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THE EFFECT OF UNEMPLOYMENT INSURANCE ON THE SAFETY NET AND INFANT HEALTH IN THE USA

ABSTRACT: *This paper examines the effects of Unemployment Insurance temporary cash transfer payments on birth outcomes in the United States. Using natality data for the years 1970–2019 and implementing a triple-difference strategy, we find that the programme has sizeable and significant effects on the health outcomes of new-borns, including birth weight, gestational age, and Apgar score. Moreover, we show that these effects are more pronounced among black mothers, low-educated mothers, and unmarried mothers.*

KEY WORDS: *social insurance, unemployment insurance, externality, foetal origin hypothesis, birth outcomes, prenatal care, health utilisation, cash transfer, safety net*

JEL CLASSIFICATION: D62, H51, I13, I18, J65, P36

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1. INTRODUCTION

Unemployment Insurance (UI) is a temporary cash transfer programme that aims to insulate against income fluctuations among workers who are laid off through no fault of their own. UI benefits were vastly expanded during and after the great recession, making the UI programme the largest safety net in the US during the crisis (Bitler and Hoynes, 2016). In addition to the benefit expansion, high unemployment rates escalated UI payments during the great recession. In 2007 the total amount of payments was $33 billion, while $94 billion was paid out in 2012 (Budget Office, 2018). In the one-year period between 2008 and 2009 total claims increased from around three to six million. The slow economic recovery accompanied by larger payments and longer duration of payments stimulated a strand of studies revisiting the social costs and benefits of the UI programme (Barr and Turner, 2015; Bitler and Hoynes, 2016; Card et al., 2015a; Mueller, Rothstein, and Wachter, 2016), as well as its unintended and unplanned externalities on other outcomes including crime (Beach and Lopresti, 2019), foreclosure (Hsu, Matsa, and Melzer, 2018), alcohol abuse (Lantis and Teahan, 2018), cigarette smoking (Fu and Liu, 2019), health (Kuka, 2018), mental health (Tefft, 2011a), college enrolment (Barr and Turner, 2015), and children's educational outcomes (Regmi, 2019).

Increases in UI benefits may have spillover effects on infants' health outcomes through several channels. The primary channel is through the effects on temporary income. UI payments can enable households to absorb negative consumption shocks (Chetty, 2006; East & Kuka, 2015a; Landais et al., 2018). This consumption-smoothing channel can influence the health outcomes of infants by providing materials that directly benefit health, such as food, or by providing goods that operate indirectly, such as health insurance and prenatal care (Figlio et al., 2009; Ga & Feng, 2012; Haeck & Lefebvre, 2016b; Mocan et al., 2015; Noghanibehambari et al., 2020b; Sonchak, 2016). Social insurance also has the potential to influence maternal mental health outcomes and help mothers experience less stressful pregnancies. Since stress has a detrimental influence on birth outcomes, UI payments can be beneficial for infants' health outcomes (Álvarez-Aranda et al., 2020; Bozzoli & Quintana-Domeque, 2014; Noghanibehambari et al., 2020a; Olafsson, 2016).

Another channel is the improvement of job-match quality. Not all pregnancies overlap with the unemployment period: earlier trimesters might overlap with unemployment and later trimesters with the period of being re-employed. The evidence suggests that UI payments can help this transition by providing more time and increasing the efficiency of job search, thus improving the quality of re-employment occupational match (Baker & Fradkin, 2017; Blau & Robins, 1986; Centeno, 2004; Tatsiramos & van Ours, 2014; van Ours & Vodopivec, 2008).

Although UI is a federally mandated programme, each state has its own eligibility criteria and payment schedule, as well as duration of UI payments. As a result, state-level differences in UI laws generate a substantial cross-sectional variation in UI benefits. States also adjust their benefits in biannual periods, for either common reasons such as inflation or state-specific reasons like economic conditions or the solvency of UI Trust Funds.

We take advantage of changes in both dimensions: across states and over time. We exploit these variations to investigate how changes in income (through changes in temporary cash transfers) influence the health outcomes of new-borns. We use the information on virtually all birth records in the US from National Vital Statistics covering the years 1970–2019 and apply a panel data fixed effects research design that implements a triple difference estimation strategy. In particular, the identification strategy compares the average health outcomes of mothers that are predicted to be eligible for UI payments with those of mothers that are not (within state variation) to state-level UI law changes over time.

The results indicate that higher UI benefits are associated with better birth outcomes. For example, an increase of $3,828 in benefit caps, the standard deviation of the maximum possible payments to an unemployed person over the sample, can increase birth weight by approximately 110 grams and weekly foetal growth by 2.3 grams.

It is worth noting that these effects are intention-to-treat effects and smaller in magnitude than treatment-of-treated effects, for several reasons. First, the UI programme does not target pregnant women or women in general but the total eligible unemployed population. Second, the regular benefits are limited in time, so they might not cover the whole critical period of pregnancy. Third, due to the

temporary nature of the transfers, families might not spend them on health-related expenditures such as prenatal care or better health insurance.

