

Impacts of a Mandatory Shift to Decentralized Online Auctions on Revenue from Public Land Leases in Ukraine*

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Abstract: We analyze the impact of a 2021 reform in Ukraine that—after earlier digitization efforts did not produce desired results—mandated use of transparent online auctions by local governments rather than a central agency to lease rights to public agricultural land. The shift to a collusion-proof electronic auction system increased lease revenue by 175% for our preferred specification. Had all public land that Ukraine transferred since 2015 been auctioned using postreform mechanisms, local governments would have received incremental lease revenue of US\$500 million per year. Where public land is important, reforms to ensure rights to such land are allocated transparently, competitively and in a decentralized way could improve social, economic, and environmental outcomes.

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1. Introduction

Population growth, urbanization, and demand for environmental services imply that public land that was traditionally considered marginal and that is often still under communal management tends to become more valuable, resulting in higher demand for transfers of use- or ownership-rights to such land to private parties. Examples include land transfers for agricultural production to agri-business or ‘emergent farmers’; designation of land for provision of environmental services; and conversion of peri-urban agricultural land for urban use. Despite the size of this phenomenon, its potentially far-reaching implications for public revenues and sustainability, and widespread reports of unsatisfactory results, ways to achieve better outcomes have been little discussed in the literature.

With more than 10 million ha, Ukraine’s endowment of public agricultural land exceeds the total land area used for agriculture in many European countries. The effectiveness with which public land assets—which are likely to appreciate further with climate change and growth in global commodity demand—are used will affect not only global food supplies but also local communities’ income and ability to provide public services. However as in other developing countries with large endowments of public land, finding ways to ensure associated benefits accrue to locals remained a challenge. Limited capacity, elite capture, and corruption prevented efforts to increase local benefits from achieving their objectives.

A legal reform that abruptly shifted the modality for transferring public land from centrally organized in-person auctions to ones managed by local governments on a transparent electronic platform (Prozorro Sale) in a way that was both unanticipated and complete, provides an opportunity to explore if and to what extent changes in the modality of and responsibility for public land transfers affect outcomes in the form of auction revenue. A regression discontinuity design suggests that the move from centralized offline to decentralized online auctions increased prices received by more than 150%.

This result is robust to changes in bandwidth and use of a piecewise regression with kernel weights. Placebo tests for a pseudo-reform date that coincides with the passage of the law in question rather than its effectiveness produce insignificant results throughout. Beyond statistical tests, descriptive data support the notion that reduction of barriers that increasing competition and reduces information cost and elimination of central intermediaries who lack local information and owners’ incentives are key mechanisms driving our result: Reservation prices and the share of unsuccessful auctions were much higher after than before the shift to e-auctions. While there is no data on number of bidders for offline auctions, it is significantly higher under Prozorro than under a previous attempt to institutionalize e-auctions.

Although less rigorous methodologically than the RD design, adding data on (offline and online) auctions conducted in the 2015 to 2020 period allows us to corroborate the above evidence and assess the impact of

an earlier reform effort in 2018/19 that temporarily allowed auctions to be conducted either in person or electronically. For the latter, auctions were to be organized by a central body, the State Service for Geodesy, Cartography & Cadaster (SGC) on a different platform (SETAM) with several shortcomings, most importantly lack of a strict separation between auctioneer and participants that reduced trust and is alleged to have left room for manipulation. Prices in SGC-organized offline auctions are associated with prices lower by 28% to 38% than those organized by local government. Contrary to what we find for Prozorro Sale, e-auctions on SETAM are associated with a 21% lower price compared to offline auctions. In other words, a local government would have been able to obtain higher lease revenue by organizing an offline in-person auction directly rather than an online auction using SETAM organized by SGC.

Our paper contributes to three strands of literature. First building on evidence that by increasing access to information and reducing the need for personal interaction with bureaucrats, e-procurement can improve the quality of public procurement by attracting a greater number of bidders with higher quality (Lewis-Faupel et al., 2016), the notion that competitive auctions rather than ‘negotiated transfers’ of public land could increase transparency, land use efficiency, and local government revenue has long been discussed and reforms undertaken in several countries. However, unless auction mechanisms are collusion-proof (Che et al., 2018; Che & Kim, 2009), they may be manipulated, rendering reforms ineffective, as in China (Cai et al., 2013), where nontransparent mechanisms to transfer public land led to vast loss of resources and corroded governance more broadly (Chen & Kung, 2018). We build on this and show that (i) legislative and regulatory actions allow to quickly implement more transparent auction formats; (ii) such changes can have immediate, significant, and economically meaningful impacts on auction revenue; and (iii) although online auctions make it easier to achieve a more competitive outcome, they are not a sufficient condition and attention to auction design is a precondition for realizing beneficial effects in either format.

Second, the fact that far-reaching improvements in public land auctions’ competitiveness and transparency were possible in a country that has been ranked in the bottom half of global rule of law and corruption rankings during the 2015-20 period¹ illustrates the potential of digitization to improve governance and market functioning. We discuss that in our case, this effect was achieved by (i) reducing barriers to entry to enhance competition and transparency; (ii) eliminating the need for (central) intermediaries whose incentives are not necessarily aligned with those of land owners and who may suffer from conflicts of interest; and (iii) providing all interested parties with access to the same set of information and allowing creation of an audit trail to unambiguously determine if any procedural rules were violated, thereby creating a level playing field and reducing opportunities for corruption. The limited impact of earlier reform efforts

¹ Information as per the 2021 version of the worldwide governance indicators (Kaufmann et al., 2011) <https://info.worldbank.org/governance/wgi/>

suggests that digitization and the use of sophisticated technology such as blockchain cannot substitute for laws and regulations to structure incentives and enforce them.

Third, there is a general recognition that delaying macroeconomic reforms can come at a high price. In the case of Ukraine, Havrylyshyn (2017) argues that a 3-year delay of reform in 1991 imposed immense economic costs.² We show that delaying governance reforms has costs even in a reasonably sound macro environment and provide a microeconomic argument and econometric evidence to show that (i) legal reform will have the desired effect only if its provisions are fully implemented and relevant regulations to govern implementation are in place; (ii) delays in enacting reform laws or regulations can reduce the scope for decentralization and local democracy by privatizing assets that could have otherwise provided a basis for local governments' provision of public goods and services; and (iii) reform delays are costly: had the 2021 reforms analyzed here been put in place in 2017 instead of the e-auction 'pilot' and applied to land transferred via free privatization, the incremental annual revenue of local councils would be approximately US\$500 million or more than US\$1 million per rayon.³

The rest of the paper is organized as follows. Section two provides context and motivation by describing the institutional setting for public land management and transfer in Ukraine and describing the legal reforms undertaken in 2021. Section three discusses data and evidence from descriptive statistics and discontinuity plots for the mandatory shift from offline to online auctions. Section four uses parametric regressions to obtain a similar result, subject it to several robustness checks, and use longer-term data to compare the 2021 reform to earlier reform attempts and make inferences on the potential cost of reform delay. Section five concludes by identifying implications for policy as well as areas for future research.

2. Background and context

In many developing countries, large areas of land are under public ownership as is the case in Ukraine with a public land endowment of some 10 million ha. Nontransparent and centralized mechanisms to transfer rights to such land often result in land transfers to private parties below market value and in ways that are not conducive to effective land use or local development. While auctions can in principle prevent such outcomes, devising mechanisms that avoid auctioneer corruption or bidder collusion has often proved challenging. We describe earlier reform efforts in Ukraine and link them to the nature and modality of the 2021 reforms that are the focus of our analysis.

² Havrylyshyn (2017) argues that these costs accrued in three areas, namely, (i) macroeconomic deterioration and a decline in output (of 59%) without parallel in neighboring countries which the country recovered from only in the early 2000s; (ii) creation of an 'oligarchate' dependent on Russian hydrocarbons that would lose from and thus oppose any serious improvements in governance and rule of law; and (iii) inability to expeditiously embark on a path toward EU accession in concert with other accession countries.

³ From 1922-2020 when they were replaced by 1,469 amalgamated communities (*hromadas*), 490 rayons (districts) formed the country's second-level administrative divisions in 24 oblasts (region).

2.1 Public land management and transfers in the developing world

Increasing demand for land due to population growth, urbanization, and rising food and commodity prices often implied that use or ownership rights to large tracts of public or communal land reserves were transferred to private parties. The modalities of such transfers will affect social and economic opportunities at the local level in multiple ways. Potentially negative social effects of noncompetitive centralized transfers of public land in rural areas have been documented, particularly in the context of large-scale land acquisition in Africa and environmental governance and deforestation in Latin America.

In Africa, centralized and often nontransparent ways in which ‘unused’ public land is transferred to outside investors (Arezki et al., 2015), often driven by political objectives (Bélair, 2021; Dieterle, 2022; Widengård, 2019), creates a danger that neglect of local rights (Engström & Hajdu, 2019) or safeguards (Nolte & Voget-Kleschin, 2014) contributes to conflict (Sulle, 2020) or environmental damage (Shete et al., 2016) rather than improving food security (Müller et al., 2021), resource use (Rulli et al., 2013), or opportunity for existing land users (Lay et al., 2021). Noncompetitive land transfers often fostered speculation (Ali & Deininger, 2022) and failed to act as a catalyst for local development through improved access to technology (Ali et al., 2019), markets (Deininger & Xia, 2016), or skill-intensive employment (Anti, 2021; Glover & Jones, 2019), as was the case elsewhere (Kraus et al., 2021).

