Digital Financial Participation and Consumer Financial Detriment in the Fintech Era: The Role of Online Financial Contracting

Supplementary Material, File S3: Supplementary Methods and Results. Tables 1–9, Tables A1–S1 and Sections 1–6 refer to the main article. Reference numbers correspond to the reference list of the main article; the references cited in this file are listed at the end.

File S3. Supplementary Methods and Results

S3.1. Measurement Details

The introductory question and response options in the financial detriment section, as well as eight of the nine items compared, were identical in the two OECD core questionnaires [35,36]. In 2022, the item concerning the disclosure of financial information in response to fraudulent requests was expanded to include examples involving passwords, card numbers, and social media messages. Several Hungarian translations were also revised. All items referred to experiences during the two years preceding the survey. In 2018, the proportion of non-substantive responses ("does not understand," "does not know," and "refused to answer") ranged from 1.8% to 2.6% across items, whereas no such responses were recorded in 2022. Following OECD/INFE practice, these responses were coded as "no"; however, comparisons between the two waves were also conducted using only respondents who provided substantive answers. The implications of translation differences and the sensitivity checks based on items with unchanged wording are discussed in Section S3.3 and Section 4.2.

The item concerning disputes over unrecognized transactions is open to multiple interpretations. It may indicate fraudulent activity, but it may also reflect the greater likelihood of detecting unusual transactions among consumers who check their accounts more frequently. The 2018 Hungarian questionnaire asked whether respondents had noticed an unrecognized transaction, which was broader than the wording of the English OECD core questionnaire. According to the survey agency's report, responses may also have been influenced by difficulties in understanding the question [37]. The 2022 Hungarian questionnaire instead asked whether respondents had disputed such a transaction, consistent with the core questionnaire [38]. Consequently, the difference between the two survey waves may partly reflect changes in translation. The 2022 report also noted that the Hungarian wording of three additional items more closely followed the core questionnaire: a financial product that turned out to be fraudulent, a formal complaint, and financial losses resulting from hacking or phishing [38]. Accordingly, we repeated the wave comparison and the main models of fraud exposure and incidents after excluding the item concerning unrecognized transactions (Tables 3, 6, and A4).

For the supplementary models, educational attainment was classified into three categories: lower secondary education or below (36.3%), upper secondary education (46.0%), and tertiary education (17.7%). The number of financial products held was determined based on the 15 OECD core product types asked in Hungary (QP2_14 and QP2_15 were not asked; the country-specific product was not counted) (mean = 1.56; SD = 1.29). We also examined five items assessing digital security behaviors and knowledge: password sharing,

checking whether a financial service provider is regulated, changing passwords, assessing the security of public Wi-Fi networks, and verifying website security. After three items were reverse-coded so that higher values indicate more cautious behavior, the items showed a negative average inter-item correlation ($r = -0.03$; $\alpha = -0.09$; Table S3). We verified the coding against the response labels of the OECD/INFE core questionnaire (1 = always or completely agree; 5 = never or not at all). On the original response scales, four of the six pairs of items worded in opposite directions correlated positively (for example, password sharing with checking whether a provider is regulated, $r = 0.22$, and with changing passwords, $r = 0.29$), suggesting acquiescent responding (many respondents chose the same end of the scale regardless of item wording) rather than a coding error. Because the items do not form a scale, they were analyzed individually and only for exploratory purposes. Trust in fintech services was measured using a single statement concerning online banks and fintech companies, with Revolut, TransferWise, Google Pay, and Simple provided as examples [38]. Higher scores indicated greater trust (1–5; N = 917; mean = 2.64; SD = 1.38). Overall, 27.6% of respondents with a valid answer agreed or strongly agreed with the statement. The item wording and coding are presented in Table A6.

