Journal of Comparative Economics 51 (2023) 1334–1343

Contents lists available at ScienceDirect

Journal of Comparative Economics

journal homepage: www.elsevier.com/locate/jce

Damaged collateral and firm-level finance: Evidence from Russia's war in Ukraine☆

Solomiya Shpak [a,b,c,*], John S. Earle [c,d], Scott Gehlbach [e], Mariia Panga [c]

[a] Kyiv School of Economics, Ukraine
[b] National Bank of Ukraine (NBU), Ukraine
[c] George Mason University, Schar School of Policy and Government, 3351 Fairfax Drive, Arlington, VA 22201, United States of America
[d] IZA, 3351 Fairfax Drive, Arlington, VA 22201, United States of America
[e] University of Chicago, Department of Political Science and Harris School of Public Policy, 5828 South University Avenue, Chicago, IL 60637, United States of America

ARTICLE INFO

Keywords:
War
Collateral
Default
Credit
Ukraine

ABSTRACT

How much has Russia's war in Ukraine damaged the collateral of Ukrainian firms, and how much damage has that caused the Ukrainian financial system? We address this question using unusually rich high-frequency supervisory data of Ukrainian banks combined with a survey of banks on the location and condition of corporate borrowers' collateral between February and November 2022. Exploiting plausibly exogenous variation in collateral value resulting from damage to collateral, we find that a 10-percent reduction in the collateral-loan ratio lowers the probability of getting any new loan by nearly eight percentage points; new lending falls by over two percentage points. Our results additionally imply that the same reduction in collateral value raises default rates and banks' assessment of firms' probability of default by approximately eight and four percentage points, respectively. The results imply that, in the absence of sufficient aid to repair the damage, Ukraine may experience reduced investment and lower economic growth in the future.

1. Introduction

There are many costs of war. Compared to the loss of life and limb, the permanent physical and psychological scars, the atrocities, and the destruction of families, hopes, and dreams, the economic costs may pale in importance, yet they remain considerable. Having reliable estimates of these costs and how they affect behavior has important implications for future recovery and reconstruction.

In this paper, we examine some of the economic consequences of war. Our case is Ukraine during the period following Russia's full-scale invasion on February 24, 2022. We emphasize firm-level outcomes in financial markets—costs that take place through damage to collateral.

Our empirical analysis relies on a remarkable dataset we have assembled using information on all large corporate loans in Ukraine outstanding from February to November 2022. The data include measures of the value and location of different types of collateral posted for each loan, information from summer 2022 on the loss of or damage to collateral, and basic characteristics of corporate borrowers and loan terms. With these data, we are able to assess how damage to collateral reduces collateral value, and how that

☆ We are grateful to Vasyl Boryshchuk for advice on data and NBU policies. For helpful comments, we thank Oleksiy Kryvtsov and Koen Schoors; participants at the Annual Bank Conference on Development Economics, the Schar School of Policy and Government, the NBU Research Seminar, and the annual meeting of the Association for Comparative Economic Studies; three anonymous referees; and the editors Tymofii Brik and Yuriy Gorodnichenko.

* Corresponding author at: Kyiv School of Economics, Ukraine.
E-mail addresses: sshpak@kse.org.ua (S. Shpak), earle@gmu.edu (J.S. Earle), gehlbach@uchicago.edu (S. Gehlbach), mpanga@gmu.edu (M. Panga).

https://doi.org/10.1016/j.jce.2023.06.010
Received 19 June 2023; Accepted 22 June 2023
Available online 28 July 2023

in turn affects the firm-level incidence of default, probability of default, and access to new borrowing. Our instrumental-variables estimates suggest that a 10-percent reduction in collateral the collateral-loan ratio lowers the probability of getting any new loan by nearly eight percentage points and decreases new lending by over two percentage points. We also find that the same reduction in collateral value raises default rates and banks' assessment of firms' probability of default by approximately eight and four percentage points, respectively.

Our research is directly related to previous studies of the "collateral channel" through which a shock to collateral value can generate multiplier effects by affecting borrowing ability (Barro, 1976; Bernanke and Gertler, 1989; Chaney et al., 2012; Gan, 2007). The small empirical literature on this topic focuses on "shocks" represented by changes in real estate prices associated with macroeconomic fluctuations. In the paper most similar to ours, Chaney et al. (2012) find that a $1 increase in collateral value of real estate increases debt issues by $0.095 and debt repayments by $0.05 in the U.S. around the turn of the century. In a similar vein, Gan (2007) finds reduced corporate borrowing and lower debt capacity associated with declines in property values in Japan during the 1990s.

Our work is also related to studies of figurative "collateral damage", which mostly focus on how war reduces international trade (Glick and Taylor, 2010). To our knowledge, however, no previous research has studied the literal damage to collateral value that takes place during a war, and the effects of that damage on financial markets.

Finally, we add to the growing efforts of many economists to estimate and analyze the costs of Russia's war in Ukraine for the Ukrainian economy. Most relevant for our work is the project "Russia Will Pay",[1] which has the goal of estimating all material damage caused to Ukraine's civilian infrastructure. According to their estimates, direct damages to the physical infrastructure of Ukraine from February 24, 2022 to February 24, 2023 reached US $143.8 billion. In related work, the World Bank estimates in its most recent Rapid Damage and Needs Assessment that the cost of reconstruction and recovery in Ukraine has grown to US $411 billion as of March 2023, and keeps rising (World Bank, 2023). Our paper is complementary to these efforts in that we focus on the cost of the war to Ukrainian firms from damage to collateral and thereby access to finance.

