\chi}'_i\}$, estimated using PPML according to (9) and (10), we compute the inward and outward multilateral resistance terms according to the following expressions:

$$\hat{P}_j^{1-\sigma} = E_j\ exp\ exp\ (-\hat{\xi}_j)\ /E_0 \tag{21}$$

$$\widehat{P'}_j^{1-\sigma} = E_j\ exp\ exp\ (-\hat{\xi}'_j)\ /E_0 \tag{22}$$

$$\hat{\Omega}_i^{1-\sigma} = E_0 Y_i exp(-\hat{\chi}_i) \tag{23}$$

$$\widehat{\Omega'}_i^{1-\sigma} = E_0 Y_i exp(-\widehat{\chi'}_i) \tag{24}$$

---

[4] Fally (2015) has shown that when (17) is estimated by PPML, it automatically satisfies any structural gravity constraint on fitted production and fitted expenditures for any i and j, because the PPML first order conditions are equivalent to the first order conditions of the model optimization. He also has shown that (19)-(22) are unique solutions for inward and outward multilateral resistance terms in the structural trade model.

where E_0 is the level of expenditure in the country for which the inward multilateral resistance is normalized to $P_0 = 1$.[5]

Finally, we evaluate welfare changes according to the following formula,

$$\widehat{W} = 100\% \times (\frac{\widehat{P}_i}{\widehat{P}_i'} - 1) \tag{25}$$

Full general equilibrium

We also compute the full general equilibrium (GE) effect of each scenario, following the algorithm suggested by Anderson et al. (2019). This accounts for adjustments in the prices of exports caused by changes in trade costs, which lead to further changes in income, expenditures, and trade. In particular, after performing the conditional general equilibrium computations, we update `factory gate’ price according to the following formula

$$\frac{p_i'}{p_i} = \frac{\widehat{\Omega}_i}{\widehat{\Omega}_i'} = \left\{\frac{exp\,(-\widehat{\chi}_i)}{exp\,(-\widehat{\chi}_i')}\right\}^{1/(1-\sigma)} \tag{26}$$

We further compute new values of income, and expenditures, and bilateral trade flows respectively as follows

$$Y_i' = \frac{p_i'}{p_i} Y_i \tag{27}$$

$$E_j' = \frac{p_j'}{p_j} E_j \tag{28}$$

and

$$X'_{ij} = \frac{\tau'^{1-\sigma}}{\tau^{1-\sigma}} \frac{Y_i' E_j'}{Y_i E_j} \frac{\widehat{\Omega_i^{1-\sigma}}}{\widehat{\Omega_i'^{1-\sigma}}} \frac{\widehat{P_j^{1-\sigma}}}{\widehat{P_j'^{1-\sigma}}} X_{ij} \tag{29}$$

Finally, we solve for a new equilibrium following the same computational procedure as described in the conditional gravity section. This iteration process continues until `factory gate’ prices converge to the full GE values. Welfare gains under full GE are computed as follows

$$\widehat{W} = 100\% \times \left(\frac{\frac{Y_i'}{\widehat{P}_i'}}{\frac{Y_i}{\widehat{P}_i}} - 1 \right) \tag{30}$$

---

[5] We chose New Zealand as the reference country. Due to its remoteness and size, the policy scenarios that we plan to study in this model are likely to affect New Zealand less than most other countries.

5. Counterfactual analysis

Impact of PTA on trade and welfare

Consider Ukraine signing a preferential free trade agreement with Turkey. It will lower the level of bilateral applied tariffs from MFN and change the value of PTA variable from 0 to 1. Following steps outlined in section 4 on conditional and full general equilibrium effects, the model predicts changes to equilibrium trade flows between Ukraine and Turkey as well as the bilateral trade flows with the other trading partners. For instance, given that the overall output of the Ukrainian economy does not change, increase in export from Ukraine to Turkey would lead to reduction in exports of Ukraine to the rest of the world. However, in the full general equilibrium analysis it would also lead to an increase in factory prices of goods produced in Ukraine, p_{UKR}, leading in turn to higher income, Y_{UKR}, and consequently, to a higher level of expenditures (assuming the trade is balanced or current account is constant proportion of Ukraine's GDP), which would increase welfare in Ukraine. It would also increase Ukrainian imports from the rest of the world due to the higher level of the aggregate expenditures.

