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THE ROLE OF ELECTRONIC CUSTOMS SYSTEMS IN ENSURING TRANSPARENCY AND EFFICIENCY OF CROSS-BORDER TRADE OPERATIONS

Анотація. *В умовах нестабільної світової торгівлі та зростання значення цифрових технологій у державному управлінні модернізація митних процедур набуває стратегічного значення для багатьох економік. Впровадження електронних митних систем для України є важливим для реалізації відкритості, ефективності та прозорості транскордонних торговельних операцій, географічно розташовуючись на перехресті західних та східних ринків. У статті розглядається вплив впровадження електронної митної системи в Україні на відкритість торгівлі та ефективність митниці в період 2020-2024 років. Метою дослідження є оцінка ступеня, до якого цифрова митна трансформація сприяє покращенню торговельних показників країни через усунення бюрократичних бар'єрів і підвищення швидкості та надійності митних процесів. Методологія даного дослідження використовується для кількісного визначення прямих і непрямих впливів проникнення електронної митниці на найважливіші результати, пов'язані з торгівлею: розроблено модель одночасних рівнянь і застосовано декілька методів оцінки динамічної панелі, щоб покращити обробку неспостережуваної неоднорідності та більш точно оцінити ефекти, що представляють інтерес. Модель складається з макроекономічних індикаторів контролю (темп зростання ВВП, волатильність обмінного курсу, інфляція та приплив прямих іноземних інвестицій) і структурних змінних (цифрова інфраструктура, інституційна готовність і стимули державної політики). Результати вказують на статистично значущий позитивний зв'язок збільшення частки електронно оброблених митних декларацій із відкритістю торгівлі при скороченні часу митного оформлення. Крім того, доведено, що цифрова готовність*

інфраструктури та якість впровадження політики є життєво важливими посередницькими змінними, які сприяють ефекту електронних митних систем. Емпіричні результати порівнюються з попередніми міжнародними дослідженнями та показують, що реформи цифрової митниці в Україні є найсучаснішими порівняно з найкращими світовими практиками та теоретичними очікуваннями. Ці результати пояснюються в рамках інституційної економіки та економіки транзакційних витрат, щоб пояснити, як цифрові інструменти можуть зменшити неефективність, підвищити відповідність і підвищити операційну прозорість. Показано, що статистичні тести, що стосуються ендогенності та специфікації моделі, підтверджують надійність висновків. Дослідження демонструє, що запровадження електронних митних систем значно підвищило відкритість та ефективність транскордонної торгівлі України протягом досліджуваного періоду. Ці висновки підкреслюють необхідність продовжувати інвестувати в цифровізацію митниці, розбудову інституційного потенціалу та міжнародну співпрацю. Подальші перспективи дослідження включають вивчення регіональних відмінностей у прийнятті системи, впровадження нових технологій, таких як блокчейн, та економічні наслідки цифрових митних реформ.

Ключові слова: *митна ефективність, митна модернізація, цифрова трансформація, електронні митні системи, міжнародна торгівля, відкритість торгівлі, торговельна політика, Україна, віртуальні активи, функціональний аспект, інвестиції.*

JEL Classification: H 25, G 28.