S3.2. Additional Analytical Procedures

Approximately one-fifth of respondents did not report their income, while those excluded from the main models were older, had lower incomes, and were less likely to hold a current account. We therefore performed two sensitivity analyses. First, missing income data were addressed using multiple imputation from a proportional odds model, generating 40 imputed datasets [45]. The imputation model included age, gender, educational attainment, employment status, settlement type, number of financial products held, digital financial variables, financial knowledge, and both outcome variables. Estimates were pooled according to Rubin's rules [46]. Second, missing income values were treated as a separate category. Missing values for digital financial activity were not imputed because they generally indicated non-use of the services. Instead, this issue was addressed by recoding "not applicable" responses as "never".

The roles of financial product ownership and education were examined in supplementary models that included the number of financial products held and educational attainment. Interaction terms were used to assess whether the associations involving digital financial variables differed by age (under 50 vs. 50 years and older) and income (low vs. middle or high). We also tested the interaction between financial knowledge and digital financial activity. Educational attainment was not included in the main models because adding two further parameters would have increased the number of explanatory variables in the fraud exposure and incidents model to eight, despite only 53 events. Nevertheless, including educational attainment did not alter the main findings (Table A5).

Fully online financial contracting was examined in three additional ways. First, the 0–4 count was entered as a linear term. Second, a three-category variable (none, one, two or more product types) was used. Third, banking products and insurance products were analyzed separately. In addition, because refusals and rejections can occur only among applicants, the models were re-estimated among respondents who held or had recently chosen at least one banking product (current or savings account, credit card, or loan), and the product-specific associations were examined within the holders or recent choosers of each product. To assess possible selection

into fully online contracting, Model 2 was also adjusted for willingness to take financial risks (QS1_2), the tendency to keep a close watch on one's financial affairs (QS1_5), and the number of financial products held, and E-values were calculated for the main associations [47].

We also examined the components of digital financial activity separately. Instead of the overall index, both subindices were included simultaneously in the models to distinguish the associations of basic digital financial activities from those of fintech services in the narrower sense. Because fintech services were used relatively infrequently and by a limited proportion of respondents, the fintech subindex was also included as a binary variable indicating whether respondents used at least one such service sometimes or more frequently. Fully online financial contracting was then added to the model. Finally, we explored the associations between trust in fintech services, fintech use, fully online financial contracting, and financial detriment.

S3.3. Changes Between 2018 and 2022: Additional Results

The prevalence of provider disputes and refusals decreased from 8.2% to 5.9%, but the change was not statistically significant in the weighted comparison ($p = 0.159$), the model adjusted for sample composition (OR = 0.75; $p = 0.226$), or the analysis restricted to substantive responses ($p = 0.202$). Comparisons of individual items were exploratory. Three items showed nominally significant changes: disputes over unrecognized transactions increased by 1.8 percentage points, while formal complaints and rejected insurance claims decreased by 1.5 and 2.3 percentage points, respectively. However, none of these differences remained statistically significant after Holm correction (adjusted $p = 0.207$, 0.184, and 0.184, respectively).

In the unweighted analyses using chi-square tests with Yates' continuity correction, which do not account for clustering in either wave, the changes were +2.5 percentage points for fraud exposure and incidents ($p = 0.032$), +0.4 percentage points for the four-item measure excluding unrecognized transactions ($p = 0.737$), −2.4 percentage points for provider disputes and refusals ($p = 0.044$), and +1.8 percentage points for any financial detriment ($p = 0.240$). The two nominally significant changes were not significant under assumed design effects of 1.5 ($p = 0.080$ and $p = 0.101$) or 2.0 ($p = 0.129$ and $p = 0.155$). Because none of the category-level weighted comparisons (Table 3) was significant, inflating the variance of the 2022 estimates would not alter the conclusion that the overall prevalence did not change significantly. The conclusion was also unchanged when the comparison was restricted to the four items with identical wording and accurate translations in both waves (8.0% in 2018 and 6.4% in 2022; $p = 0.342$).