In countries such as Brazil or Indonesia, public land is often located at the agricultural frontier and deforested to myopically claim tenure rights despite the associated negative global and local externalities and revenue losses (Brito et al., 2019). Unless monitoring or enforcement systems are in place, policy makers may turn a blind eye to such ‘land grabs’, often to garner political favors (Bragança & Dahis, 2022; Cisneros et al., 2021; Pailler, 2018). In Colombia, large public land transfers replicated existing power structures and often benefited elites (Faguet et al., 2020).⁴

Auctions have been widely used to successfully transfer rights to valuable public assets, including radio spectrum (Weber, 1997), mineral exploration (Compiani et al., 2020), timberland (Athey et al., 2011), or debt obligations (Hortaçsu et al., 2018). Theory suggests that auctions will result in higher revenue than negotiated sales for sellers (Bulow & Klemperer, 1996) in a wide range of situations (Bulow & Klemperer, 2009). Actioning of public land indeed resulted in prices above those of available alternatives in urban settings such as Beijing (Qu & Liu, 2012), Singapore (Agarwal et al., 2018; Chow et al., 2015) or Hong Kong (Shen et al., 2019). They were also used to privatize or liquidate agricultural land (Croonenbroeck et

⁴ Schemes to pay for environmental services (PES) can be allocated competitively even in settings with limited capacity (Ajayi et al., 2012) and provide public goods effectively if land rights are clear, leakage is avoided, and mechanisms to ensure additionality and sustainability are in place (Chabe-Ferret & Voia, 2021). The introduction of PES in settings where land rights or selection mechanisms are unclear may have unintended negative effects (Kansanga & Luginaah, 2019) by setting off a rush for property rights.

al., 2020; Hüttel et al., 2014; Hüttel et al., 2016) in former East Germany and elicited environmental conservation more effectively than random issuance of contracts in Malawi (Jack, 2013). However, vast amounts of rural land have been transferred to outside investors in Africa (Anseeuw et al., 2012), often in centralized and nontransparent ways (Arezki et al., 2015) in ways that fail to increase local food security (Müller et al., 2021), deplete local resources (Rulli et al., 2013), and may cause environmental externalities. Reliance on noncompetitive centralized processes for transferring land was often justified with reference to local elite capture or a lack of capacity to implement transparent auctions. Indeed, implementing collusion-proof auction mechanisms (Che et al., 2018; Che & Kim, 2009) to prevent manipulation has been a challenge in many settings. For example, in urban China, where income from public land leases accounts for large shares of local revenue, the conduct of auctions for all leases was mandated to halt corruption in 2010. However, the auction formats adopted were easy to manipulate (Cai et al., 2013), and collusive practices continued (Cai et al., 2017).⁵ The use of electronic online auctions could possibly alleviate such constraints, and we will draw on the example of Ukraine to assess the extent to which this is possible in practice.

2.2 Challenges of public land management in Ukraine

With approximately 25% of 41.5 million ha of agricultural land or 10.4 million ha in 2017, Ukraine's endowment of public agricultural land exceeds the total land area used for agriculture in most European countries.⁶ While public land cannot be sold, it can be leased with the resulting income expected to provide resources for local councils to deliver public services. However, public land—except that located within settlement boundaries—was traditionally administered by the SGC as a central agency.

To increase public lands' contribution to local revenue, leases have been auctioned to the highest bidder since 2013. The initial requirement of conducting auctions in person and in most cases having them organized by the SGC, a body whose incentives were not always aligned with those of local councils, tended to reduce auction revenue, however. In fact, a multiplicity of overlapping roles by SGC created potential conflicts of interest and opportunities for manipulation in three respects.

First, as information on what land is surveyed and its ownership status is available only to SGC officials, it was difficult for local governments to identify public land that could potentially be auctioned or to assemble attractive lots that would fetch high prices in an auction. Second, most public land to be auctioned still had

⁵ In Thai public procurement, there is indeed strong evidence of bid collusions in e-auctions, suggesting that other mechanisms may be more cost-effective (Santoso & Bourpanus, 2019).

⁶ At the beginning of 2017, the total area of agricultural state land was approximately 10.4 million hectares, 3.2 of which was used by state-owned enterprises (including 0.47 by the National Academy of Sciences), 2.5 in reserve, and 4.7 under lease. This is larger than total agricultural land in smaller European countries (e.g., the Baltics, the Czech Republic, the Slovak Republic, and Hungary) and close to all agricultural land in larger ones (e.g., Romania, Poland, France, and Germany).

to be surveyed and registered. As a result, the SGC could effectively regulate the supply of land via its de facto monopoly on cadastral surveying and its ability to initiate procedures of free land privatization as an alternative to land auctions.⁷ Finally, as the auction organizer, the SGC was able to influence the level of competition at any given auction, e.g., by disqualifying certain bidders or changing auction time or location at short notice. Analysis of pre-2021 agricultural land auctions suggests that SGC involvement is associated with 20-30% lower returns (Kvartiuk et al., 2022) and a much lower likelihood of successful auction completion (Neyter & Nivievskyi, 2022).

Implementation challenges associated with this model are illustrated by the fact that the area of public land transferred via noncompetitive means in 2017-20 exceeded that of land auctioned by a factor of at least five (Nivievskyi, 2020).⁸ The results of completed auctions also often fell short of expectations or were marred by allegations of auctioneer corruption and bidder collusion, not unlike those reported for Russian oil auctions (Marshall & Marx, 2009). Weak governance of public land spilled over into markets for private land through exercise of market power (Graubner et al., 2021) and manipulation by political elites (Zadorozhna, 2020).

In Ukraine, a first reform attempt in 2018 involved providing the option of conducting auctions online on an electronic auction platform (SETAM) already used to liquidate bankrupt firms' assets subsequently linked to a private blockchain. However, SGC's monopoly on auction organization remained in place, and concerns about the scope for manipulating the platform were never clearly resolved.⁹ The use of SETAM for public land auctions was discontinued at the end of 2019.

2.3 Ukraine's transition to and mechanisms for mandatory e-auctions

Ukraine has been in the vanguard of adopting of electronic processes for public procurement since 2015, a step that increased the number of bidders and reduced cost as well as contracting time (Kovalchuk et al., 2019). To build on this experience to help remedy the shortcomings described above, laws that mandated the use of a transparent electronic auction platform and the transfer of public land ownership to elected local councils were passed in mid-2021 after more than two years of discussion. Law 1423-IX (adopted on April 28, 2021) transferred ownership of nearly all state land to local communities, allowing them to organize auctions independently of the SGC. Law 1455-IX (adopted on May 18, 2021) mandates the exclusive use of an electronic online trading system to auction public land leases. A cabinet resolution

⁷ A monopoly of SGC on surveying implied that, for land yet to be surveyed, individuals had to pay SGC to identify, survey and auction the land.

⁸ Under 'free privatization', a right anchored in the constitution and executed by SGC, every Ukrainian citizen has the right to receive up to 6 parcels of land (of different land use types) for free. While this provision was rarely exercised in 2010-14, it was rediscovered in 2014, ostensibly to compensate war veterans. Anecdotal evidence -including by high-ranking officials claiming privatization of 5 million ha based on unpublished audits- suggest these provisions were widely abused.

⁹ See for example <https://ti-ukraine.org/en/blogs/selling-seized-assets-what-needs-to-change-in-setam-system/>.

appointing the state enterprise Prozorro Sale as the sole electronic trading platform was adopted on September 22, 2021. Software to conduct auctions was rolled out thereafter, and the first auctions using it were completed in November 2021. Auctions continued until February 2022, when the war brought auction activity for agricultural land to a temporary halt.¹⁰

The Prozorro Sale system, which has been used to auction other asset classes since 2017, aims to adapt insights from auction theory and mechanism design to Ukrainian conditions (Mylovanov et al., 2017). For public agricultural land, a sealed bid English auction is implemented in three steps. Auctions start with each of the participants offering a starting price after which they have 5 minutes to review (anonymous) offers by competitors. In each round, every participant has 3 minutes to either increase her bid by an increment of at least 1% or leave it unchanged in a sequence where the first to revise her offer is the bidder who submitted the lowest price in the previous round. Thus, the participant who submitted the highest bid in any given round has an advantage, as she can see and outbid other participants' offers in the next round.¹¹

The Prozorro Sale system differs from alternatives (including SETAM) in three ways. First, the system is accessed via Application Programming Interface (API) by trading platforms that provide services and assistance to users and earn commission on auctions they win. These platforms (currently 47) compete with each other, creating a strong incentive to monitor. The system administrator's role is strictly separate from that of trading platforms, and an oversight commission with representatives from government, business, and civil society independent from Prozorro Sale hears and arbitrates any disputes. Second, beyond trading platforms' and users' ability to monitor the progress of any auction on the system in real time, detailed information on auction participants' real identity and the documents they submitted is disclosed immediately after the auction ends. This allows interested parties to check results and, if collusion is suspected, file a case with the complaints commission or the court. Finally, to eliminate the danger of backdoors allowing access or manipulation by insiders, the software code for Prozorro Sales is open source and publicly available, so everyone can check and understand the working of the system.

3. Data and evidence from regression discontinuity plots

Descriptive data show that once regulation was in place, the legally mandated shift to online auctions was fully implemented; that number of bidders was significantly higher than in previous attempts at e-auctions and starting prices, the share of unsuccessful auctions, and final auction prices were significantly higher after than before the reform. Discontinuity plots suggest the shift to e-auctions was associated with a

¹⁰ Auctions were suspended in the context of martial law but reinstated by law on October 19, 2022.

¹¹ See <https://prozakupki.prom.ua/shho-obovyazkovo-treba-znati-dlya-efektivnoi-kupivli-u-prozorro-prodazhi/> for detailed description of auction rules and https://zakupki.prom.ua/sale_auction_sandbox to run a mock auction.

discontinuous jump in lease revenue to about double the original amount without significant change in parcels' size or normative value.

3.1 Data and descriptive statistics

Auction data for our analysis come from two sources. Data on a total of 31,483 auctions of public land for agricultural use¹² initiated before November 2021 were obtained from SGC's website, while information on 2,752 auctions of public land for the same land use classes conducted through the Prozorro Sales auction platform between November 2021 and March 2022 is available on the Prozorro Sales website.¹³ For each auction, we have information on the auction organizer (i.e., SGC or local government), auctioned parcels' normative monetary value (NMV),¹⁴ the auction outcome and, for successful auctions, contract length and the lease price paid by the winning bidder in UAH which we convert into US\$ at the auction month's rate.