Absztrakt. *Az instabil világkereskedelem és a digitális technológiák állami irányításban betöltött szerepének növekedése miatt a vámeljárások modernizálása stratégiai jelentőséget nyer számos gazdaság számára. Az elektronikus vámrendszerek bevezetése Ukrajna számára fontos a nyitottság, a hatékonyság és a határon átnyúló kereskedelmi műveletek átláthatóságának megvalósítása szempontjából, mivel az ország földrajzilag a nyugati és keleti piacok kereszteződésében fekszik. A cikk az elektronikus vámrendszer bevezetésének hatását vizsgálja Ukrajnában a kereskedelem nyitottságára és a vámhatóság hatékonyságára a 2020–2024 közötti időszakban. A kutatás célja annak értékelése, hogy a digitális vámátalakítás milyen mértékben járul hozzá az ország kereskedelmi mutatóinak javulásához a bürokratikus akadályok eltávolításával, valamint a vámeljárások gyorsaságának és megbízhatóságának növelésével. A jelen tanulmány módszertana az elektronikus vámkezelés közvetlen és közvetett hatásainak számszerűsítésére szolgál a kereskedelem legfontosabb eredményeire: kidolgozták az egyidejű egyenletek modelljét és több dinamikus panel értékelési módszert alkalmaztak a nem megfigyelhető heterogenitás kezelésének javítása és a vizsgált hatások pontosabb értékelése érdekében. A modell makrogazdasági kontrollindikátorokból (GDP-növekedés, árfolyam-volatilitás, infláció és közvetlen külföldi befektetések beáramlása) és strukturális változókból (digitális infrastruktúra, intézményi felkészültség és állami politikai ösztönzők) áll. Az eredmények statisztikailag szignifikáns pozitív összefüggést mutatnak az elektronikus úton feldolgozott vámáru-nyilatkozatok arányának növekedése és a kereskedelem nyitottsága között, a vámkezelés időtartamának csökkenésével. Ezenkívül bebizonyosodott, hogy az infrastruktúra digitális felkészültsége és a politika végrehajtásának minősége létfontosságú közvetítő változók, amelyek elősegítik az elektronikus vámrendszerek hatását. Az empirikus eredményeket összehasonlítjuk korábbi nemzetközi tanulmányokkal, és azt mutatják, hogy az ukrán digitális vámreformok a világ legjobb gyakorlataival és elméleti elvárásokkal összehasonlítva a legkorszerűbbek. Ezeket az eredményeket az intézményi gazdaságtan és a tranzakciós költségek gazdaságtana keretében magyarázzák, hogy a digitális eszközök hogyan csökkenthetik a hatékonyság hiányát, javíthatják a megfelelést és növelhetik a működési átláthatóságot. Kimutatták, hogy az endogenitásra és a modell specifikációjára vonatkozó statisztikai tesztek megerősítik a következtetések megbízhatóságát. Végül, ez a cikk azt mutatja, hogy az elektronikus vámrendszerek bevezetése jelentősen növelte Ukrajna határon átnyúló kereskedelmének átláthatóságát és hatékonyságát a vizsgált időszakban. Ezek a következtetések aláhúzzák annak*

szükségességét, hogy továbbra is beruházzanak a vámhatóság digitalizálásába, az intézményi kapacitás kiépítésébe és a nemzetközi együttműködésbe. A kutatás további perspektívái között szerepel a rendszer bevezetésének regionális különbségeinek vizsgálata, új technológiák, például a blokklánc bevezetése, valamint a digitális vámreformok gazdasági hatásainak elemzése.

Kulcsszavak: *vámhatékonyság, vámmodernizáció, digitális átalakulás, elektronikus vámrendszerek, nemzetközi kereskedelem, kereskedelem liberalizációja, kereskedelempolitika, Ukrajna, virtuális eszközök, funkcionális aspektus, beruházások.*

Abstract*. On the background of unstable worldwide trade and rising significance of digital technologies in public administration, customs procedures modernization gains a strategic importance for many economies. As a geographically relevant crossroads of Western and Eastern markets, adoption of electronic customs systems for Ukraine is essential for realization of openness, efficiency and transparency in cross border trade operations. This article looks into the influence of the electronic customs system implementation for Ukraine in respect to the trade openness and customs efficiency during the time period of 2020-2024. The objective of the study is to assess the degree to which the digital customs transformation adds to the improvement of the country's trade performance in eliminating bureaucratic barriers and enhancing faster and reliable customs processes. Methodology of this research is used to quantify the direct and indirect effects of electronic customs penetration on the most important trade related outcomes: a simultaneous equations model is designed and several dynamic panel estimation techniques are employed in order to improve treatment of unobserved heterogeneity and to estimate with more precision the effects of interest. The model consists of macroeconomic controls (GDP growth rate, exchange rate volatility, inflation and FDI inflows) and structural variables (digital infrastructure, institutional readiness and government policy incentives). The results indicate statistically significant positive relationship of an increase in the proportion of electronically processed customs declarations on trade openness while reducing customs clearance times. Also, digital readiness of infrastructure and quality of policy implementation are proven to be vital mediating variables which contribute to the effect of electronic customs systems. The empirical results are compared with the previous international research and show that Ukraine's digital customs reforms are state-of-the art in comparison with the global best practices and theoretical expectations. These results are explained in frameworks of institutional and transaction cost economics in order to explain how digital tools can reduce inefficiency, increase compliance, and increase operational transparency. The statistical tests relevant to endogeneity and model specification are shown to provide support for the robustness of the findings. Finally, this article shows that the adoption of the electronic customs systems has greatly increased openness and efficiency in Ukraine's cross border trade during the studied period. These findings stress the need to keep investing in customs digitalization, institution capacity building, and international cooperation. Further research prospects include the examination of regional differences in the adoption of the system, the embedding of new technologies such as blockchain and the economic effects of the digital customs reforms.*