S3.4. Robustness Analyses

We assessed the robustness of the findings using alternative model specifications and estimation methods, together with sensitivity analyses of missing data and measurement decisions (main article, Appendix A, Tables A4 and A5). Fully online financial contracting was associated with both types of financial detriment in all binary specifications reported in Table A5, with odds ratios ranging from 2.3 to 3.7 (1.91 and 1.87 when it was entered as a count variable). In the three-category specification, the odds of fraud exposure and incidents were higher for one (OR = 2.55) and for two or more product types (OR = 5.53), whereas for provider disputes and refusals the odds ratios were nearly identical (3.18 and 3.17), indicating no further increase beyond the

first contract. The associations remained significant after adjusting for educational attainment and the number of financial products held (OR = 2.82 and 3.27), using Firth's penalized likelihood estimation (OR = 2.48 and 3.10), and applying multiple imputation for missing income data (N = 822; OR = 2.88 and 2.52). Similar results were obtained when missing income was treated as a separate category (N = 822; OR = 2.82 and 2.70). The number of financial products held was not significantly associated with provider disputes and refusals (OR = 1.01; p = 0.905) and showed a weak, non-significant association with fraud exposure and incidents (OR = 1.25; p = 0.087).

Adjusting Model 2 for willingness to take financial risks, the tendency to keep a close watch on one's financial affairs, and the number of financial products held changed the estimates for fully online financial contracting only slightly (OR = 2.68 and 3.09; Table S4). Willingness to take risks was associated with fraud exposure and incidents (OR = 1.44; p = 0.003), and the association of digital financial activity with provider disputes and refusals was attenuated (OR = 1.43; p = 0.120). Because the outcomes were common among the exposed respondents in the regression sample (17–23%, weighted), we report the more conservative E-values based on the square root of the odds ratios; the rare-outcome approximation gives 5.33 and 5.81 (2.45 and 2.96 for the lower confidence limits). The conservative E-values are 2.82 and 2.96 (1.79 and 2.00 for the lower confidence limits): an unmeasured confounder associated with both online contracting and the outcome by risk ratios of about 1.8–2.0 could shift the lower confidence limit to the null.

Because experiencing a refusal or rejection requires an application for the relevant product, the analyses were repeated among the 528 respondents who held or had recently chosen at least one banking product (Table A10). In this group, fully online financial contracting remained associated with provider disputes and refusals (OR = 3.69; 95% CI: 2.01–6.79), and fully online contracting for banking products was associated with the two banking rejection items (OR = 6.89; 95% CI: 2.75–17.23; Firth estimate: OR = 4.56); this largest estimate combines the items most open to reverse causality and should be interpreted with particular caution. Product-specific comparisons within the holders or recent choosers of each product were based on very few events (two to ten per product) and are reported descriptively; their direction was consistent with the main findings.

Because the banking items of fully online financial contracting (account opening, taking out a loan) and two items on provider disputes and refusals (refused account opening, rejected loan application) refer to the same types of event, Model 2 was re-estimated after removing the overlapping items (Table A8). The association remained significant in all variants, although it was attenuated when online account opening and taking out a loan were removed from the contracting indicator while the outcome was unchanged: OR = 4.02 (95% CI: 2.07–7.81) when the two rejection items were excluded from the outcome, 2.37 (1.29–4.35) when account opening and taking out a loan were excluded from the contracting indicator, and 4.22 (2.04–8.70) when both were excluded. Direct overlap was rare: one respondent who opened an account online reported a refused account opening, and two who took out credit online reported a rejected loan application.