To obtain parcel attributes that serve as controls in regression analysis, we used auctioned parcels' cadastral numbers to obtain parcel boundaries from the public cadastral map to compute distance from the parcel's centroid to Kyiv and the nearest main road, grain elevator, and city. Overlaying parcel shapes with land use maps constructed based on remotely sensed data that are available for every year since 2019 (Kussul et al., 2017; Shelestov et al., 2020) allows us to determine whether parcels up for auction were devoted to crops, pasture, forest, or other uses.

Figure 1 illustrates the national scope of the data and the timing of events by displaying the locations of the four types of public land parcels used in our analysis. Panel (a) shows the location of the 17,471 parcels auctioned offline in the pre-reform period (2015-November 2021); panel (b) that of the 2,581 parcels auctioned *online* via the SETAM electronic auction platform during the 2018/19 pilot; panel (c) the location of 1,172 parcels auctioned post-reform using Prozorro Sale between November 1, 2021 and February 24, 2022; and panel (d) the location of 329 parcels for which auctions were started on Prozorro Sales before the war and completed in its first three weeks (i.e., between end of February and mid-March 2022).

Table 1 documents auction volume and the evolution of the institutional environment, highlighting that since 2015, a total of 345,399 ha of agricultural land was transferred via 21,553 successful auctions, while 12,682 auctions were unsuccessful and had to be canceled. The annual auction volume increased from fewer than 2,000 (offline) auctions in 2015 to a peak of 8,710, 5,327 of which were successful and transferred

¹² Data state the intended purpose of the land with categories of commercial agricultural production (для ведення товарного виробництва); individual farming (для ведення фермерського господарства); individual farmers (фермерське господарство); or individual rural farming (для ведення особистого селянського господарства) by private individuals.

¹³ All auctions completed by March 31, 2022, had been initiated before the start of the war. We add a war dummy for auctions completed after February 24, 2022, to control for the change in expectations regarding future revenue from such land associated with the war.

¹⁴ The 'normative monetary value' provides the basis for land taxation. It is based on the presumed rental income from a parcel accounting for land quality, distance to infrastructure, parcel shape, and other environmental conditions and indexed to inflation.

83,269 ha, in 2018. It is evident that auctions initiated after the new legal framework had become effective in late September 2021 relied exclusively on the Prozorro online platform and were conducted by local governments rather than the SGC. This contrasts with the earlier attempt at policy reform, where voluntary use of the SETAM e-auction platform resulted in 6% and 51% of auctions in 2018 and 2019, respectively, having been conducted on this platform.

Table 2 provides descriptive statistics on auctions parameters (panel A) and parcel attributes (panel B) for auctions that were successfully completed in the 2021/22 period that is the focus of our analysis with data for offline and online auctions in columns 2 and 3, respectively, and a t-test for equality of means (or a non-parametric test for medians) between the two in column 3. With 3.75 bidders on average, auctions seem to have been competitive and, with 11.6% as compared to 10.6% of a parcels' NMV, the auction starting value was significantly higher for online auctions.¹⁵ Corresponding information for all auctions in appendix table 1 shows that, with 55% vs. 67%, the success rate is much lower for online as compared to offline auctions, consistent with auction organizers having stronger incentives.

There are also significant differences in auction outcomes: Median annual rent paid per ha is approximately \$87 for parcels auctioned offline vs. \$342 for those auctioned online through the Prozorro Sales platform, mirroring a similar jump (from \$157 to \$417) in mean value. With \$677 vs \$437, the median NMV is higher for parcels auctioned online than those offline, but the advantage of online auctions persists even if auction rental value is divided by NMV with increases from 20% to 51% for the median and from 26% to 47% for the mean associated with the shift from offline to mandatory online auctions.

With about 10 ha, auctioned parcels' size is well above the 3.5 ha for privately owned parcels based on the country's privatization (Deininger & Ali, 2023) and parcels auctioned online are more likely to be used for crops than forest or pasture and more distant from roads and Kyiv. Adding data on unsuccessful auctions in appendix table 1 does not result in significant changes in these.

3.2 Regression discontinuity analysis

Figure 2 panels (a) to (d) present discontinuity plots (Calonico et al., 2017) for weekly means of auction prices from January 1, 2021, to March 31, 2022, a period that spans 44 weeks before and 20 weeks after reform took effect with fitted polynomials of order 1 to 4. All plots suggest a significant and discontinuous upward shift with reform (from 4.5 to 5.5 in log terms), equivalent to a lease price increase of 1.5 times.¹⁶

¹⁵ While information on number of bidders is not available for offline auctions, table 5 shows that auctions on the Prozorro platform attracted a significantly larger number of bidders than those on the earlier e-auction platform SETAM.

¹⁶ As the war started on February 24, 2022 in week 17, the last three periods (week 17-19) refer to auctions completed under war conditions but initiated before the Russian invasion.

There are three reasons to believe that the timing and content of these laws were unexpected and that landowners did not delay auctioning off land in anticipation of obtaining a better outcome once legal changes had become effective. Almost two years elapsed between Parliament's approval of the two laws in the first reading and their final adoption in the second reading, so the timing of legal approval was difficult to anticipate. Drafts for the two laws, together with broader issues of opening the agricultural land sales market, were discussed intensively by officials and members of Parliament during the summer of 2019 and approved in the first reading (as draft laws 2194 and 2195) on November 14, 2019. The expectation at that point was that they would quickly become law to create the basis for transparent land governance needed for opening the agricultural land market, under a separate bill, to have expected effects. However, the issue became politicized, and an unprecedented number of amendments were made to both laws, aiming to overturn virtually all of the bills' substantive provisions.¹⁷ Moreover, laws 1423-IX and 1444-IX eventually became effective in the middle of the growing season in April/May when entering into new leases for crop or pasture lands (more than 80% of the total) seems impractical. After the Russian attack on February 24, 2022, martial law suspended new auctions of public land,¹⁸ providing us with a window from November 1, 2021, to March 31, 2022, in which mandatory use of e-auctions was in place that we use for our analysis.

If reform was not anticipated, other characteristics of auctioned parcels should not display any discontinuity around the temporal threshold (Hausman & Rapson, 2018). To check this, appendix figures A1-A3 provide discontinuity plots identical to figure 2 for weekly means of the size of auctioned parcels, their normative value, and the lease price obtained in the auction divided by the normative value with fitted polynomials of order 1 to 4. In the absence of anticipatory action, characteristics of auctioned parcels other than their price should not display any discontinuity around the temporal threshold. Regression discontinuity plots for weekly means of the size for auctioned parcels in figure A1 and their normative value in figure A2 point to little if any discontinuity that coincides with the reform date. While a minor increase in the normative value may be triggered by the automatic annual adjustment of normative values for inflation, we divide the

¹⁷ The laws' content remained unpredictable as, after their approval in first reading. More than 5,500 amendments were submitted for draft law 2194 (later passed as 1423-IX) and more than 2,000 for 2195 (1444-IX). Procedural rules required that every amendment be read, discussed, and put to a separate parliamentary vote. Political leadership was thus put in a situation where these laws could only be passed by having Parliament spend weeks of precious session time debating these amendments. Legal opinions unequivocally advised that the alternative of holding a vote to change procedural rules retroactively was not desirable as it would have resulted in all these laws to be rendered ineffective by court challenges to their legality. In fact, although the two laws had been envisaged as necessary precursors to the opening of the market for agricultural land, the law (552-IX) to effect this change was adopted on March 31, 2020, without the legal basis for transparent land market functioning in place. COVID19-related restrictions created additional hurdles soon thereafter, adding further uncertainty to the laws' timing and content. Eventually, the timing for passing the laws (in April/May of 2021), their entry into force (on May 24, 2021, for law 1423-IX and July 6, 2021, for law 1444-IX), and passage of regulations (in September 2021) were dictated by the need to avoid missing deadlines that would have resulted in forfeiture of large amounts of multilateral financing. The substantive content of regulating e-auctions remained highly contentious; with public pronouncements from influential Ministries for the President to veto law 1444 or to block issuance of implementing regulations, thus rendering the law ineffective.

¹⁸ We thus limit our analysis to auctions completed before March 31, 2022, all of which were initiated before the Russian invasion and add a war dummy for those completed after February 24, 2022, to account for the physical destruction (Deininger, Ali, Kussul, et al., 2023) and shift in farms' terms of trade (Deininger, Ali, & Fang, 2023) associated with this event.

auction price by parcels' normative value to allay fears that differences in productive capacity may drive our findings. The resulting discontinuity plot in figure A3 shows a discrete shift of this variable with the initiation of e-auctions on the Prozorro Sales platform, supporting our main argument.

4. Evidence from parametric regressions

Parametric regressions allow us to check the robustness of the above result, including via a placebo test, a narrower time window, and a piecewise linear regression. While none of these change the basic result, they also allow us to use data for the 2015-22 period to make comparisons between the impact of the 2021 reform and those of earlier reform attempts and make inferences on the potential cost of reform delay.

4.1 Parametric regressions and robustness checks

To complement the above regression discontinuity plots, we use rayon fixed effect regressions to assess the impact of exogenous legal and regulatory changes for auctions completed between January 1, 2021, and March 31, 2022. Indexing auctions by a , rayons by i , and years by t , we estimate

$$Y_{ait} = \beta_1 P_{ait} + \beta_2 SGC_{ait} + \delta X_{ait} + \alpha_i + \lambda_t + \epsilon_{ait} \quad (1)$$

where Y_{ait} is the log of the highest bid (US\$/ha) received for auction a in rayon i in year t ; P_{ait} is a dummy indicating whether the auction was conducted electronically on Prozorro Sales, SGC_{ait} is an indicator of whether the auction had been organized by SGC; X_{ait} is a vector of parcel characteristics that includes the normative value in logs, parcel area in logs, land use, and geographic characteristics, and a war dummy that equals one if the auction was completed after the war started; α_i s are rayon fixed effects; λ_t s can be either a year dummy or year fixed effects depending on the sample; and ϵ_{ait} is a random error term. Standard errors are adjusted for clustering at the rayon level throughout. Our main interest is in β_1 , the estimated impact of mandatory use of the Prozorro electronic trading system.