Keywords*: customs efficiency, customs modernization, digital transformation, electronic customs systems, international trade, trade openness, trade policy, Ukraine, virtual assets, functional aspect, investments.*

Problem statement. In recent years, with the acceleration of the global trade and the complexity of the proliferation of International supply chains, national customs systems' demands have increased [1]. Ukraine, as a country located in a key location between East and European markets, realizes its primary importance to ensure the transparency and openness and efficiency of cross border trade operations. A country

where traditional customs procedures based on paper work, bureaucratic delays and ad-hoc practices do not make it possible to be totally inserted in global trade networks. An inevitable and a strategic step towards modernizing national customs infrastructure is the implementation of electronic customs systems as the global standards are shifted towards digital trade facilitation.

This study aims to analyze the influence of the electronic customs systems on the increase in trade openness and effective performance of Ukraine's economy from 2020 to 2024. The research aims at finding out whether the application of such systems has helped to reduce the times required for customs clearance, lower costs of transaction and increase volume and simplicity of flows of trade.

The gap in the current literature is addressed by this research, which carries out a comprehensive econometric assessment of how digital transformation in the area of customs administration affects macroeconomic indicators of the trade sector. There exists an urgent need for Ukraine to increase its role in world trade in a regulatory compliance, quasi transparent and economically resilient manner amid various regional and global challenges that make the problem under examination justified.

The introduction provides the background of the subject and brings the existing situation of customs operations in Ukraine into relevance. Afterwards, an advanced econometric analysis model is developed in the next section. The empirical results and corresponding discussion to analyze the quantitative findings follows. The concluding section also presents the conclusions derived from the study's outcomes.

Analysis of recent research and publications. For years on end, international trade processes have been digitally transformed with special interest highlighted on how blockchain, and other digital platforms, can be integrated to supply chain and customs operations. The present article for its turn studies the impact of the electronic customs systems on trade openness and efficiency in Ukraine on the basis of these studies. Iakovou, Shi, and Chang therefore provided a critical synthesis of how blockchain technologies are transforming global supply chain and cross border trade [1]. However, their research, based on a thorough investigation of technological developments and challenges for realization, stressed the significance of digital trust and traceability in these scenarios. The authors argued that blockchain has the potential for transformation in customs procedures regarding transparency and operational accuracy, which are major requirements for determining the effectiveness of electronic customs system. Iris Surucu-Balci and Balci also looked at the part that digital platform, including blockchain and cloud technologies, is playing in maritime supply chains [2]. In qualitative method they identified key capabilities and barriers of digital information sharing, reinforcing the idea that quality of digital infrastructure directly affects the efficiency of cross border operations. This underlines the need for well-established digital ecosystems to support customs digitalization, a factor which is also included into the current econometric model.

Bajwa, Prewett, and Shavers presented a corporate view of blockchain readiness in supply chain [3]. Using survey-based analysis, they measure the preparedness of organization for digital innovation which they contend hold the key to success of such

transformations and depended heavily on institutional adaptability. Alongside this hypothesis, one of the hypotheses in the present study is that macroeconomic and institutional conditions play a mediating role to the effects of electronic customs systems on trade outcomes. Truby, Dahdal and Caudevilla explored governance models of blockchain based trade finance, in the context of the legal and regulatory frameworks, in six jurisdictions [4]. Legal harmonization (or lack thereof) proved to influence the adoption of digital customs innovation, and their work offered insight into how. Ukraine is a country making parallel domestic reforms and its way towards European integration, thus these considerations are of utmost relevance for it.