The paper continues in the next section with a background overview of the Ukrainian banking sector. The following sections discuss data, empirical strategy, and results. The final section concludes.

2. Overview of the banking sector in Ukraine

During the past two decades, the banking sector in Ukraine has undergone several macroeconomic crises and policy-related changes. The quality of corporate portfolios deteriorated dramatically in 2014–2015 due to the macroeconomic shock of the annexation of Crimea, the military conflict in the Donetsk and Luhansk regions, and large-scale structural imbalances in the economy (National Bank of Ukraine, 2016a). The crisis affected not only firms located in regions directly impacted by Russia's aggression but the whole Ukrainian economy. Losses for banks would have been smaller if the pre-shock quality of assets had not been overestimated and risks had not been systematically hidden and accumulated since the crisis in 2008–2009. There had been little control over the issuance of loans to related parties, business groups, and low-quality borrowers. Moreover, the concentration of loans in foreign currency was high. As a result, the macroeconomic shock of 2014–2015 triggered old hidden risks in the banking sector and significantly damaged the performance of corporate borrowers. The share of non-performing loans has been measured reliably only since 2017, and as Fig. 1 shows, it was 58 percent that year as banks recognized and provisioned against losses.

[1] See https://kse.ua/russia-will-pay/.

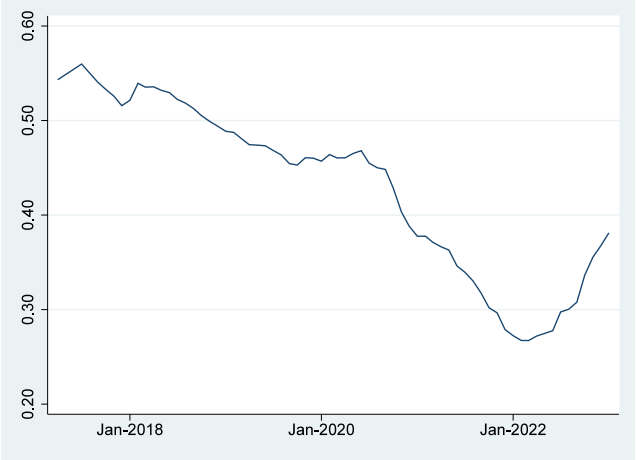

Fig. 1. Share of non-performing loans. Data from National Bank of Ukraine.

Recognition of the true quality of banks' corporate portfolios was an important condition for the development of further policies and the recovery of corporate lending. The National Bank of Ukraine (NBU) was reformed and strengthened its independence and institutional capacity in 2014–15 (Gontareva and Stepaniuk, 2020). In the following years, the NBU implemented Basel principles regarding the assessment of credit risk, limitations on related party lending, and on concentration of large exposures, among others (National Bank of Ukraine, 2016b). More than 100 banks exited the market due to lack of equity, nontransparent ownership structure, money laundering, bank fraud, and other factors. PrivatBank, the largest domestic bank by assets, was nationalized at the end of 2016. As a result of these reforms and other macroeconomic policies, the banking sector began to recover in 2016–2017. Corporate lending increased as the cost of loans fell; demand for credit gradually rose (National Bank of Ukraine, 2017).

By the onset of the pandemic, the banking sector in Ukraine had become more transparent, liquid, and profitable, associated with improved banking supervision and higher quality loan portfolios. The pandemic did not cause significant losses (National Bank of Ukraine, 2020a); those industries most affected by the pandemic had only moderate exposure in Ukrainian banks (National Bank of Ukraine, 2020b). As Fig. 2 shows, corporate lending was growing in 2021, with lending to small and medium-size borrowers increasing most rapidly (National Bank of Ukraine, 2021). The share of non-performing loans was declining.

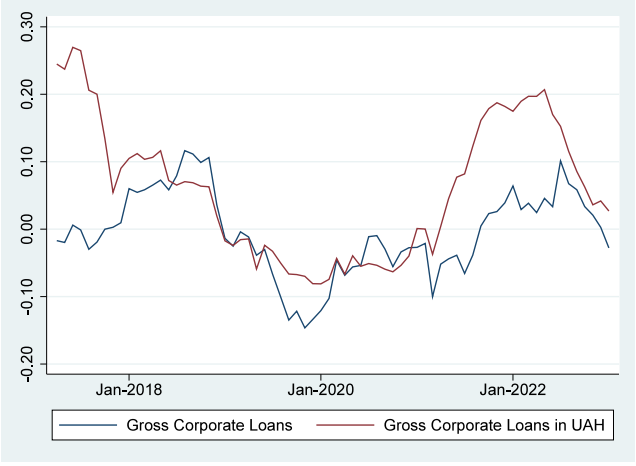

Fig. 2. Loans to corporate borrowers, year-over-year change. Data from National Bank of Ukraine. The figure represents year-over-year change in total outstanding gross loans and gross loans issued in Ukrainian hryvnia (UAH) to corporate borrowers.

Although Russia's full-scale invasion has caused a deep crisis, the Ukrainian banking system has generally maintained liquidity and continued to issue loans (National Bank of Ukraine, 2022a). In the first months of full-scale war, corporate lending grew modestly, driven mostly by the state support program "Affordable Loans 5–7–9%", which predominantly targeted micro and small firms (National Bank of Ukraine, 2022b). At the same time, as banks have received more recent data about their corporate borrowers and loan-related collateral, credit losses and the share of non-performing loans have gone up. Between February and November 2022, banks reported an overall 9-percent increase in non-performing loans (National Bank of Ukraine, 2022b). The ongoing war and systematic attacks on power infrastructure have caused significant deterioration of business performance and, consequently, higher credit losses for banks.