Table 3 displays the results from the basic regression for the entire time span of 65 weeks (column 1) and the narrower time window of 20 weeks centered around November 1 as the reform implementation date (column 2).¹⁹ The point estimate of 0.938 for β_1 suggests a 155% ($e^{0.938} - 1$) increase in rental revenue due to reform. Although the 65-week window is already quite short, there may be a concern that institutional changes that were implemented during this time may confound effects. Three candidate events are (i) the opening of agricultural land sales markets on July 1, 2021; (ii) the formal transfer of property rights to public land to local communities (on July 6, 2021); and (iii) the Russian invasion of Ukraine on February 24, 2022. As the 20-week window centered around the reform date excludes the first two events and we

¹⁹ The 2022-year dummy was included in the 2021/22 sample to capture any time effect that may have led to an increase in the price of Prozorro auctions. However, re-running the regression in table 3 (column 1) without a year dummy does not affect results.

can control for the third one by including a war dummy that takes the value of 1 for all auctions completed after the Russian invasion (but started before it), it is our preferred specification. Results are reported in column 2 of table 3. Using the shorter time window increases the point estimate for β_1 to 1.013, suggesting that the mandatory use of electronic auctions increased lease revenue by 175%.

Beyond estimates for β_1 , the point estimate of β_2 documents the association between auction revenue and organization of auctions by SGC rather than local councils. Although they cannot be interpreted in a causal sense due to underlying selection issues, point estimates of -0.418 and -0.559 suggest that having offline auctions organized by SGC rather than local councils resulted in significantly lower revenue. Agency costs thus seem to have outweighed any capacity advantages SGC as a central agency may have had over local councils. Other controls include (with coefficients in brackets) the parcel's normative value (0.596), its area (0.176), its use for crops (0.211) or forest (-0.266) compared to pasture as the omitted category, and -for the entire period- a war dummy (-0.408) that suggests a steep decline in leases after the war started.

Beyond using a narrower time window, we also perform a falsification test that uses only pre-reform data to see if any other unobservables may drive our results. We choose a hypothetical reform implementation date of May 18, 2021, the date when the law mandating e-auctions was passed, thus providing an implicit test of whether passage of the law rather than its mandatory implementation had any effect on auction outcomes. The results, in table 3 columns 3 and 4 for the full and narrow windows, respectively, show that in both cases, the coefficient on hypothetical online auctions is insignificantly different from zero while the size and significance of the coefficients on all other variables are similar to those obtained earlier.

As a further robustness check, we estimate a piecewise linear regression with a weekly time trend and the interaction of this trend with the postreform indicator in addition to the variables included earlier. Table 4 reports the results in a format identical to table 3. While the coefficients on the actual reform indicator are highly significant and similar in magnitude to those obtained earlier for the full and narrow windows, those on the time trend or its interaction with the postreform indicator are not significantly different from what had been obtained earlier in both cases. Similarly, the placebo test yields insignificant coefficients throughout, allaying concerns about other unobserved factors confounding the result.

The above regressions are for successfully completed auctions where winning lease prices are observed. Appendix table 1 suggests that, with 55% vs. 67%, the success rate for online auctions is much lower than for offline ones. Together with a higher starting price (11.6% vs. 10.2 of NMV) in online auctions organized by local governments rather than SGC, this could partly explain the rise in auction revenue observed here. We thus make use of information on reserve prices available in the data for an additional robustness check.

As we do not have a good instrument that could be used for a Heckman-type selection model,²⁰ we estimate a rayon random effects Tobit model with variable censoring point across auctions where, for unsuccessful auctions, the auction starting price as a percentage of the NMV is used as a left censoring point. Results, reported in appendix table 2, are substantively unchanged with online Prozorro auctions fetching significantly higher prices than offline ones. In our preferred specification, i.e., the 20-week window, the size of the estimated effect in the Tobit model is about 1.3 times that of the he fixed effects estimate and the absolute value of the coefficient on SGC organization is much larger, supporting the robustness of our estimates.

4.2 Price predictions and estimates of revenue loss from reform delay

The fact that the 2018/19 pilot discussed above allowed use of an alternative e-auction platform (SETAM) and the conduct of offline auctions pre-2021 by local councils and SGC allow us to make inferences on the potential effect of these arrangements on lease revenue. Table 5 displays descriptive data for successful auctions overall (column 1) and those conducted offline, online on SETAM, and online on Prozorro (in columns 2, 3, and 4), respectively. While mean area of auctioned parcels earlier is, with about 17 ha, much higher than those auctioned in 2021/22, the starting value is, with 8.44% and 9.72% of NMV under SETAM and offline auctions, respectively, much lower than for 2021/22 online Prozorro auctions.

We estimate regressions equivalent to (1) for two scenarios. One involves auctions conducted during 2018/19 when electronic and offline auction options were both available to compare offline vs. online auctions and those organized by SGC vs. local councils. A second one involves all auctions conducted in the 2015-22 period. As in both cases identification is much less robust, these regressions serve mainly to qualitatively illustrate differences between earlier and 2021 reforms.

Results, presented in table 6 for parcels auctioned in 2018/19 (columns 1 and 2) and those auctioned in the entire 2015-22 period (columns 3 and 4), suggest that offline auctions organized by SGC resulted in lease revenues that were lower by 20-33% than those organized by local governments, consistent with earlier findings. They also show, surprisingly, that lease revenue from auctions that were conducted electronically on SETAM (linked to the blockchain) rather than in person was 12% to 19% lower than that achieved by offline auctions. One explanation could be that, for the latter, bidders' physical presence limited the scope for manipulation. This illustrates that, while the use of IT provides enormous advantages if regulations are appropriate, digitization will not automatically improve transparency and, if the regulatory environment is

²⁰ Following Goncalves (2013), an indicator for repeat auctions that takes the value of one for parcels that had been put up for auction earlier but not been sold is a candidate for an instrument that is correlated with the reserve price but not the final price of an auction. While we can identify parcels that put up for auction that had not been sold earlier in our data, these were just mechanically relisted without any change in the auction starting price expressed as a percentage of the NMV, implying its unsuitableness to be used as an instrument.

defective, may make it easier to manipulate outcomes than traditional procedures. Coefficients on other variables are broadly in line with those obtained earlier.

Leasing out public land at a rate that is less than what could have been obtained via a transparent process constrains local governments' fiscal space and their ability to provide local public goods or social services for the duration of the contract. Using the coefficients estimated above allows us to quantify the amount of incremental income that could have been obtained had the two policy reforms discussed above, i.e., putting local governments rather than the SGC in charge of auction organization and using the Prozorro electronic auction platform, been implemented earlier. We do so by predicting, for each parcel auctioned in the pre-reform period, the lease price if, instead of conducting them offline or on SETAM, auctions would instead have been conducted on the Prozorro Sales platform and organized by local government rather than SGC.

The results presented in table 7 show that the mean annual lease revenue gain from shifting to the postreform modality of leasing would have been about US\$200/ha. Summing this over the 19,267 parcels (312,813 ha) auctioned before November 2021 suggests that local governments could have obtained additional annual lease revenue of US\$64.5 million over the life of the leases.

Beyond the 0.3 million ha of land that was leased via auction, at least 1.5 million ha of public land was transferred to individuals through 'free privatization' in 2017-2020 (Nivievskyi & Neyter, 2019). If the average quality of these parcels were equal to those subjected to auction, potential annual lease fees would be close to US\$ 300 per ha per year, implying a minimum of US\$ 450 million in lost lease revenue every year due to free land privatization. Taking the two figures together suggests that, had the 2021 reforms been enacted instead in 2017 and covered land subject to free privatization, incremental annual lease revenue would be more than US\$500 million per year. To put this in perspective, note that this could provide each of the country's approximately 400 rural rayons with an average income of US\$1 million per year in addition to paying an annuity to those who received land under free privatization in line with legal requirements.

5. Conclusion and policy implications

Secular increases in demand for land, including for environmental services, are likely to result in higher welfare, equity, and productivity only if rights to such land are clear and transferred competitively with local participation. Concerns about local capacity gaps or elite capture have often been used to justify the central allocation of rights to such land. The evidence presented here shows that even in a weak governance setting, a mandatory shift from centralized offline auctions to a well-designed electronic auction format by elected local councils instantly doubled revenue, pointing toward large unrealized potential for legal and regulatory changes to ensure that public land is transferred via competitive transparent processes.

We find that the mandatory introduction of transparent e-auctions organized by local councils instead of a central agency instantly increased revenue from public land leases by 175%. This effect materialized in an environment where corruption and elite capture were widespread; earlier introduction of e-auctions resulted in worse rather than better performance; and the modified process was in place for less than four months before being (temporarily) discontinued due to war. This suggests that a combination of legislative and regulatory action can quickly transform arrangements for public land transfers and have immediate and economically meaningful impacts. Conversely, the unsuccessful 2018/19 e-auction pilot implies that the use of IT is not a sufficient condition for transparent and competitive land transfer processes and, in a weak governance setting, may lead to worse outcomes.

While the literature has long pointed to the importance of rights recognition as a basis for effective land management (Baragwanath & Bayi, 2020; Blackman et al., 2017), our results suggest that ways to exercise or transfer such rights also matter, especially if demand for public land shifts. In Ukraine, auctions allowing local communities to transfer use rights to public land competitively could be implemented quickly and, as the software used is open source, can be adopted by countries interested in transparent public land transfers. However, the passage of laws to mandate a transparent and decentralized process incurred lengthy delays and was politically controversial, and significant amounts of potential local revenue were lost. Interventions that increase demand for public land thus may be more likely to have the desired impact and avoid unintended side effects if they are combined with laws and regulations that allow local institutions to benefit from such increases in demand.