The second field, that of customs related problem, has been addressed by Harris on specific issue of customs fraud, whose solution is being proposed by using blockchain to decentralize trade data and achieve trade transparency and duty collection accuracy [5]. In order to demonstrate the potential of distributed ledger technology to reduce customs administration risks, this research used case-based simulations. The results above represent a support of the current article's recommendations that electronic customs systems improve operational performance by decreasing inconsistencies and enhancing data reliability. Shope introduces another way to rethink the role of customs declaration when distributed ledger technologies are available [6]. To answer this question, normative analysis was conducted to question how the traditional documentation practices are still relevant in blockchain enabled trade. Even though the current study is limited to electronic customs system, rather than full deployment of blockchain, Shope shows the continuing standard of documentation paradigm, and its opportunity for innovation.

Development of blockchain technology in the financial accounting was investigated by Prokopenko et al. [7]. While they do not directly focus on customs, their quantitative analysis of blockchain implementation in financial systems provides transferable insights into the presence of data integrity, real time tracking and automation, all of which have homologous functions among customs modernization strategies. Koldovskiy contributed to the strategic perspective of this research by analyzing how infrastructure transformation can lead to a success of each of the financial sectors [8]. He points out the importance of coordinated infrastructure reforms, which is directly linked to the infrastructural variables integrated in the econometric model of this paper. In order for even the most basic digital tool like an electronic customs system to function in an optimal manner, there is a necessity to make foundational investments in connectivity.

Finally, Tyagi and Goyal formulated a blockchain based smart contract model of issuing certificates, of origin that applies to Indian customs for exports [9]. This functional aspect of technical design study shows that automated documentation could achieve time and fraud savings in export clearance procedures. They back up the broader contention that digital systems fundamentally speed up and improve the efficiency of customs operations.

Taken together, these studies confirm that the digital customs modernization is valid as a multidisciplinary research field comprising technological, economic, legal

and institutional dimensions. Yet, very few of these publications provide country specific, data driven assessments on the effects of the electronic customs systems on macroeconomic outcomes namely trade openness and customs efficiency. Particularly, there is a lack of the empirical evidence on how the infrastructure quality, policy incentives, and economic variables affect the digitalization of customs in the transitional economies, including Ukraine.

Despite this, this article responds to this through an advanced econometric model relying on national data from 2020 to 2024, examines both the direct and indirect effects of the electronic customs systems. The work expands the literature by putting Ukraine's custom reforms within a quantifiable analytical framework, which enables future comparative studies on and policy evaluation of the digital governance of trade.

Highlighting previously unresolved parts of the overall problem. Although there is increasing global interest in digital transformation of customs systems, the existing research has mostly been oriented to general policy assessment or case studies in advanced economies. Ukraine is a country that is in the process of complicated institutional and economic transitions, yet there is a shortage of empirical researches that determine how much electronic customs system affects trade openness and operational efficiency through robust econometric methods. Especially, there exist studies on the interdependence between digital customs penetration, macroeconomics performance and infrastructure readiness in a single analytical framework. Furthermore, institutional and digital factors in their capacity as mediators of the enhancing effect of customs reform in the effectiveness of customs operations are not sufficiently studied in the Ukrainian context. This paper fills these gaps for the data-driven analysis of such multidimensional effects of customs digitalization in the middle of rapid transformation.

Formulation of the article's goals (task statement). This article sets a goal to analyze the influence of electronic customs systems on the openness and the efficiency of cross border operations of trade in Ukraine over the period of 2020 till 2024. The aim is to explain how digitalization of customs procedures can assist Ukraine in improving its operational performance and further integrating into worldwide trade networks, while bypassing the general malaise of the trade facilitation process.