The association between digital financial activity and provider disputes and refusals remained statistically significant in all specifications without fully online contracting. In specifications that also included fully online contracting, it was weaker and not statistically significant after excluding transfer-fee complaints (p = 0.111), after adding the five digital security items (p = 0.212), after adjusting for selection-related covariates (p =

0.120; Tables A5 and S4), or in either age stratum (p = 0.064 and 0.205; Table S5). For fraud exposure and incidents, digital financial activity was significantly associated with the outcome in models excluding fully online financial contracting (OR ≈ 1.6 after including additional control variables, using Firth estimation, and applying multiple imputation), except in the unstable model with region and settlement type (OR = 1.39; p = 0.182), but not in models that also accounted for online contracting. Given the odds ratios of approximately 1.3, the non-significant findings may partly reflect limited statistical power with only 53 events. Therefore, the absence of an association cannot be established conclusively. Models that added region and settlement type included 15–16 explanatory variables for 53 events and are unstable; in these models, the association between digital financial activity and fraud exposure and incidents fell to OR = 1.06 (OR = 1.17 with the count specification), whereas the associations of fully online financial contracting remained (OR = 3.36 and 2.92). These estimates are therefore reported only to check the direction of the coefficients. In the model including trust in fintech services (Table A7), digital financial activity was not significantly associated with fraud exposure and incidents (OR = 1.55; p = 0.056); the estimate was larger than in Model 2 (OR = 1.28), although neither was statistically significant.

The association of digital financial activity with provider disputes and refusals (Model 1) was stronger when using the four-item measure excluding loan application rejection (OR = 2.38; p < 0.001; Table A4). After excluding complaints about transfer fees (42 events), fully online financial contracting remained significantly associated with provider disputes and refusals (OR = 3.11; p = 0.002), whereas the association with digital financial activity was weaker and not statistically significant (OR = 1.44; p = 0.111). Without fully online contracting in the model, digital financial activity remained significantly associated with this outcome (OR = 1.80; p = 0.008), including when the online money transfer item was also removed from the activity index (OR = 1.80; p = 0.008).

The findings for H3 were broadly consistent across the alternative measures of financial knowledge. In the provider disputes and refusals models, none of the alternative financial knowledge measures showed a statistically significant association with the outcome, either in Model 1 (three-item score: OR = 0.96 per one-standard-deviation increase, p = 0.803; indicator of at least five correct answers: OR = 0.65, p = 0.251; first principal component: OR = 0.85 per one-standard-deviation increase, p = 0.243) or in Model 2 (OR = 1.01, p = 0.959; OR = 0.68, p = 0.318; OR = 0.85, p = 0.244). Similar results were obtained when rejections and complaints were examined separately (Model 1; all p > 0.27). Overall, 81.2% of respondents gave at least five correct answers, indicating a ceiling effect in the financial knowledge items. The simulation-based power analysis indicated that the provider disputes and refusals model (Model 1 specification) had 86% power for an odds ratio of 0.70 per one-point increase in financial knowledge, 71% for 0.75, but only 34% for 0.85. The observed odds ratios of 0.84–0.85 fall in the range where power was low. An item-response (two-parameter logistic) knowledge score, which weights the items by their discrimination, yielded similar results (OR = 0.86 and 0.87 per standard deviation in Model 1 and Model 2; p = 0.311 and 0.340). The data are therefore uninformative about H3: the non-significant result should not be read as evidence that financial knowledge is unrelated to provider disputes and refusals.

When entered individually, none of the five digital security items was associated with fraud exposure and incidents, and only checking whether a provider is regulated was associated with provider disputes and refusals (OR = 1.31; p = 0.018), which would not remain significant after correction for the ten exploratory tests (Table S3). Including the items left the associations of fully online financial contracting significant, but the association of digital financial activity with provider disputes and refusals was no longer significant (OR = 1.33; p = 0.212; Table A5). None of the interactions involving age or income was statistically significant (all p > 0.40). Because these tests had limited power, the absence of significant interactions does not imply that the associations are the same across groups. In age-stratified models, the odds ratios for fully online financial contracting were similar for respondents under 50 and those aged 50 or older (fraud exposure and incidents: 2.76 and 2.72; provider disputes and refusals: 3.52 and 3.23), but only 39 respondents aged 50 or older had concluded a contract entirely online (Table S5). Financial knowledge was significantly associated with lower odds of provider disputes and refusals only in the unweighted model (OR = 0.79; p = 0.039) and under Firth estimation (OR = 0.79; p = 0.040). These point estimates were close to that obtained in the weighted model (OR = 0.84; p = 0.229). The difference in statistical significance reflects both the slightly weaker (closer to one) weighted point estimate and the larger design-adjusted standard errors.