Table 1: Summary of data and timing of policy reforms

	No. of auctions		Transferred area (ha)	Share of auctions..	
	Total	Successful		..online	..org. by SGC
2015	1,935	1,530	28,345	0	0.54
2016	2,817	1,916	42,754	0	0.87
2017	3,388	2,139	43,358	0	0.84
2018	5,108	3,519	65,859	0.06	0.85
2019	8,710	5,327	83,269	0.51	0.69
2020	2,431	847	13,408	0	0.50
2021	7,805	5,232	58,442	0.09	0.38
Pre-reform	7,094	4,774	54,425	0	0.41
Post-reform	711	458	4,017	1	0
2022	2,041	1,043	9,964	1	0
Total	34,235	21,553	345,399	0.22	0.61

Source: Own computation from SGC and Prozorro Sales data as described in the text.

Note: 'Reform' implies mandatory use of the Prozorro Sale e-auction platform by local governments as auction organizers from November 1, 2021, based on legislation and associated implementing regulations approved earlier.

Table 2: Descriptive statistics for successful auctions conducted in 2021/22

	Total	Offline	Online	t-test
Panel A: Key auction parameters				
Auction starting value (%)	11.26	10.62	11.60	***
Number of bidders	3.75	NA	3.75	
Auction contract price (US\$/ha) median	116.02	87.21	341.69	***
Auction contract price (US\$/ha) mean	219.36	157.28	416.79	***
NMV (US\$/ha) median	485.50	437.34	677.06	***
NMV (US\$/ha) mean	681.47	616.34	888.47	***
Organized by SGC	0.27	0.36	0.00	***
Contract length (years)	8.61	8.33	9.51	***
Panel B: Parcel attributes				
<i>Area and land use in 2020</i>				
Area (ha)	10.90	11.40	9.31	
Crops	0.43	0.42	0.46	***
Pasture	0.41	0.42	0.38	***
Forest	0.15	0.15	0.13	**
<i>Distance in km to</i>				
Main road	8.65	8.48	9.22	***
Nearest city	15.64	15.66	15.58	
Grain elevator	13.39	13.55	12.84	***
Kyiv	297.22	295.17	304.04	**
Total # of auctions	6,275	4,774	1,501	

Source: Own computation from SGC and Prozorro data as described in the text and t-test is for equality of means (medians) between online and offline auctions.

Note: Auction starting value is expressed as a percentage of the normative monetary value (NMV) to adjust for differences in land values. For offline auctions, information on auction starting value is available only for 816 out of the 4,774 auctions. Number of bidders is not available for offline auctions but as explained in the text, the number of bidders under Prozorro is significantly above that (3.57) under the Government's earlier effort to organize online auctions on the SETAM platform. Equality of medians is tested using nonparametric chi-squared test with the null hypothesis that the online and offline samples are drawn from populations with the same median. Stars indicate significance: * p<0.10, ** p<0.05, *** p<0.010.

Table 3: Regressions and placebo test for effect of Prozorro Sale online auction on lease prices

	Actual reform (reform on Nov1, 2021)		Placebo (reform on May 18, 2021)	
	all observations	20-week window	all observations	20-week window
Online auction on Prozorro Sales	0.938*** (0.0994)	1.013*** (0.154)	-0.0465 (0.0541)	-0.0707 (0.0645)
Offline auction organized by SGC	-0.418*** (0.0721)	-0.559*** (0.185)	-0.384*** (0.0795)	-0.284*** (0.0940)
Normative value (US\$/ha)	0.596*** (0.0324)	0.551*** (0.0645)	0.668*** (0.0347)	0.671*** (0.0417)
Parcel area (ha)	0.176*** (0.0251)	0.131*** (0.0473)	0.167*** (0.0248)	0.191*** (0.0271)
Dist. to primary road (km)	-0.0367* (0.0204)	-0.0163 (0.0310)	-0.0317 (0.0242)	-0.0251 (0.0279)
Crop land (lagged)	0.211*** (0.0324)	0.149*** (0.0527)	0.206*** (0.0378)	0.173*** (0.0511)
Forest (lagged)	-0.266*** (0.0407)	-0.287*** (0.0627)	-0.247*** (0.0466)	-0.290*** (0.0606)
Other land class (lagged)	-0.326 (0.282)	0.236 (0.215)	-0.423 (0.405)	-0.625 (0.642)
Post-invasion dummy	-0.408*** (0.105)			
Distance to nearest city (km)	0.0145 (0.0207)	0.00621 (0.0340)	0.0188 (0.0245)	0.0143 (0.0293)
Distance to Kyiv (km)	-0.385 (0.356)	0.224 (0.709)	-0.314 (0.414)	-0.357 (0.470)
Distance to elevators (km)	0.0388 (0.0395)	0.0524 (0.0568)	0.0252 (0.0402)	0.0142 (0.0433)
Slope	-0.00915 (0.00604)	-0.00413 (0.00781)	-0.00639 (0.00675)	-0.00372 (0.00866)
Altitude (m)	0.0870*** (0.0322)	0.130 (0.0881)	0.0640** (0.0269)	0.0381 (0.0244)
2022-year dummy	-0.0449 (0.108)	0.0373 (0.140)		
Constant	2.266 (1.990)	-1.061 (3.953)	1.571 (2.324)	1.899 (2.591)
N	6,134	2,124	4,716	2,800
R ² (within)	0.367	0.348	0.318	0.290

Note: Dependent variable is the lease price (US\$/ha) in logs. Regressions include rayon fixed effects. Covariates that are not indicator variables (i.e., normative value, distance to road) are in natural logs. The observations in the narrow window regressions are limited to days within 10 weeks of the start of online Prozorro auction. For the placebo test (columns 3 and 4), data is restricted to offline auctions in 2021 comparing prices on either side of the cutoff date May 18, 2021 (i.e., the date when the law that mandates electronic auction was passed). Robust standard errors adjusted for clustering at the rayon level in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 4: Regressions and placebo test with segmented regression and weekly trend

	Actual reform (reform on Nov1, 2021)		Placebo (reform on May 18, 2021)	
	all observations	20-week window	all observations	20-week window
Online auction on Prozorro Sales	1.046*** (0.0775)	0.801*** (0.177)	-0.0427 (0.0641)	0.0251 (0.0833)
Weekly trend	-0.00413* (0.00218)	0.0238 (0.0199)	-0.00539 (0.00514)	-0.0238** (0.0109)
Prozorro # Weekly time trend	-0.0107 (0.00758)	-0.0274 (0.0243)	0.00314 (0.00734)	0.0164 (0.0153)
Normative value (US\$/ha)	0.602*** (0.0212)	0.594*** (0.0380)	0.695*** (0.0258)	0.701*** (0.0368)
Offline auction organized by SGC	-0.520*** (0.0504)	-0.556*** (0.205)	-0.429*** (0.0528)	-0.383*** (0.0718)
Parcel area (ha)	0.165*** (0.0137)	0.127*** (0.0253)	0.171*** (0.0158)	0.188*** (0.0228)
Dist. to primary road (km)	-0.0363** (0.0143)	-0.0177 (0.0246)	-0.0364** (0.0186)	-0.0574** (0.0266)
Crop land	0.170*** (0.0290)	0.186*** (0.0469)	0.186*** (0.0351)	0.164*** (0.0481)
Forest	-0.279*** (0.0370)	-0.271*** (0.0606)	-0.248*** (0.0446)	-0.271*** (0.0656)
Other land class	0.0197 (0.164)	0.343 (0.239)	-0.0200 (0.292)	-0.0450 (0.253)
Post-invasion dummy	-0.340*** (0.0900)			
Distance to nearest city (km)	0.0288* (0.0161)	-0.00233 (0.0287)	0.0277 (0.0200)	0.0473 (0.0299)
Distance to Kyiv (km)	-0.274 (0.228)	-0.0858 (0.411)	-0.516* (0.280)	-1.008** (0.434)
Distance to elevators (km)	0.0548** (0.0239)	0.0257 (0.0431)	0.0282 (0.0293)	-0.0133 (0.0433)
Slope	-0.00345 (0.00524)	-0.000131 (0.00872)	-0.00108 (0.00683)	0.00876 (0.00968)
Altitude (m)	0.100*** (0.0240)	0.145** (0.0687)	0.0480*** (0.0171)	0.0350* (0.0195)
Constant	1.444 (1.269)	0.504 (2.337)	2.600* (1.564)	5.370** (2.424)
N	5,905	2,038	4,567	2,731
R ² (within)	0.619	0.737	0.557	0.584

Note: Dependent variable is the lease price (US\$/ha) in logs. Regressions include rayon dummies but not reported. Covariates that are not indicator variables (i.e., normative value, distance to road) are in natural logs. The observations in the narrow window regressions are limited to days within 10 weeks of the start of online Prozorro auction. For the placebo test (columns 3 and 4), data is restricted to offline auctions in 2021 comparing prices on either side of the cutoff date May 18, 2021 (i.e., the date when the law that mandates electronic auction was passed). Triangular kernel weights are used in all the specifications and robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 5: Descriptive statistics for successful auctions conducted in 2015-22

	Total	Offline	Online		t-test
			SETAM	Prozorro	
Panel A: Key auction parameters					
Auction starting value (%)	9.66	9.72	8.44	11.60	***
Number of bidders	3.64	NA	3.57	3.75	***
Auction contract price (US\$/ha) median	87.59	81.21	93.81	341.69	***
Auction contract price (US\$/ha) mean	153.17	132.96	136.64	416.79	***
NMV (US\$/ha) median	582.25	563.82	596.59	677.06	***
NMV (US\$/ha) mean	760.05	763.78	672.76	888.47	**
Organized by SGC	0.58	0.57	0.99	0.00	***
Panel B: Parcel attributes					
<i>Area and land use in 2020</i>					
Area (ha)	16.03	16.41	17.32	9.31	***
Crops	0.61	0.62	0.65	0.46	***
Pasture	0.27	0.26	0.23	0.38	***
Forest	0.09	0.09	0.07	0.13	***
<i>Distance in km to</i>					
Main road	9.31	9.30	9.38	9.22	
Nearest city	16.58	16.59	17.16	15.58	***
Grain elevator	13.56	13.50	14.43	12.84	***
Kyiv	312.33	309.85	334.55	304.04	***
Total # of auctions	21,553	17,471	2,581	1,501	

Source: Own computation from SGC and Prozorro data as described in the text and test is for equality of means (medians) between online auctions on SETAM and Prozorro.