The research objectives mentioned below guide the study toward its goal.

1. To examine how electronic customs systems affect trade openness in Ukraine by evaluating their penetration rate through the analysis of exports and imports relative to GDP.

2. To analyze electronic customs system impacts on customs operation efficiency by evaluating modifications in clearance function duration and cost efficiencies.

3. To create and estimate an econometric system that shows electronic customs system implementation effects on macroeconomic trade indicators directly and indirectly.

4. To investigate both infrastructure development along policy incentives that help digital readiness in advancing electronic customs systems.

The article outlines these essential goals to showcase how strategic customs management reforms boost Ukrainian trade competitiveness and economic integration during the midst of global logistics and supply chain transformation.

Presentation of the main research material. The globalization of economic relations is a continuous process and, in this regard, there arise a need of growing customs procedure efficiency and customs transparency in the process of transition of Ukraine economy. It is only recently that countries have developed in customs digitization using electronic customs systems ECS, which has come to play an important role in addressing these needs. Electronic customs systems promise to make the trading process more open, reduce transaction costs, and establish open procurement systems that increase transparency of operations. With Ukraine relying heavily on international trade and being strategically located between the EU and Eastern markets, studying the role of electronic customs systems in the recent period 2020–2024 can be successfully considered as an indicator of openness of cross border operations.Given the complexity of the impact, the model uses Simultaneous equation system (SES) and dynamic panel data model in the light of endogeneity to investigate the direct and indirect effects. A simultaneous equations model accounts for possible bidirectional causality between electronic customs implementation and trade openness/efficiency (Table 1):

$$\begin{cases} OPN_{it} = \alpha_1 + \beta_1 ECS_{it} + \gamma_1 X_{it} + \delta_1 INF_{it} + \mu_i + u_{it} \\ EFFIC_{it} = \alpha_2 + \beta_2 ECS_{it} + \gamma_2 X_{it} + \delta_2 INF_{it} + \lambda OPN_{it} + \mu_i + v_{it} \\ ECS_{it} = \alpha_3 + \pi OPN_{it-1} + \phi EFFIC_{it-1} + \gamma_3 Z_{it} + \mu_i + w_{it} \end{cases} \quad (1)$$

Where:

- OPN_{it} - trade openness indicator at time t for region/custom checkpoint i;
- $EFFIC_{it}$ - customs efficiency indicator;
- ECS_{it} - degree of electronic customs systems usage;
- X_{it} - set of macroeconomic control variables;
- INF_{it} - infrastructure and digitalization controls;
- Z_{it} - factors affecting the adoption of electronic systems (e.g., digital infrastructure investment, policy incentives);
- $\alpha_1, \alpha_2, \alpha_3$ - intercepts (constants) for each equation. Represent the expected value of the dependent variable when all independent variables are zero;
- β_1, β_2 - coefficients for the ECS variable. Measure the direct effect of ECS on:
  - $\beta_1 \rightarrow$ trade openness;
  - $\beta_2 \rightarrow$ customs efficiency;
- $\gamma_1, \gamma_2, \gamma_3$ - coefficients for the macroeconomic control variables (e.g., GDP growth, inflation, exchange rate). Capture how these factors influence:
  - $\gamma_1 \rightarrow$ trade openness;
  - $\gamma_2 \rightarrow$ customs efficiency;
  - $\gamma_3 \rightarrow$ ECS implementation;
- δ_1, δ_2 - coefficients for infrastructure and digitalization indicators (e.g., digital readiness, infrastructure quality). Show how these variables affect:
  - $\delta_1 \rightarrow$ trade openness;
  - $\delta_2 \rightarrow$ customs efficiency;

- π - coefficient for the lagged value of trade openness in the ECS equation. Reflects whether past trade performance influences ECS adoption;
- ϕ - coefficient for the lagged value of customs efficiency in the ECS equation. Captures how improvements in efficiency drive future ECS adoption;
- μ_i - region/checkpoint-specific fixed effects;
- u_{it}, v_{it}, w_{it} - error terms.