The NBU reacted to Russia's full-scale invasion with a package of policy changes intended to mitigate the impact of damage and preserve stability of the banking sector. Among other changes, in the first months, until June 30, 2022, banks were not required to declare default automatically after 90 days of nonpayment. The requirement to revalue and verify the availability and condition of collateral was also suspended during this period. Some provisions remain into 2023, as in the case of loans restructured due to financial difficulties resulting from the invasion, where banks continue to be allowed not to recognize defaults (National Bank of Ukraine, 2022a). Required financial reporting for firms is also lifted. For determining the probability of default banks use such information as current state of the borrower's industry, operating cash flow based on bank accounts, access to the state lending support programs, the condition of operating facilities, and how much the operating location was affected by the war (National Bank of Ukraine, 2022a).

The lack of information, difficulty of revaluation, and relaxation in credit risk assessment imply that real losses have not been fully recognized and provisioned by banks. Therefore, the NBU expects total losses from credit risk will continue to increase as banks gradually reflect the impact of war on corporate portfolios. To better estimate the banking sector's losses, the NBU carried out additional surveys of banks to collect detailed information regarding large exposures and collateral conditions—data that we use in this paper.

3. Data and sample construction

We use several datasets to analyze the effect of damage to collateral on various firm outcomes. The first is a one-time survey conducted by the NBU of the largest Ukrainian banks on different collateral conditions as of July 1, 2022 (hereafter *survey*). This survey includes information on up to the 100 largest corporate borrowers from each of 66 banks that collectively hold 96 percent of

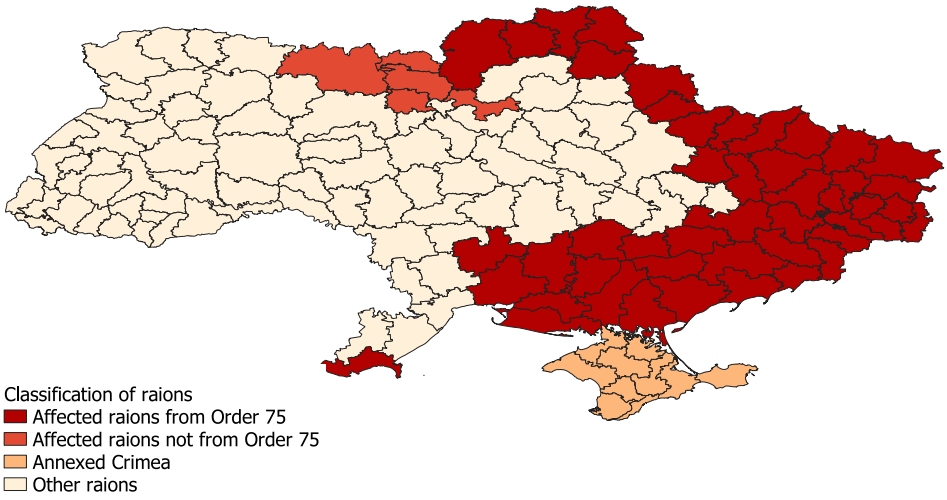

Fig. 3. Classification of raions affected by Russia's invasion. The map depicts 136 raions of Ukraine. Dark red raions are those in which at least one hromada was listed in Order 75. Light red raions were temporarily occupied and then liberated prior to April 25, 2022, and so are not listed in Order 75. The detached raion in Odesa region is Izmail, which includes Zmiinyi (Snake) Island, which was occupied from February to June 2022.

the total loan portfolio in the Ukrainian banking system. The initial sample contains 2,770 unique bank-borrower pairs. We exclude loans that are unsecured, have exclusively liquid collateral (such as bank deposits), and for which banks did not provide information about collateral location. The resulting sample provides micro-level data for 58 banks and 2,090 unique bank-borrower pairs. Each entry in the dataset is a collateral asset or set of assets of a specific type located in a particular raion and associated with a particular borrower (not loan). For example, a borrower might have two collateral assets that are both land, possibly associated with the same loan but located in different raions. For each observation, we observe *Collateral location*; *Collateral condition*, of which more below; and *Collateral type* (residential real estate, transportation, etc.) Collateral location is reported at the level of raion, a second-level administrative division between oblast (province) and hromada (municipality). Odesa oblast, for example, contains 7 raions and 91 hromadas.

Based on this information, we create the dummy variable *ColAffected*, which takes a value of one if the collateral asset was located in a raion directly affected by the war. We make this determination as follows. First, we code a raion as affected if it is classified as such in Order 75 ("On approval of the list of hromadas (municipalities) which are located in the area of fighting, under temporary occupation, or encirclement (blockade)") of the Ministry of Reintegration of the Temporarily Occupied Territories of Ukraine as of April 25, 2022 or thereafter. Second, because some raions were occupied and then liberated prior to April 25, we use information from public sources to additionally identify raions as affected if at least one territorial community was located in the area of fighting, under temporary occupation, or blockade. Fig. 3 illustrates this coding.