Note: Auction starting value is expressed as a percentage of the normative monetary value (NMV) to adjust for differences in land values. For offline auctions, information on initial value is available in 13,513 cases and number of bidders is not available. Equality of medians is tested using nonparametric chi-squared test with the null hypothesis that the online and offline samples are drawn from populations with the same median. Stars indicate significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.

Table 6: Comparing effects of different e-auction platforms

	Auctions conducted in			
	2018/19		2015-22	
e-auction on Prozorro Sales			0.934*** (0.112)	0.926*** (0.108)
e-auction on SETAM	-0.158** (0.0615)	-0.124** (0.0613)	-0.209*** (0.0430)	-0.192*** (0.0413)
Offline auction organized by SGC	-0.273** (0.111)	-0.248** (0.107)	-0.394*** (0.0360)	-0.372*** (0.0350)
Normative value (US\$/ha)	0.678*** (0.0315)	0.649*** (0.0316)	0.627*** (0.0211)	0.595*** (0.0212)
Parcel area (ha)	0.125*** (0.0160)	0.130*** (0.0156)	0.113*** (0.0169)	0.119*** (0.0167)
Dist. to primary road (km)	-0.0380* (0.0217)	-0.0327 (0.0204)	-0.0416*** (0.0123)	-0.0376*** (0.0120)
Crop land (lagged)		0.238*** (0.0351)		0.278*** (0.0226)
Forest (lagged)		-0.233*** (0.0618)		-0.168*** (0.0303)
Other land class (lagged)		-0.0720 (0.327)		-0.109 (0.142)
Post-invasion dummy			-0.315** (0.123)	-0.340*** (0.118)
Distance to nearest city (km)	0.0221 (0.0257)	0.0134 (0.0257)	0.0173 (0.0153)	0.00755 (0.0153)
Distance to Kyiv (km)	-0.601 (0.536)	-0.530 (0.519)	-0.287 (0.191)	-0.309 (0.189)
Distance to elevators (km)	0.00293 (0.0384)	0.0137 (0.0375)	-0.000623 (0.0234)	0.00250 (0.0231)
Slope	-0.00968 (0.00761)	-0.0102 (0.00730)	-0.0155*** (0.00372)	-0.0137*** (0.00362)
Altitude (m)	-0.00223 (0.0535)	-0.00611 (0.0537)	0.117*** (0.0445)	0.101** (0.0424)
No. of obs.	4,480	4,480	20,699	20,688
R ² (within)	0.273	0.292	0.277	0.297

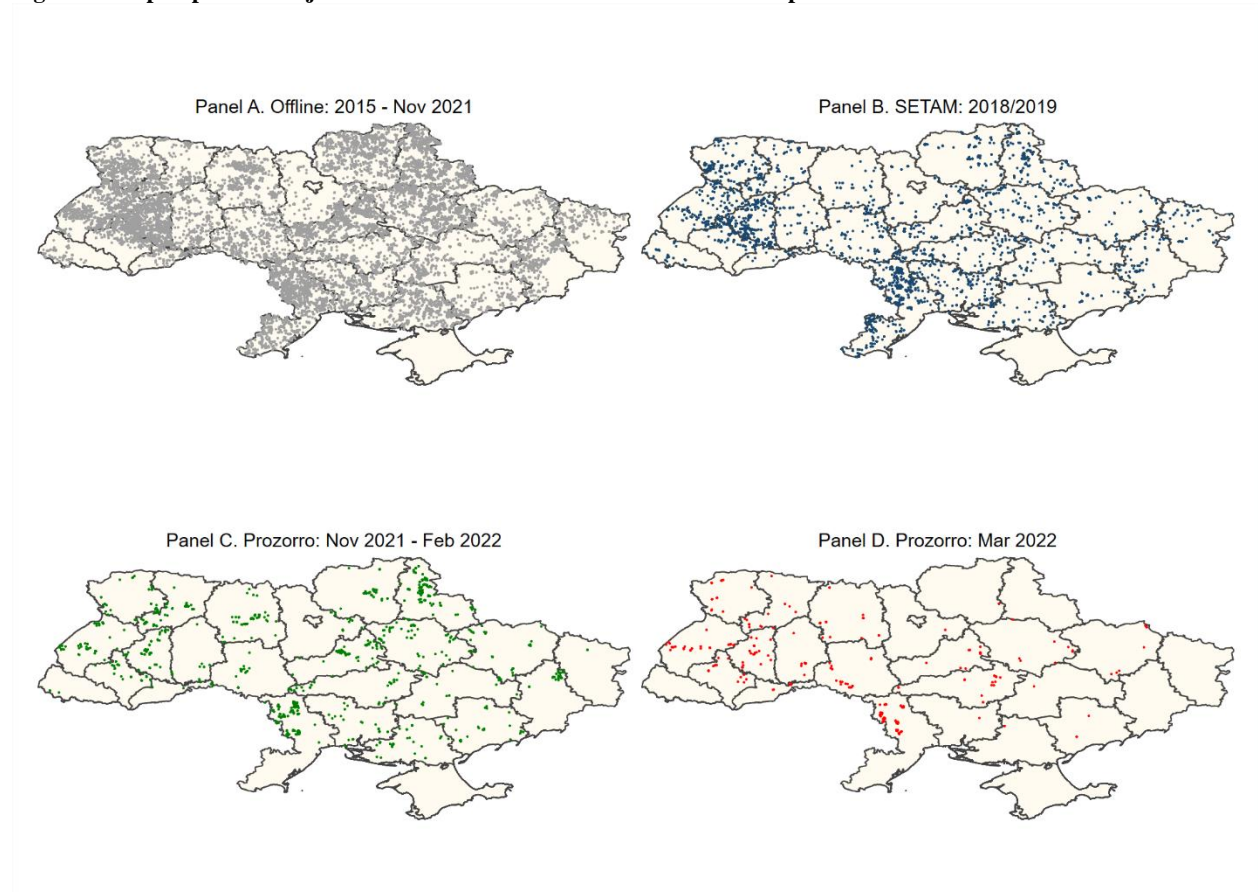
Note: Dependent variable is the lease price (US\$/ha) in logs with rayon fixed effects. Covariates that are not indicator variables (i.e., normative value, distance to road) are in natural logs. The observations for the SETAM sample are restricted to months when the SETAM platform was operational (2018/19). A year dummy for 2019 in columns 1 and 2, and year dummies for 2016-2022 in columns 3 and 4 are included but not reported. As we have access to annual crop cover estimates only for the period 2018-2022, we use the 2018 land use information for pre-2019 auctions. To show that the results do not depend on controlling for crop cover information, we estimate columns 1 and 3 by excluding these variables. Robust standard errors adjusted for clustering at the rayon level in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 7: Predicted revenue gain from transferring parcels transacted pre-reform under reform modality

	All parcels	Auction modality	
		Offline	SETAM
Predicted lease price (\$/ha per year) without reform	98.27	98.07	99.66
Predicted lease price (\$/ha per year) with reform	298.29	297.39	304.55
Total area auctioned Jan 2015-Nov. 2021 (ha)	312,813	271,727	41,086
No of parcels auctioned Jan 2015-Nov 2021	19,267	16,852	2,415
Potential lease price increment w. reform (US\$ mn/a)	64.48	55.66	8.81

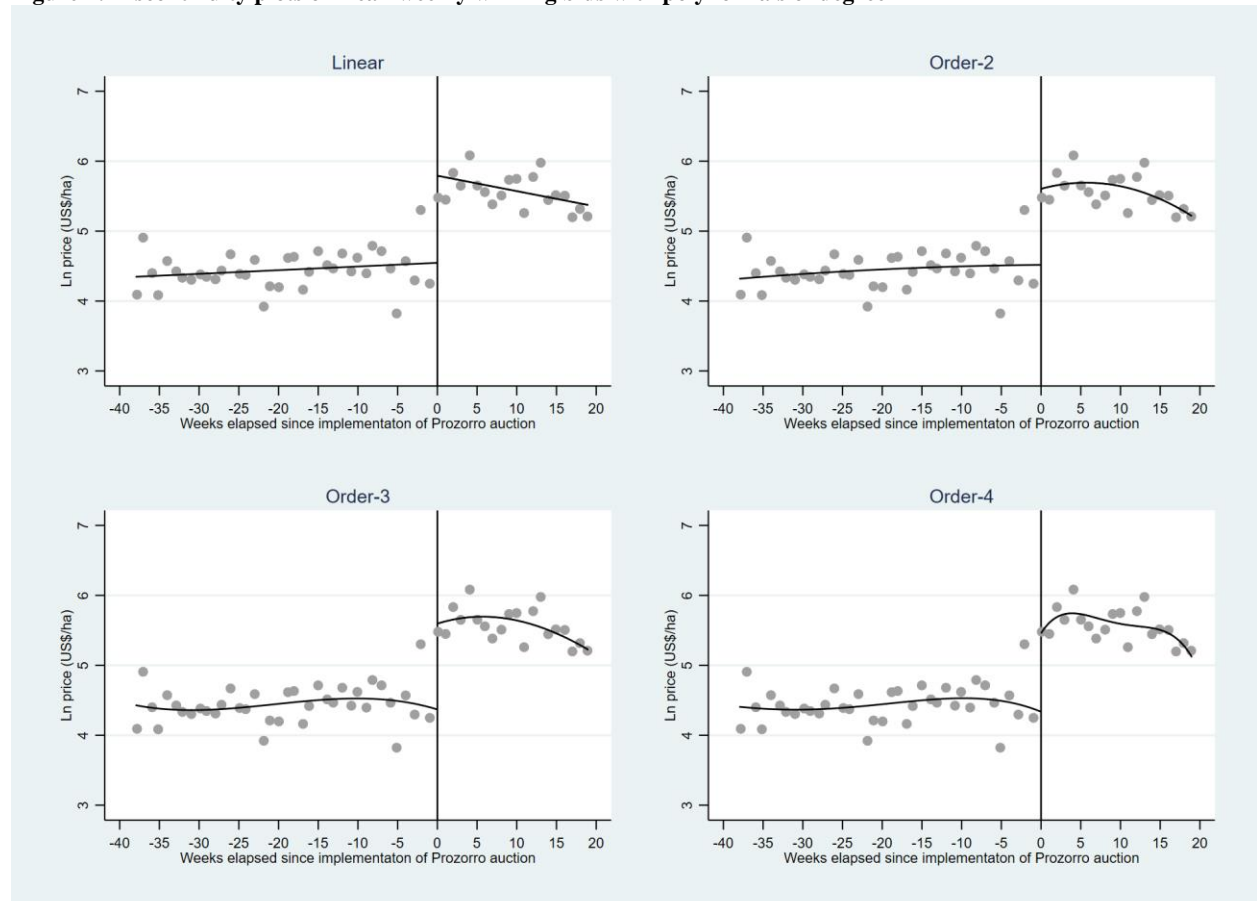
Source: Own computation based on regression results (table 6, column 4)