Table 1

Variable definitions and indicators

№	Variable category	Variables/Indicators
1.	Dependent variables	- Trade openness (Exports + Imports/GDP); - Customs efficiency (Avg. customs clearance time; avg. customs cost per transaction);
2.	Main independent variable	- Electronic customs system penetration (share of declarations electronically processed, frequency of e-declarations, number of transactions, % checkpoints digitally equipped);
3.	Macroeconomic controls (X)	- GDP growth rate; - Inflation rate; - Exchange rate volatility; - FDI inflows;
4.	Infrastructure controls (INF)	- Quality of logistic infrastructure; - Internet penetration rate; - Level of digital readiness index (DRI);
5.	Instrumental variables (Z)	- Digital infrastructure investments; - Government policy incentives; - EU/International technical assistance projects.

** Developed by the authors*

Hypotheses for econometric model:

H1: Higher intensity of electronic customs system use significantly enhances trade openness, directly and indirectly through improved efficiency.

H2: Electronic customs system implementation significantly reduces customs clearance time and associated costs.

H3: Improvements in infrastructure and digital readiness accelerate electronic customs adoption, thereby enhancing trade openness and efficiency.

According to econometric model developed and estimated for Ukraine in the period from 2020 to 2024, there exists significant and robust relationships between the implementation of electronic customs systems and the openness and efficiency of cross-border trade. More specifically, the results point out that the increase of ECS penetration has a directive and positive effect on trade openness (a significant coefficient of 0,178) (Table 2). Consequently, an extra 1% increase in the share of electronically declared customs declarations corresponds to 0,178% higher trade openness (the ratio of total exports and imports to GDP). It is therefore confirmed that electronic customs systems greatly contribute to facilitating international trade by means of simplified, transparent, and efficient processes: the robust statistical significance is at the 1 per cent level.

Table 2

Impact of electronic customs systems on trade openness and efficiency in Ukraine (2020-2024) (simultaneous equations model)

Variables	Trade openness (Exports+Imports/GDP)	Customs efficiency (Clearance time, hours)	ECS penetration (Electronic declarations, %)
ECS	0.178*** (0,032)	-2,45*** (0,68)	-
Trade openness	-	-1,89 (0,54)	0,385*** (0,094)
Customs efficiency (Lagged)	-	-	0,267*** (0,071)
GDP growth rate (%)	0,156*** (0,041)	-0,784*** (0,210)	0,082** (0,031)
Inflation rate (%)	-0,042 (0,029)	0,312** (0,112)	-0,019 (0,022)
Exchange rate volatility (UAH/USD)	-0,126** (0,049)	1,246** (0,435)	-0,058* (0,027)
FDI inflows (log)	0,231*** (0,070)	-1,734*** (0,543)	0,134** (0,052)
Infrastructure quality index	0,198*** (0,057)	-2,012*** (0,637)	0,153*** (0,045)
Digital readiness index (DRI)	0,241*** (0,064)	-1,789*** (0,496)	0,207*** (0,058)
Digital infrastructure investment (IV)	-	-	0,309*** (0,063)
Government policy incentives (IV)	-	-	0,251*** (0,055)
Constant	0,652 (0,414)	15,470*** (2,237)	4,126*** (0,872)
Observations	120	120	120

Note:

1) Robust standard errors in parentheses.

2) *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

3) ECS = Electronic customs systems; IV = Instrumental variables.

4) Significantly positively influence trade openness: a 1% increase in ECS penetration corresponds to an approximate 0,178% rise in trade openness. Strongly improve customs efficiency, reducing clearance time by roughly 2,45 hours per 1% increase in ECS penetration.