Productivity growth due to higher level of R&D

Another example that can be analyzed within the framework of the model is an exogenous increase in the level of R&D investment. It may be the result of the government policies to encourage more innovations due to tax credit (see US example discussed in (Akcigit et al., 2018)) patent 'patent boxes' in Ireland, research grants in US and EU, intellectual property protection, and investment in education system (Bloom, Van Reenen, & Williams, 2019)). In the framework of our model, which does not have a government as another economic agent, it is represented by the higher value of T_{UKR}, which increase productivity by $\Delta A_{UKR} = \gamma \Delta \mathrm{T}_{\mathrm{UKR}}$, where ΔT_{UKR} is an increase in technology due to more R&D. It would in turn increase output Q_{UKR}, income Y_{UKR}, and expenditures E_{UKR}in Ukraine. From the trade perspectives, it will also boost exports and imports of Ukraine in bilateral trade with the rest of the world.

6. Conclusions

In this note we presented a long-run general equilibrium model, where changes in trade policy instruments and trade costs in general, influence consumption and trade flows across countries in the global equilibrium. In addition, the model captures changes in the macroeconomic environment caused by shocks to population growth, R&D investment, unemployment that leads to changes in productivity and output, which in turn affects economic growth and adjustments in the global trade patterns. We also explain how to compute counterfactual scenarios and provided formulae for welfare analysis.

The current model has some shortcomings. In particular, it does not have sectoral level analysis, which is typically present in CGE models. It also does not allow for firm heterogeneity. However, both these features can be incorporated into the analysis. The model can also be extended by introducing government as an economic agent. For example, government may subsidize research and development to promote long-run economic growth as, for instance, in Acemoglu et al. (2018). Finally, the analysis can be extended to look at the impact on different regions and sectors of the Ukrainian economy. We leave these very interesting extensions for further research.

Reference

Acemoglu, D., Akcigit, U., Alp, H., Bloom, N., & Kerr, W. (2018). Innovation, reallocation, and growth. *American Economic Review.*

https://doi.org/10.1257/aer.20130470

Aghion, P., Akcigit, U., & Howitt, P. (2013). *What Do We Learn From Schumpeterian Growth Theory?* Retrieved from https://scholar.harvard.edu/files/aghion/files/what_do_we_learn_0.pdf

Akcigit, U., Ates, S. T., & Impullitti, G. (2018). *Innovation and trade policy in a globalized world*. Retrieved from http://www.nber.org/papers/w24543

Anderson, J. E., Larch, M., & Yotov, Y. V. (2018). GEPPML: General equilibrium analysis with PPML. *The World Economy*, *41*(10), 2750–2782. https://doi.org/10.1111/twec.12664

Anderson, J. E., Larch, M., & Yotov, Y. V. (2019). Trade and investment in the global economy: A multi-country dynamic analysis. *European Economic Review*, *120*, 103311. https://doi.org/10.1016/J.EUROECOREV.2019.103311

Anderson, J. E., & Wincoop, E. van. (2003). Gravity with Gravitas : A Soiution to the Border Puzzie. *The American Economic Review*, *93*(1), 170–192. https://doi.org/10.1257/000282803321455214

Baqaee, D. R., & Farhi, E. (2019). Productivity and Misallocation in General Equilibrium. *The Quarterly Journal of Economics*. https://doi.org/10.1093/qje/qjz030

Bloom, N., Van Reenen, J., & Williams, H. (2019). A Toolkit of Policies to Promote Innovation. *Journal of Economic Perspectives*, *33*(3), 163–184. https://doi.org/10.1257/jep.33.3.163

Costinot, A., & Rodríguez-Clare, A. (2015). Trade Theory with Numbers: Quantifying the Consequences of Globalization. *Handbook of International Economics*, *4*(March), 197–261. https://doi.org/10.1016/B978-0-444-54314-1.00004-5

Eaton, J., & Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, *70*(5), 1741–1779. https://doi.org/10.1111/1468-0262.00352

Head, K., & Mayer, T. (2015). *Gravity Equations: Workhorse,Toolkit, and Cookbook. Handbook of International Economics* (Vol. 4). Elsevier. https://doi.org/10.1016/B978-0-444-54314-1.00003-3

Ossa, R. (2014). Trade wars and trade talks with data? *American Economic Review.* https://doi.org/10.1257/aer.104.12.4104

P., R., & Romer, P. M. (1986). Increasing Returns and Long-run Growth. *Journal of Political Economy*, *94*(5), 1002–1037. https://doi.org/10.1086/261420