Figure 1: Map of parcels subjected to offline and online auction in different periods



Note: Panels A to D display the location of the public land parcels subject to offline auctions in 2015-21 (panel A); online auctions on the SETAM platform in 2018/19 (panel B); electronic online auctions completed on the Prozorro Sales platform post-reform but before the Russian invasion (Nov. 1, 2021 - Feb. 24, 2022); and electronic online auctions completed on Prozorro Sales after the invasion (panel D). While auction completed during the war are located outside of conflict-affected areas, in the pre-war period, all regions except Crimea were covered.

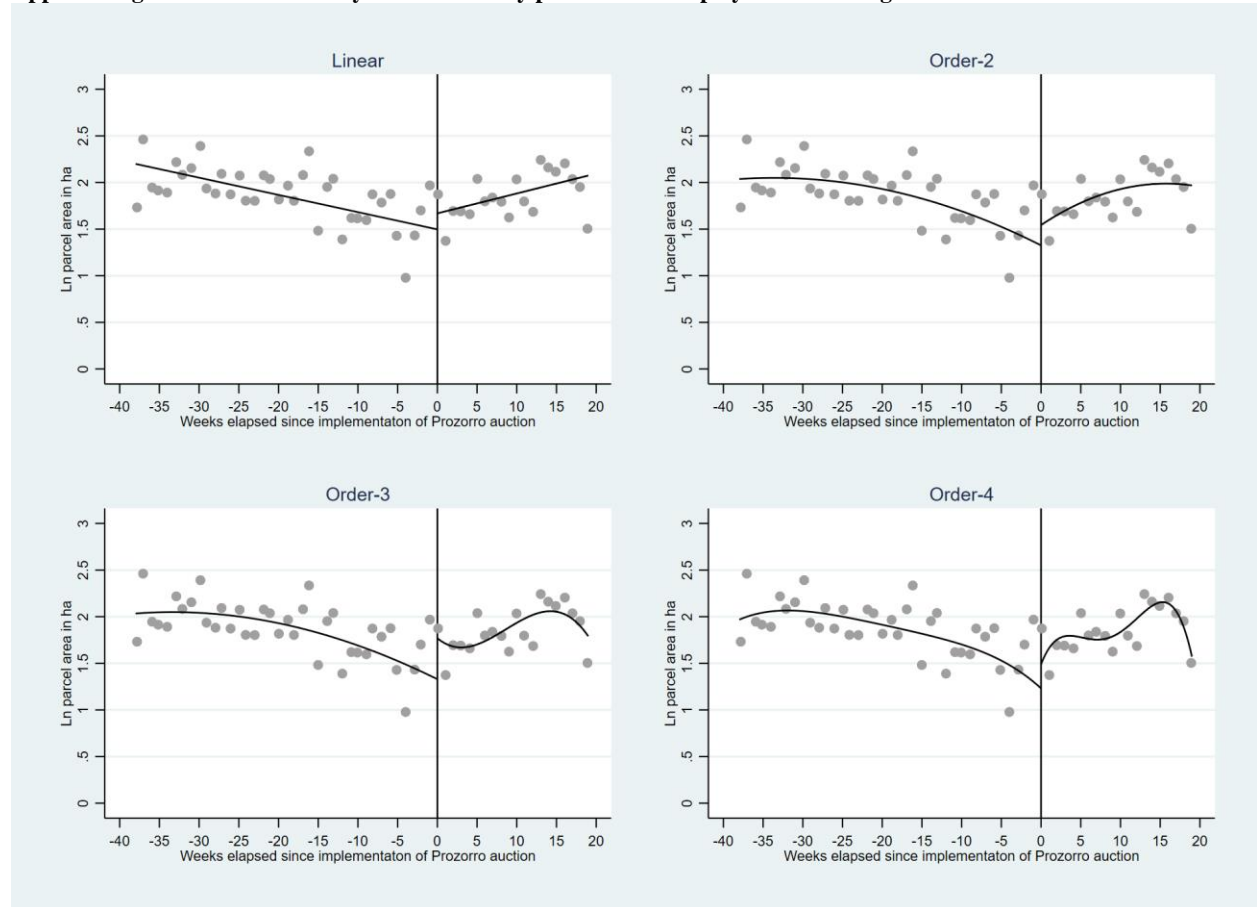
Figure 2: Discontinuity plots of mean weekly winning bids with polynomials of degree 1-4



Note: Panels 1-4 display discontinuity plots of mean auction prices achieved in each of the 40 weeks before and the 20 weeks after electronic auctions on the Prozorro sales platform were made mandatory (and after auctions were temporarily suspended due to Russia's invasion of Ukraine) using polynomials of order 1-4. A clear upward shift is visible in all cases.

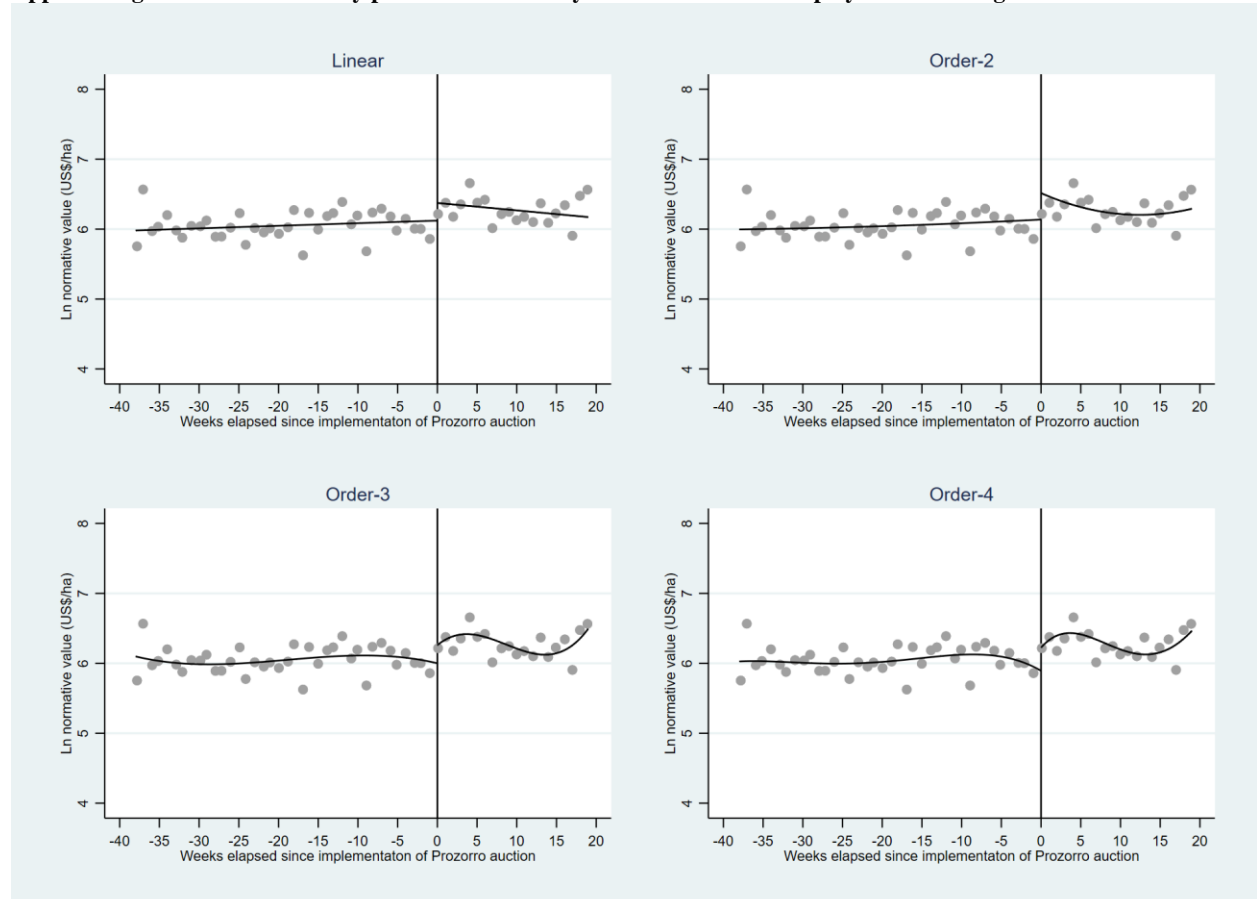
APPENDIX FIGURES – NOT FOR PUBLICATION

Appendix figure A1: Discontinuity of mean weekly parcel size with polynomials of degree 1-4