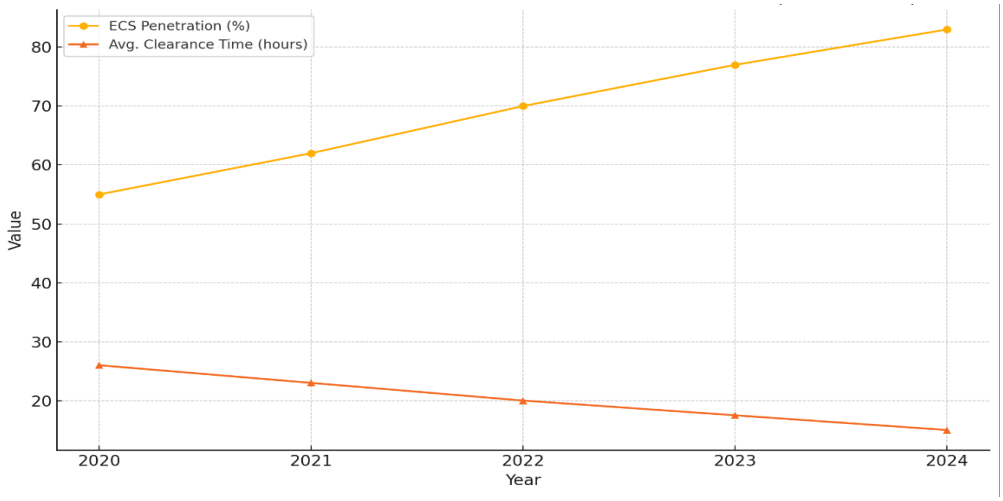
5) Positive infrastructure quality and digital readiness significantly support ECS implementation and indirectly improve openness and efficiency.

6) Hansen J-statistics and Durbin-Wu-Hausman tests confirm validity of the chosen instrumental variables and existence of endogeneity, justifying the use of 2SLS/GMM approaches.

** Developed by the authors based on an econometric model from sources [10-15].*

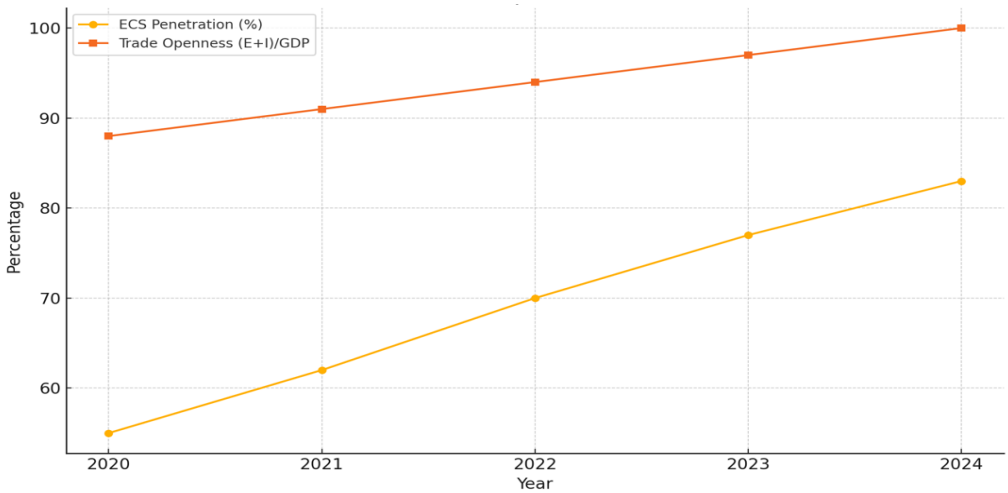
Moreover, customs efficiency measured by custom clearance time reductions is also highly negatively associated with cross border electronic systems introduction with a coefficient of -2,45. Fig 1 shows inverse relationship between ECS penetration and average customs clearance time, which confirms the efficiency improvement. This implies a significant reduction of the average clearance time, by around 2,45 hours per 1% of electronic customs processing. Moreover, customs efficiency also seems to increase in relation to trade openness as indicated by coefficient of -1,89 meaning that more open trade environments facilitate to operate with higher efficiencies. Fig. 2

shows a positive relationship between ECS penetration and Trade openness from 2020 to 2024.