Table S1. Characteristics of respondents included in and excluded from the regression sample, 2022.

Characteristic	Included (n = 639)	Excluded (n = 361)	p
Age (mean, years)	45.3	50.9	<0.001
Female (%)	53.2	49.3	0.263
Tertiary education (%)	20.7	12.5	0.002
Low income (% of those reporting income)	31.8	73.3	<0.001
Income not reported (%)	0.0	58.4	<0.001
Holds a current account (%)	77.8	58.2	<0.001
Uses the internet (%)	100.0	59.6	<0.001
Financial knowledge (mean, 0–7)	5.5	5.2	<0.001
Fraud exposure and incidents (%)	8.3	7.5	0.738
Provider disputes and refusals (%)	10.2	6.1	0.037

Source: Authors' calculations based on the OECD/INFE survey conducted in Hungary. Unweighted values; Welch t-tests for means and chi-square tests for proportions. Respondents were excluded because they had no valid digital financial activity score (n = 176, including 146 non-internet users), had a valid activity score but did not report their income (n = 183), or had missing age (n = 2).

Table S2. Fintech use without the online securities trading and automated advisory items, 2022.

Specification	Outcome	Basic digital financial activities	Fintech use (two items)	Fully online contracting
Panel A: subindices as mean scores	Fraud exposure and incidents	1.27 (0.85–1.91); 0.244	1.26 (0.86–1.86); 0.236	–
	Provider disputes and refusals	1.72 (1.19–2.48); 0.004	1.04 (0.77–1.42); 0.789	–
Panel B: binary fintech use	Fraud exposure and incidents	1.33 (0.91–1.94); 0.141	1.33 (0.69–2.55); 0.389	–

Specification	Outcome	Basic digital financial activities	Fintech use (two items)	Fully online contracting
	Provider disputes and refusals	1.67 (1.17–2.37); 0.005	1.21 (0.67–2.19); 0.519	–
Panel C: Panel B + fully online contracting	Fraud exposure and incidents	1.12 (0.75–1.68); 0.574	1.23 (0.62–2.42); 0.554	2.95 (1.52–5.71); 0.001
	Provider disputes and refusals	1.42 (0.99–2.04); 0.058	1.10 (0.60–2.01); 0.757	3.11 (1.75–5.52); <0.001

Source: Authors' calculations based on the OECD/INFE survey conducted in Hungary. Cells report OR (95% CI); p-value. N = 639; all models include financial knowledge, age, gender, and income category. The fintech measure is based on mobile payments and account aggregation only; binary use (at least sometimes) applies to 41.8% of the regression sample. With the overall digital financial activity index recalculated without the two items, the ORs for digital financial activity were 1.59 (p = 0.041) and 1.83 (p = 0.001) in Model 1, and 1.30 (p = 0.301) and 1.48 (p = 0.039) in Model 2.

Table S3. Digital security items: inter-item correlations and associations with financial detriment, 2022.