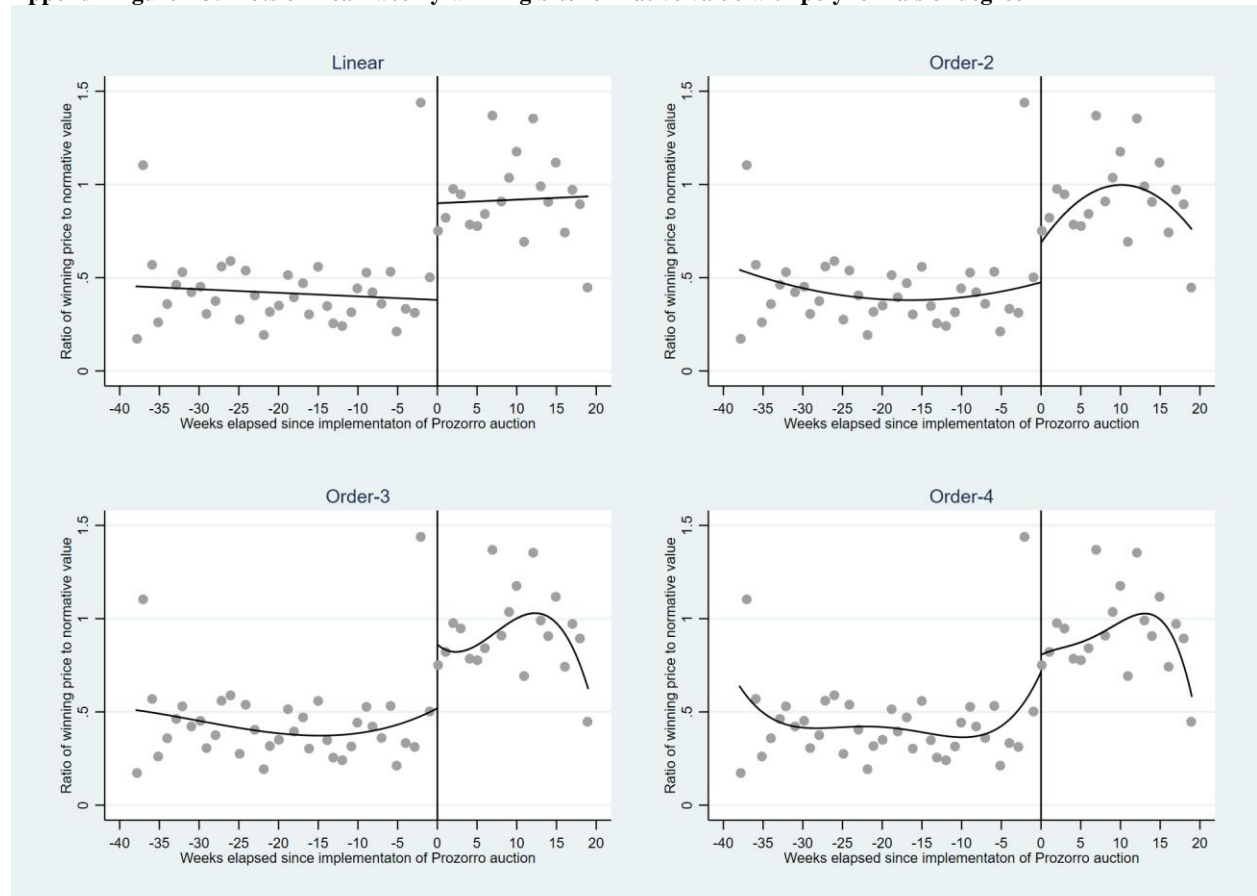
Note: Panels 1-4 display discontinuity plots of the mean size of parcels auctioned in each of the 40 weeks before and the 20 weeks after electronic auctions on the Prozorro sales platform were made mandatory using polynomials of order 1-4. In all cases, no clear shift can be detected as required for the RD design to be valid.

Appendix figure A2: Discontinuity plots of mean weekly normative value with polynomials of degree 1-4



Note: Panels 1-4 display discontinuity plots of the mean normative value of parcels auctioned each of the 40 weeks before and the 20 weeks after electronic auctions on the Prozorro sales platform were made mandatory using polynomials of order 1-4. In all cases, no clear shift around the cut-off can be detected as required for the RD design to be valid.

Appendix figure A3: Plots of mean weekly winning bid/normative value with polynomials of degree 1-4



Note: Panels 1-4 display discontinuity plots of mean auction prices divided by parcels' normative value achieved in each of the 40 weeks before and the 20 weeks after electronic auctions on the Prozorro sales platform were made mandatory (and after auctions were temporarily suspended due to Russia's invasion of Ukraine) using polynomials of order 1-4. A clear upward shift is visible in all cases.

Appendix table 1: Descriptive statistics for all auctions conducted in 2021/22

	Total	Offline	Online	t-test
Panel A: Key auction parameters				
Successful auctions (%)	63.73	67.30	54.54	***
Starting value (% of NMV)	11.16	10.20	11.58	***
Number of bidders	3.72	NA	3.72	
NMV (US\$/ha) median	462.78	423.75	579.29	***
NMV (US\$/ha) mean	756.88	680.93	952.51	***
Organized by SGC	0.30	0.41	0.00	***
Panel B: Parcel attributes				
<i>Area and land use in 2020</i>				
Area (ha)	13.22	11.82	16.81	
Crops	0.38	0.37	0.41	***
Pasture	0.44	0.46	0.41	***
Forest	0.16	0.16	0.15	
<i>Distance in km to</i>				
Main road	8.99	8.85	9.37	***
Nearest city	15.67	15.78	15.36	*
Grain elevator	13.69	13.83	13.31	**
Kyiv	311.94	316.06	300.97	***
Total # of auctions	9,846	7,094	2,752	

Source: Own computation from SGC and Prozorro data as described in the text.

Note: Auction starting value is expressed as a percentage of the normative monetary value (NMV) to adjust for differences in land values. For offline auctions, information on starting value is available only for 1,202 out of the 7,094 auctions. Number of bidders is not available for offline auctions but as explained in the text, the number of bidders under Prozorro is significantly above that (3.57) under the Government's earlier effort to organize online auctions on the SETAM platform. The equality of medians are tested using nonparametric chi-squared test with the null hypothesis that the online and offline samples are drawn from populations with the same median. Stars indicate significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.

Appendix table 2: Random Effects Tobit with variable censoring point

	2021/2022 sample	20-week window
Online auction on Prozorro Sales	0.665*** (0.0605)	1.197*** (0.0830)
Offline auction organized by SGC	-0.516*** (0.0402)	-1.505*** (0.321)
Normative value (US\$/ha)	0.710*** (0.0174)	0.673*** (0.0296)
Parcel area (ha)	0.202*** (0.0134)	0.178*** (0.0241)
Dist. to primary road (km)	-0.0273* (0.0145)	-0.0376 (0.0245)
Crop land (lagged)	0.338*** (0.0309)	0.256*** (0.0520)
Forest (lagged)	-0.332*** (0.0383)	-0.270*** (0.0610)
Other land class (lagged)	-0.366 (0.245)	-0.869** (0.437)
Post-invasion dummy	-0.924*** (0.0620)	
Distance to nearest city (km)	0.00698 (0.0169)	-0.00452 (0.0287)
Distance to Kyiv (km)	-0.409*** (0.0610)	-0.436*** (0.119)
Distance to elevators (km)	0.0372 (0.0248)	0.151*** (0.0455)
Slope	-0.0161** (0.00640)	-0.0196* (0.0106)
Altitude (m)	0.178*** (0.0288)	0.0214 (0.0629)
2022-year dummy	-0.102 (0.0672)	-0.141 (0.0901)
Constant	0.690* (0.399)	1.317* (0.764)
No. of obs.	9,396	3,341
Censored observations	3,262	1,217
Uncensored observations	6,134	2,124

Note: Dependent variable is the lease price (US\$/ha) in logs. Regressions include rayon random effects. Covariates that are not indicator variables (i.e., normative value, distance to road) are in natural logs. The observations in the narrow window regressions are limited to days within 10 weeks of the start of online Prozorro auction. Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Appendix table 3: Descriptive statistics for all auctions conducted in 2015-22

	Total	Offline	Online		t-test
			SETAM	Prozorro	
Panel A: Key auction parameters					
Percentage of successful auctions (%)	62.96	65.26	54.80	54.54	
Auction starting value (%)	9.55	9.52	8.44	11.58	***
Number of bidders	3.66	NA	3.62	3.72	
NMV (US\$/ha) median	522.57	505.48	548.08	579.29	***
NMV (US\$/ha) mean	810.68	818.49	704.38	952.51	***
Organized by SGC	0.61	0.61	0.99	0.00	***
Panel B: Parcel attributes					
<i>Area and land use in 2020</i>					
Area (ha)	16.47	16.34	16.97	16.81	
Crops	0.52	0.53	0.53	0.41	***
Pasture	0.32	0.31	0.30	0.41	***
Forest	0.13	0.13	0.12	0.15	***
<i>Distance in km to</i>					
Main road	9.25	9.24	9.24	9.37	
Nearest city	16.28	16.27	16.89	15.36	***
Grain elevator	13.92	13.81	14.97	13.31	***
Kyiv	319.37	318.57	335.13	300.97	***
Total # of auctions	34,235	26,773	4,710	2,752	

Source: Own computation from SGC and Prozorro data as described in the text.

Note: Auction starting value is expressed as a percentage of the normative monetary value (NMV) to adjust for differences in land values. For offline auctions, information on initial value is available only for 20,881 out of the 26,773 auctions. Number of bidders is not available for offline auctions. The equality of medians are tested using nonparametric chi-squared test with the null hypothesis that the online and offline samples are drawn from populations with the same median. Stars indicate significance: * p<0.10, ** p<0.05, *** p<0.010.

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