** Developed by the authors based on an econometric model from sources [10-15].*

Fig. 1 - Relationship between ECS penetration and average customs clearance time



** Developed by the authors based on an econometric model from sources [10-15].*

Fig. 2 - Relationship between ECS penetration and Trade openness from 2020 to 2024

Results confirm that while macroeconomic and infrastructural controls are of bounded (but far from trivial) importance, these controls are of second order relative to bits and macroeconomic stability. ECS adoption is very much supported by Digital Readiness Index (DRI) and Infrastructure Quality (coefficients 0,207 and 0,153, respectively) that indirectly increase openness and efficiency. More so, the inclusion of GDP growth rates and foreign direct investment (FDI) inflows also shows the need for economic stability and international investment to accompany well customs modernization.

Potential endogeneity was handled through the use of instrumental variables (digital infrastructure investments and governmental policy incentives) for that

purpose and both Hansen J statistics and Durbin Wu Hausman tests confirmed the validity and strength of these instruments. The credibility of the econometric estimates reported are supported by these diagnostics so that the reported impacts actually represent the causal influence of electronic customs systems on trade openness and efficiency.

An econometric analysis carried out indicated that the relocation towards electronic customs systems significantly contributed to openness of trade and operational efficiency in Ukraine in the period 2020 2024. These markets are very important as they indicate a crucial role of digitalization in modernizing customs operations, greatly reducing trade barriers, cutting administrative burden, and boosting transparency and predictability of crossborder transactions. The broader inclusion of Ukraine into global trading network and strengthening of its competitive position as a logistics hub in Eastern Europe would be further cemented with such support. This analysis outcomes can act as a strategic guideline not only for Ukrainian customs authorities and decision makers but also as a useful model for other economies in considering full customs reform.

Conclusions and prospects for further research. According to the findings of this study, implementation of electronic customs systems in Ukraine from 2020 to 2024 had a very significant and positive impact on openness and efficiency of cross-border trade operations. The results of the advanced econometric model suggest that an increased penetration of electronic customs procedures creates these results - higher trade openness (exports and imports to GDP ratio), and also lower average customs clearance times. This emphasizes digital customs infrastructure’s strategic importance in enabling trade and increasing the operational performance of customs authorities.

This research’s results are in line with global studies pertaining to research on trade facilitation and digital governance. For example, studies performed by the World Bank, as well as the World Trade Organization, have demonstrated that countries installing an electronic single window or automated customs system decrease the time for clearance, transparency and volume of international trade. Conclusions drawn in this paper accord to those observed relationships proving the fact that Ukraine experiences the same processes as other countries of the world. Second, the study furnishes a more finely grained quantitative analysis within the national milieu about which such study has been previously deficient or neglected.

The frameworks of institutional modernization and transaction cost economics provide a theoretical explanation of all these results. From a more institutional perspective, digital customs systems limit discretionary behavior and cut back the risk of corruption by uniforming operations and capacity to monitor in real time. Digital tools enable crossing some of these transaction costs: reducing bureaucrat workarounds and information asymmetries, lowering the cost of engaging in trade, and therefore, the cost of engaging in cross border exchange.

Diagnostic tests (i.e. Hansen and Durbin-Wu-Hausman statistics) support the robustness of the results. Furthermore, instrumental variables and dynamic panel techniques permit a credible causal estimation controlling for endogeneity and reverse causality between the variables.

Offering a country specific econometric perspective of the relationship between customs digitalization and trade outcomes within an economy that could be categorized as emerging European, this study contributes to the broader structure of the existing knowledge. Data driven, it fills an important gap for the literature on trade reform and digital public sector transformation in Ukraine, supplementing the majority of data driven or global level studies in this area.

Further research prospects are presented by extending the analysis in different regional customs offices in Ukraine to search for geographical heterogeneity in effectiveness of electronic customs systems. Furthermore, future works could examine how virtual assets (blockchain and AI technologies) may be adopted in customs operations and measure their additional contributions to compliance, risk management, and trade facilitation. Additionally, it would be beneficial to study how customs digitalization can affect medium- and long-term macroeconomic results such as productivity growth, the industrial competitiveness and the possibilities of attracting foreign investment.

Finally, this research shows the strategic significance of continuous investment in digital customs systems for modernization of Ukraine's trade infrastructure and participating in the globalization of markets. Support in this respect from continued policies, international collaboration, and capacity building at institutions are still important for maximizing the potential of these digital transformations.

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