We also construct the indicators *Damaged*, *Destroyed*, *Loss of control*, and *No information*, which correspond to the possible values of collateral condition from the survey. In what follows, we generally collapse these variables into the indicator *AnyDamage*, which takes a value of one if any of our four measures of collateral condition is equal to one. We thus implicitly assume that if banks were not able to get information about the condition of collateral independently or from the borrower, or if a borrower lost control of its collateral or was not able to verify the condition of its collateral, it is very likely that this collateral was either destroyed, damaged, or could not otherwise be used to secure current or future borrowing. The unit of observation in this sample is bank-borrower-collateral asset.

We merge these survey data with supervisory loan data (hereafter *loan data*): monthly administrative data reported by all banks to the NBU for outstanding corporate loans above UAH 2 mln and for loans issued to related parties. This rich dataset includes information at the bank-borrower-loan level on loan volume and characteristics such as exposure at default, collateral value, type of collateral asset, credit risk, maturity, interest rate, and so forth. Collateral assets in these data are again characterized by type (land, transportation, equipment, real estate, integrated property, or other), with each asset associated with a specific loan contract.[2] These data also contain information about the quality of borrowers, including default and probability of default. (Banks assign default probability to the borrower based on the borrower's financial state and timeliness of loan repayments, among other factors; these are thus borrower, and not just loan, characteristics.) We use these data to obtain information on collateral values and to calculate outcomes as of November 1, 2022.

We further use data from financial statements collected by the State Statistical Service of Ukraine, which allow us to identify the borrower's 2-digit industry code and raion of registration. Based on the latter variable, we then create the indicator *BorrAffected*,

[2] "Integrated property" refers to a collection of assets, including different types that are tied together as collateral.

Table 1
Outcomes by collateral condition.

	All collateral assets	Any damage	No damage
Default	0.14	0.34	0.12
PD change	0.09	0.21	0.09
New loans	0.19	0.15	0.20
Share new loans	0.14	0.09	0.15
Number of bank-borrowers	995	80	915
Collateral change	−0.01	−0.26	0.02
Number of bank-borrower-loan-collateral assets	5,667	476	5,161

Notes: Table reports means of four outcome variables and collateral change as well as number of bank-borrowers and number of bank-borrower-loan-collateral assets. Default = 1 if borrower defaulted as of November 2022. PD change = change in probability of default from February to November 2022. New loans = 1 if borrower had at least one new loan between February and November. Share new loans = ratio of new loans initiated between March and November (and outstanding as of November), relative to all loans in February. Collateral change is change in collateral-loan ratio between February and November. Any damage = 1 if any collateral asset was damaged or destroyed, experienced loss of control, or had missing information about its condition.

which takes a value of one if the borrower is registered in an affected raion, as defined above. A limitation of all the data sources is that we do not observe place of operation or location where the loan is used.

The main question we address is whether change in collateral value, as induced by wartime damage to collateral, had financial consequences for Ukrainian firms. We study four outcomes. *Default* takes a value of 1 if the borrower was in default as of November 1, 2022. *PDChange*, in turn, is the difference between probability of default (PD) as of November 2022 and probability of default as of February 2022, where PD is the bank's estimate of the likelihood that a borrower will be unable to meet its debt obligations. (This estimate, which is one of the main inputs for credit-risk assessments, is based primarily on a borrower's financial health, with additional weight given to other factors such as transparency of a borrower's ownership structure and number of days a loan payment is overdue). *NewLoan* takes a value of one if a borrower had at least one new loan between February and November 2022, and zero otherwise. Finally, *ShareNewLoans* is defined as the ratio of the sum of new loans as of November (i.e., initiated between March and November and still outstanding as of November) to the sum of all outstanding loans as of February 2022.[3]

We construct our determinant of interest, the change in collateral-loan ratio from February to November 2022 (*ColChange*), from the loan data:

$$ColChange_{clib} = \frac{ColSumNov_{clib}/LoanSumNov_{lib} - ColSumFeb_{clib}/LoanSumFeb_{lib}}{ColSumFeb_{clib}/LoanSumFeb_{lib}},$$

where $ColSumNov_{clib}$ ($ColSumFeb_{clib}$) is the value of collateral asset c of loan l for borrower i in bank b as of November (February) and $LoanSumNov_{clib}$ ($LoanSumFeb_{clib}$) is the outstanding amount of loan l for borrower i in bank b as of November (February). To calculate this measure, we use collateral value adjusted for the NBU's liquidity coefficients by collateral type and restrict our sample only to loans that we can track over time (those outstanding as of February and November). This ensures that we calculate change in collateral value for the same loan and that the change is not driven by changes in the structure of loan portfolios.

Table 1 reports summary statistics on firm outcomes for the entire sample and by collateral condition. Between February and November, borrowers default in 14 percent of borrower-bank pairs, while default probabilities rise by nine percent on average. New loans are obtained in 19 percent of borrower-banks, accounting for an average of 14 percent of the outstanding loans of the borrower-banks in February. However, borrowers with any damage to their collateral had much higher default rates and probabilities of default, and much lower probabilities of a new loan and shares of new loans as of November 2022 than did those that did not report any damage to their collateral. Moreover, borrowers with any damage to their collateral experienced a decrease in collateral value between February and November, while borrowers with no damage saw a slight increase in collateral value. Overall, about eight percent of all collateral assets in the sample were damaged or destroyed, experienced loss of control, or had missing information about their condition.[4]

Table 2 provides a breakdown of collateral condition by the location (raion) of the collateral. It is notable that across all collateral conditions that indicate any damage to collateral, most collateral assets are located in affected raions. In contrast, out of all collateral assets that experienced no damage, about 25 percent were located in affected raions. There is also substantial overlap among different collateral conditions – one collateral asset for a specific borrower may have more than one condition – which follows from the fact that collateral assets of the same type are grouped by borrower in the survey data.