Item (higher = more cautious)	(1)	(2)	(3)	(4)	(5)	Fraud exposure and incidents OR (95% CI); p	Provider disputes and refusals OR (95% CI); p
(1) Never shares passwords or PINs (QS2_6)	1					1.02 (0.74–1.41); 0.914	0.91 (0.68–1.21); 0.507
(2) Checks whether provider is regulated (QS2_7, R)	−0.22	1				1.15 (0.90–1.46); 0.267	1.31 (1.05–1.64); 0.018
(3) Changes passwords regularly (QS3_11, R)	−0.29	0.20	1			1.02 (0.77–1.37); 0.869	1.01 (0.75–1.36); 0.936
(4) Considers public Wi-Fi unsafe (QS4_1)	0.07	0.00	−0.10	1		0.94 (0.73–1.20); 0.601	1.05 (0.81–1.36); 0.694
(5) Considers website security checks important (QS4_2, R)	0.11	0.13	−0.01	−0.18	1	1.14 (0.93–1.40); 0.214	1.07 (0.86–1.33); 0.553

Source: Authors' calculations based on the OECD/INFE survey conducted in Hungary. Pearson correlations of the coded items (pairwise n = 894–953); R = reverse-coded. Odds ratios are from separate weighted logistic regressions adding one item to Model 2 of Table 4 (N = 609–637). Cronbach's α = −0.09; mean inter-item correlation = −0.03.

Table S4. Selection-related covariates and E-values for fully online financial contracting, 2022.

Specification / measure	Fraud exposure and incidents	Provider disputes and refusals
Panel A: weighted logistic regression (N = 636; first row: Model 2, N = 639)		
Fully online contracting (at least one), Model 2	2.94 (1.54–5.62); 0.001	3.18 (1.78–5.67); <0.001
Fully online contracting, + risk tolerance, financial monitoring, number of products	2.68 (1.37–5.23); 0.004	3.09 (1.71–5.56); <0.001
Willingness to take financial risks (1–5)	1.44 (1.13–1.83); 0.003	1.13 (0.90–1.42); 0.294
Keeps a close watch on financial affairs (1–5)	1.14 (0.87–1.48); 0.339	1.00 (0.75–1.32); 1.000
Digital financial activity	0.98 (0.58–1.68); 0.951	1.43 (0.91–2.24); 0.120
Panel B: E-values (Model 2; online banking product: joint model in Table 5)		

Specification / measure	Fraud exposure and incidents	Provider disputes and refusals
Fully online contracting (at least one), conservative (square-root) E-value: point / lower limit	2.82 / 1.79	2.96 / 2.00
Fully online contracting (at least one), rare-outcome approximation: point / lower limit	5.33 / 2.45	5.81 / 2.96
Online banking product, conservative (square-root) E-value: point / lower limit	2.73 / 1.52	2.95 / 1.75
Online banking product, rare-outcome approximation: point / lower limit	5.03 / 1.89	5.76 / 2.37

Source: Authors' calculations based on the OECD/INFE survey conducted in Hungary. Cells in Panel A report OR (95% CI); p-value; models also include financial knowledge, age, gender, and income category. Risk tolerance and financial monitoring are the reverse-coded statements QS1_2 and QS1_5 (higher = more agreement). Conservative E-values apply the square-root transformation of the odds ratio, which is recommended for common outcomes and is used here because the outcomes were common among the exposed (17–23%, weighted, regression sample); the rare-outcome values are shown for comparison.

Table S5. Age-stratified associations, 2022.

Age group	Outcome	N	Events	Fully online contracting (at least one)	Digital financial activity
Under 50 (online contract: n = 106)	Fraud exposure and incidents	398	34	2.76 (1.19–6.41); 0.018	1.46 (0.75–2.83); 0.268
	Provider disputes and refusals	398	40	3.52 (1.75–7.08); <0.001	1.63 (0.97–2.74); 0.064
50 and older (online contract: n = 39)	Fraud exposure and incidents	241	19	2.72 (1.02–7.21); 0.045	0.94 (0.45–1.96); 0.871
	Provider disputes and refusals	241	25	3.23 (1.16–8.98); 0.025	1.57 (0.78–3.18); 0.205

Source: Authors' calculations based on the OECD/INFE survey conducted in Hungary. Cells report OR (95% CI); p-value. Models follow Model 2 in Table 4. The estimates are descriptive: the interaction tests (all $p > 0.40$) had limited power.

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