We further explore the differences across borrowers in outcomes and changes in collateral value by location of borrower and collateral, as well as by participation in the state support program "Affordable Loans 5–7–9%". Lending through this program drove the majority of new loans to corporate borrowers in the spring of 2022; this support was targeted to borrowers who experienced financial difficulties caused by the war and agricultural firms involved in a spring planting season (National Bank of Ukraine, 2022a).

[3] An alternative definition of *ShareNewLoans* uses November 2022 as the base. In Appendix Table A1 we show that our results are robust to this alternative definition.

[4] This may represent a lower bound, as the data pertain to July (the survey date) rather than November, and because banks may fail to reevaluate damaged collateral.

Table 2
Collateral condition and collateral location.

Collateral condition	Collateral in affected raions	Collateral in other raions
Damaged	66	29
Destroyed	9	0
Loss of control	330	1
No information	117	7
Not damaged/not destroyed/not lost	1,287	3,874
Missing condition	15	15

Notes: One collateral asset can have several collateral conditions. Out of 95 damaged collateral assets, 69 experienced loss of control; there is no information on three others. Out of nine destroyed collateral assets, five experienced loss of control. Out of 124 assets with no information, three are damaged, and 52 experienced loss of control.

Table 3
Outcomes by location of borrower and collateral.

	Borrower		Collateral		State loan program	
	Affected	Unaffected	Affected	Unaffected	Yes	No
Default	0.16	0.14	0.17	0.13	0.00	0.15
PD change	0.16	0.08	0.14	0.08	0.05	0.10
New loans	0.17	0.20	0.19	0.20	0.89	0.13
Share new loans	0.11	0.15	0.13	0.15	0.60	0.10
Number of bank-borrowers	183	812	289	759	92	903
Collateral change	−0.04	0.01	−0.06	0.02	0.14	−0.03
Number of bank-borrower-loan-collateral assets	1,170	4,497	1,741	3,926	823	4,844

Notes: Table reports mean values of four outcome variables and collateral change by registration of borrower, location of collateral, and participation in state loan program "Affordable Loans 5–7–9%" as well as number of bank-borrowers and number of bank-borrower-loan-collateral assets in the sample. Default = 1 if borrower defaulted as of November 2022. PD change = change in probability of default from February to November 2022. New loans = 1 if borrower had at least one new loan between February and November. Share new loans = ratio of new loans initiated between March and November (and outstanding as of November), relative to all loans in February. Collateral change is change in collateral-loan ratio between February and November. In Column 1, Affected = 1 if borrower is registered in the affected raion and in Column 3, Affected = 1 if collateral is located in affected raion. In Column 2 (Column 4), UnAffected = 1 if borrower was registered (collateral was located) in unaffected raion (marked as "other" in Fig. 3).

Table 3 shows that borrowers who are registered in affected raions and borrowers with collateral in affected raions have higher default rates and larger increases in probability of default. Such borrowers also experience decreases in collateral value and are less likely to get new loans. About half the borrowers with new loans, 92 of 199 total, participate in the state loan support program. Figure A1 in the Appendix shows that affected raions, largely in Eastern oblasts of Ukraine, tend to have the largest increase in the probability of default between February and November; Figure A2 shows that the geographical distribution of share of new loans varies significantly among unaffected raions.

4. Empirical strategy

We are interested in the effect of changes in collateral value on firm financial outcomes. In estimating this effect, we face various identification problems. Firms that experience negative shocks to the value of collateral they have posted may also be more likely to suffer from other effects of the war, such as loss of production capacity, personnel, and market demand. Moreover, change in collateral value is likely measured with error due to the changes in NBU policy regarding collateral assessment and revaluation, and the lags in revaluing collateral in a suddenly and drastically changed environment. The fog of war may induce uncertainty in how collateral has been affected. Finally, firms in Ukraine, as in most countries, tend to borrow only from a single bank, and if it happens that their bank has a loan portfolio with a heavy weight towards firms damaged by the war, then the bank may be less likely to extend future loans, which is one of the outcomes we examine.

To address these estimation problems, we condition on various observed and unobserved characteristics of banks, borrowers, and collateral, including borrower registration and collateral presence in an affected raion and fixed effects for bank, borrower's industry, and "macro" region. We additionally estimate the effect of collateral value on firm-level financial outcomes using instrumental variables, where we exploit plausibly (and conditionally) exogenous variation in collateral value induced by any damage to collateral.

Our baseline estimating equation relates change in collateral value to firm outcomes, where an observation is a collateral asset c associated with a particular loan l for a borrower-bank pair (i and b, respectively):

$$Y_{clib} = \beta * ColChange_{clib} + \gamma * ColAffected_{cib} + \omega * BorrAffected_{i} + \theta_b + \alpha_{j(i)} + \phi_{r(i)} + \epsilon_{clib}, \quad (1)$$

Table 4
Change in collateral-loan ratio and collateral condition.

	(1)	(2)	(3)	(4)	(5)	(6)
Any damage	−0.277***	−0.294***	−0.318***	−0.318***	−0.287***	−0.289***
	(0.076)	(0.090)	(0.098)	(0.094)	(0.097)	(0.098)
Collateral in affected raion					−0.061**	−0.053
					(0.028)	(0.035)
Borrower in affected raion						−0.015
						(0.050)
Bank FE		✓	✓	✓	✓	✓
Industry FE			✓	✓	✓	✓
Macro-region FE				✓	✓	✓
Observations	5,667	5,667	5,499	5,499	5,499	5,499
R-squared	0.047	0.101	0.140	0.144	0.148	0.148

Notes: The table shows the results of OLS regressions with change in collateral-loan ratio between February and November as dependent variable. The unit of observation is bank-borrower-loan-collateral asset. *Any damage* takes a value of 1 if any of the collateral asset was damaged, destroyed, experienced loss of control, or had missing information about its condition. In parentheses, heteroskedasticity-robust standard errors that correct for correlation of error terms at the borrower level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

where Y represents in alternative specifications the four outcome variables: *Default*, *PDChange*, *NewLoan* or *ShareNewLoans*. Each outcome is measured at the borrower-bank level, such that the same outcome may be repeated for multiple observations, and we report robust standard errors that allow for arbitrary correlation of errors across observations for the same borrower. The variable $ColChange_{clib}$ is change in collateral-loan ratio between February and November. In turn, $ColAffected_{cib} = 1$ if any part of the collateral asset is located in an "affected" raion, as defined above, and $BorrAffected_i = 1$ if the borrower is registered in an affected raion. The parameters θ, α, and ϕ represent bank, industry (j), and region (r) fixed effects, respectively, where the latter two characteristics are defined for borrowers. The variable ϵ is an idiosyncratic error term.

Our motivation for including region fixed effects is the possibility that banks are less likely to lend to firms in less safe regions (e.g., close to Donetsk and Luhansk oblasts, and to annexed Crimea), whether their collateral was damaged or not. The region effects are defined using the typology in Clem and Craumer (2005) to partition oblasts (and thus raions) into four sets, each corresponding to a geographic region (western, southern, eastern, and central) of the country. These regional controls also potentially capture the varying extent to which demand at the regional level was affected by the war.

Because the dependent variables all measure changes (including for defaults, because none of the observations are in default as of February) and the determinant of interest is also a change, this equation can be interpreted as resulting from time-differencing a level equation with two time periods (as of February and November). That level equation could include fixed effects at the collateral-loan-borrower-bank level that are differenced away, so that any time-invariant heterogeneity associated with characteristics at that level are controlled for. The bank, industry, and macro-region fixed effects control for idiosyncratic changes in the dependent variable associated with these dimensions from February to November.

As discussed, we also instrument the change in collateral-loan ratio, $ColChange$, using $AnyDamage$, as defined above. This approach allows us to disentangle the effect of change in collateral value induced by (presumed) damage to collateral from that caused by overall worsening of market conditions related to the war. Our controls for *ColAffected* and *BorrAffected* account for generalized exposure to the war at the raion level, implying that the instrument reflects idiosyncratic damage resulting from that exposure. In addition, instrumenting provides a multiple-indicator method of reducing bias associated with measurement error—which is likely if, as we have discussed, banks cannot verify the condition of collateral and continue reporting and using pre-war values for credit risk assessment.

Table 4 reports estimates from the first-stage regression of change in the collateral-loan ratio, *ColChange*, on the dummy *AnyDamage*. The results are consistent across specifications. There is a strong negative relationship between any damage to collateral and change in collateral value. Table A2 in the Appendix, which unpacks *AnyDamage* into its components, shows that the overall negative effect of *AnyDamage* is mostly driven by the collateral assets of which borrowers lost control. The estimated effect of the remaining indicators of collateral condition are of inconsistent sign and/or significance, likely reflecting the smaller number of assets within each category and overlap among the various measures of (presumed) damage to collateral.

A possible threat to identification is if damage to collateral is associated with damage to revenue-generating assets, which would represent a violation of the exclusion criterion if such damage reduces a firm's ability to repay loans. In what follows we therefore additionally report results in which we exclude those types of collateral assets most likely to be used in the production process (equipment and integrated property). The remaining collateral types are land, residential real estate, transportation, and other.

5. Results

Table 5 presents estimates of the effect of change in collateral value on default incidence and change in probability of default. The point estimates are consistently negative. They are much larger in magnitude and more precisely estimated in the IV specifications, which may reflect substantial error in measured change in collateral value. The point estimate in Column 2 implies that a decline of 10 percentage points in collateral value raises the default rate by 8.0 percentage points, versus an unconditional mean for the

Table 5
Default and probability of default.

	(1)	(2)	(3)	(4)
	Default		Change in default probability	
	OLS	IV	OLS	IV
Change in collateral-loan ratio	−0.130**	−0.798***	−0.031	−0.425**
	(0.058)	(0.230)	(0.043)	(0.191)
Collateral in affected raion	0.027	−0.058	0.004	−0.046
	(0.034)	(0.042)	(0.031)	(0.037)
Borrower in affected raion	0.061	0.066	0.130**	0.134**
	(0.047)	(0.048)	(0.054)	(0.060)
Bank FE	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓
Macro-region FE	✓	✓	✓	✓
Observations	5,499	5,499	5,499	5,499
Mean dep. variable	0.122	0.122	0.121	0.121

Notes: Dependent variable is default as of November 2022 (columns 1–2) and change in default probability between February and November 2022 (columns 3–4). The unit of observation is bank-borrower-loan-collateral asset. First-stage F-stat is 13.51. In parentheses, heteroskedasticity-robust standard errors that correct for correlation of error terms at borrower level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6
New loans.

	(1)	(2)	(3)	(4)
	New loans		Share of new loans	
	OLS	IV	OLS	IV
Change in collateral-loan ratio	0.219***	0.769***	0.001	0.244***
	(0.047)	(0.166)	(0.049)	(0.061)
Collateral in affected raion	0.058	0.129**	−0.003	0.028
	(0.048)	(0.054)	(0.046)	(0.043)
Borrower in affected raion	−0.093	−0.094	−0.052	−0.051
	(0.082)	(0.080)	(0.038)	(0.038)
Bank FE	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓
Macro-region FE	✓	✓	✓	✓
Observations	5,499	5,499	5,499	5,499
Mean dep. variable	0.284	0.284	0.121	0.121

Notes: In columns 1 and 2, dependent variable is indicator that takes a value of one if borrower obtained a new loan between February and November 2022. In columns 3 and 4, dependent variable is new loans obtained between February and November 2022 as share of all outstanding loans as of February 2022. The unit of observation is bank-borrower-loan-collateral asset. First-stage F-stat is 13.51. In parentheses, heteroskedasticity-robust standard errors that correct for correlation of error terms at borrower level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

default rate of 12 percent. The result in Column 4 implies a corresponding increase of 4.3 percentage points in banks' assessments of the probability of default. This difference in estimated magnitudes – larger for actual default than for probability of default – implies that banks may be underestimating default risk. It also suggests that defaults due to damaged collateral may be likely to increase in the future.

The estimated coefficients on borrower registration are generally consistent with a positive effect of geographic exposure to war on default risk. However, collateral location is estimated to have either a zero or negative effect, possibly because any positive effect is already captured by change in collateral value or borrower registration. In Appendix Tables A3 and A4, we report results from regressions that omit borrower registration. In OLS regressions, there is a large, positive, and statistically significant estimated effect of collateral location on default rate and change in default probability, with estimated coefficients of 0.060 and 0.075, respectively. The IV estimates are much smaller—likely the consequence of a naturally high correlation (0.708) between collateral location and damage to collateral.

Table 6 presents analogous results for the new-borrowing outcomes: the discrete presence of any new loan and a continuous variable measuring the ratio of new loans as of November 2022 to the level of borrowing as of February 2022. Again, the estimated coefficients are larger with the IV specification than with OLS. The point estimate in Column 2 implies that the probability of a new loan falls 7.7 percentage points for each 10-percentage-point decline in collateral value. Column 4 implies that the amount of new lending falls by approximately 2.4 percentage points for the same decline. Tables A5 and A6 show inclusion of neither collateral nor

Table 7
Default and probability of default: Non-production assets.

	(1)	(2)	(3)	(4)
	Default		Change in default probability	
	OLS	IV	OLS	IV
Change in collateral-loan ratio	−0.120*	−0.904***	−0.023	−0.511**
	(0.055)	(0.256)	(0.042)	(0.214)
Collateral in affected raion	0.032	−0.066	0.022	−0.039
	(0.035)	(0.048)	(0.034)	(0.041)
Borrower in affected raion	0.064	0.079	0.124**	0.134*
	(0.049)	(0.059)	(0.062)	(0.073)
Bank FE	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓
Macro-region FE	✓	✓	✓	✓
Observations	3,913	3,913	3,913	3,913
Mean dep. variable	0.128	0.128	0.128	0.128

Notes: Dependent variable is default as of November 2022 (columns 1–2) and change in default probability between February and November 2022 (columns 3–4). The unit of observation is bank-borrower-loan-collateral asset. First stage F-stats is 13.48. In parentheses, heteroskedasticity-robust standard errors that correct for correlation of error terms at borrower level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8
New loans: Non-production assets.

	(1)	(2)	(3)	(4)
	New loans		Share of new loans	
	OLS	IV	OLS	IV
Change in collateral-loan ratio	0.210***	0.814***	0.000	0.278***
	(0.053)	(0.211)	(0.050)	(0.080)
Collateral in affected raion	0.086	0.162**	0.021	0.057
	(0.057)	(0.065)	(0.052)	(0.050)
Borrower in affected raion	−0.100	−0.110	−0.054	−0.057
	(0.092)	(0.088)	(0.042)	(0.043)
Bank FE	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓
Macro-region FE	✓	✓	✓	✓
Observations	3,913	3,913	3,913	3,913
Mean dep. variable	0.291	0.291	0.121	0.121

Notes: In columns 1 and 2, dependent variable is indicator that takes value of one if borrower obtained a new loan between February and November 2022. In columns 3 and 4, dependent variable is new loans obtained between February and November 2022 as share of all outstanding loans as of February 2022. The unit of observation is bank-borrower-loan-collateral asset. First-stage F-stats is 13.48. In parentheses, heteroskedasticity-robust standard errors that correct for correlation of error terms at borrower level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

borrower location substantially affect the point estimate of change in collateral-loan ratio. Again, borrower location more strongly affects the outcomes than does collateral location.[5]

As discussed above, a potential challenge to our identification strategy is that damage to collateral could affect a firm's production capability, worsening its financial condition through a channel different than collateral value. We therefore exclude those types of collateral that could be involved in production: equipment and integrated property. This exclusion pertains to 1,586 collateral assets, implying a reduction in sample size of approximately 29 percent. The remaining collateral types include land, transportation, and real estate, among others. The corresponding results in Tables 7 and 8 show estimated coefficients very similar to those with the baseline sample—indeed, even slightly larger in magnitude.

6. Conclusion

What can economists, as economists, do to help Ukraine during this time of tremendous need? Perhaps not a great deal, but in this paper we try to do what we can. Constructing and analyzing a remarkable dataset of all large corporate loans in Ukraine, we assess the firm-level financial consequences of damage to collateral during the first nine months of Russia's full-scale war on Ukraine.

We find that reductions in collateral value induced by damage to collateral have been substantial and that this has damaged firms' and banks' financial performance. Loan defaults and banks' assessments of expected default probabilities both increased,

[5] In Appendix Table A7, we show that qualitative results for our various outcomes are generally robust to inclusion of oblast fixed effects, notwithstanding the much smaller cell sizes in these exercises.

while firm borrowing decreased in association with the decline in collateral value. The impact is greater on actual defaults than on default probability, and we speculate that banks' assessments may lag the true default probability due to the relaxation of credit risk assessment and lack of information, which would suggest increasing defaults in the future.

We address potential endogeneity and measurement error with an instrumental-variables/multiple-indicator strategy that exploits plausibly exogenous changes to collateral value resulting from damage to collateral, controlling for bank, industry, and macro-region fixed effects and whether collateral and borrower are located in areas directly affected by invasion and occupation. Our finding of substantially larger magnitudes of the IV compared to the OLS coefficients is consistent with the presence of substantial measurement error in assessments of collateral value. Faced with uncertainty about the extent of damage and loss of control over collateral, accountants may opt to maintain the same values on the books. If so, then the full extent of damage to collateral has not yet been recognized, suggesting that defaults and capital access could worsen still further.[6]

How this situation will evolve in the future is a major caveat to our analysis. The war is ongoing and great damage still being done, with the breach of the Kakhovka Dam and all the destruction from flooding downstream a salient example at this moment of writing. Based as it is on very recent data from the first nine months after the full-scale invasion, our study likely captures only a fraction of damage from the war. Even for damage during this time period, the lack of change in collateral value recorded for many loans may simply reflect the time-consuming and uncertain process of collateral revaluation, as we have discussed. In attempting to deal with this measurement error as well as potential endogeneity, we have had to rely on a survey from an earlier time period (July rather than November). The short lapse of time also means that data on outcomes are extremely limited. Nor do we observe changes in firm and establishment location resulting from the war. Addressing these issues would present fruitful avenues for future research.

Nonetheless, with these caveats, the results in this paper provide further evidence complementing the small empirical literature on the collateral channel in amplifying business cycles. By contrast with that literature, which generally studies the impact of changes in collateral value resulting from shocks to real estate and land prices in countries such as the U.S. and Japan, the "shock" we examine is the destruction and havoc wrought by Russia's sudden full-scale invasion of Ukraine. Our analysis also demonstrates the importance of indirect ("collateral") damage to Ukraine's financial system resulting from the war and begins to quantify part of the massive reconstruction effort that will – soon, we hope – be necessary.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jce.2023.06.010.

References

Barro, Robert J., 1976. The loan market, collateral, and rates of interest. J. Money Credit Bank. 8 (4), 439–456.
Bernanke, Ben, Gertler, Mark, 1989. Agency costs, net worth and business fluctuations. American Economic Review, March 1989, 14–31. Financial Fragility Econ. Perform. Q. J. Econ. 87–114.
Chaney, Thomas, Sraer, David, Thesmar, David, 2012. The collateral channel: How real estate shocks affect corporate investment. Amer. Econ. Rev. 102 (6), 2381–2409.
Clem, Ralph S., Craumer, Peter R., 2005. Shades of orange: The electoral geography of Ukraine's 2004 presidential elections. Eurasian Geogr. Econ. 46 (5), 364–385.
Gan, Jie, 2007. Collateral, debt capacity, and corporate investment: Evidence from a natural experiment. J. Financ. Econ. 85 (3), 709–734.
Glick, Reuven, Taylor, Alan M., 2010. Collateral damage: Trade disruption and the economic impact of war. Rev. Econ. Stat. 92 (1), 102–127.
Gontareva, Valeria, Stepaniuk, Yevhen, 2020. Mission Possible: The True Story of Ukraine's Comprehensive Banking Reform and Practical Manual for Other Nations. AuthorHouse.
National Bank of Ukraine, 2016a. Financial stability report, june 2016. Kyiv, Ukraine.
National Bank of Ukraine, 2016b. Financial stability report, december 2016. Kyiv, Ukraine.
National Bank of Ukraine, 2017. Financial stability report, december 2017. Kyiv, Ukraine.
National Bank of Ukraine, 2020a. Financial stability report, june 2020. Kyiv, Ukraine.
National Bank of Ukraine, 2020b. Financial stability report, december 2020. Kyiv, Ukraine.
National Bank of Ukraine, 2021. Financial stability report, december 2021. Kyiv, Ukraine.
National Bank of Ukraine, 2022a. Financial stability report, june 2022. Kyiv, Ukraine.
National Bank of Ukraine, 2022b. Financial stability report, december 2022. Kyiv, Ukraine.
World Bank, 2023. Ukraine rapid damage and needs assessment: February 2022 - February 2023 (English). Washington, DC.

[6] For this reason, we leave it as a task for future research to estimate the aggregate impact of damaged collateral.