This study builds on the work of Noghanibehambari and Salari (2020). We add to their paper in several ways. First, we add 23 additional data years so that our sample covers 50 years of data and virtually all birth records across the US. Second, we investigate the heterogeneity of the results across subsamples. This aspect of our research has more policy implications, revealing the subpopulations that are most affected. Third, we analyse extended UI benefits. This is important because the extended UI programmes could confound the health effects of the regular UI programmes.

The rest of the paper is organised as follows. Section 0 reviews the literature. Section 0 introduces the data sources. Section 0 discusses the empirical method. Section 0 reviews the main results. Section 0 provides the results of the heterogeneity analysis. Section 0 replicates the main results for extended benefits. Section 1 explores endogenous fertility. Finally, section 0 concludes the paper.

2. A BRIEF LITERATURE REVIEW

UI payments generate a transitory income shock to the unemployed. The changes in income may affect infants' health outcomes through several channels, which we discuss below.

Income increase expands the demand curve for normal products. Some known determinants of health inputs, such as health insurance and healthcare spending, are shown to be normal goods (Alfonso et al., 2016; Cameron and Trivedi, 1991). Therefore, an increase in income may encourage households to allocate more resources to infants' health. A small strand of literature provides evidence that income is positively associated with improved birth outcomes (Bhalotra and Rawlings, 2013; Hoynes et al., 2011). For instance, Hoynes et al. (2015) evaluate the effects of changes in the Earned Income Tax Credit (EITC) payments schedule as a federal tax reform on infants' health. The cash transfers created a significant and also permanent shock to households' income. The increased income encouraged healthcare spending, including prenatal care and private health insurance. They find that a $1,000 treatment-on-the-treated increase in income is associated with 6.4 grams higher birth weight and about 2%–3%

reduction in low birth weight. On the other hand, Cole and Currie (1993) explore the effect of cash transfers from Aid to Families with Dependent Children (AFDC) on birth outcomes and find no evidence of an increase in birth weight.

Income increases may also shift mothers' demand for prenatal health care and insurance. This shift might be manifested by obtaining health insurance for uncovered mothers or choosing better quality health insurance, both of which are associated with better pregnancy outcomes (Conway and Kutinova, 2006; Currie and Grogger, 2002).

The UI programme is considered a successful social insurance programme that aims to smooth the income and consumption of the unemployed (East and Kuka, 2015). Consumption smoothing and having a safety net may alleviate the financial burden, anxiety, and distress associated with job loss (Tefft, 2011b). A small strand of literature evaluates the health effects of maternal stress during pregnancy and suggests a positive though small association (Duncan et al., 2017; Olafsson, 2016). If the UI programme is also successful in reducing maternal anxiety and stress, it could improve birth outcomes.

Another critical health input that may increase by income is nutrition. It is well documented that better nutrition leads to better health outcomes for infants (Almond et al., 2011a; Haeck and Lefebvre, 2016; Majid, 2015).

3. DATA

The main source of data is the restricted version county-identified US Vital Statistics Natality Detailed files. They cover all birth records in the US over the years 1970–2019 and contain information on a child's health measures, mother's characteristics, and limited father's characteristics.

We drop observations with missing values on birth weight and gestational weeks. In addition, we restrict the sample to singleton births, since outcomes of plural births might be driven by factors other than intrauterine determinants of infants' health.

The Measure of UI Payments

The UI benefit rules and payment schedule are obtained from the US Department of Labor. Following Hsu et al. (2018), we proxy the UI payments by the maximum benefit that eligible unemployed can receive, which is the maximum weekly allowance times the maximum duration of payments, hereafter called 'maximum benefit'. Figure 1 presents a graphic of each state's 'maximum benefit' in each year. There is a large cross-sectional variation in the 'maximum benefit' across states. Over the sample period (1970–2019) the average 'maximum benefit' is $11,897 and its standard deviation is $3,828, both in real 2019 dollars. In 2019, the 'maximum benefit' in the most and the least generous state was $33,090 (Massachusetts) and $3,300 (Florida). Rhode Island, Washington, and Connecticut are the next most-generous states after Massachusetts.

Imputation of Mother's Unemployment Status

Since the Natality files do not report mothers' employment status, we impute the likelihood of each mother being unemployed and eligible for UI benefits based on their demographic characteristics and residential location using monthly Current Population Survey (CPS) data. In so doing, we compute the share of women who are unemployed and identified as job losers or on lay off[1] in each month, year, state, and for the following demographic characteristics: age, education, race, and marital status. This share is calculated using CPS weights. Since job losers or individuals on lay off are probably eligible for unemployment insurance, we name the generated variable 'predicted eligibility'. Figure 2 shows a graphical visualization of 'predicted eligibility' among CPS women across each state and over the years 1970–2019.

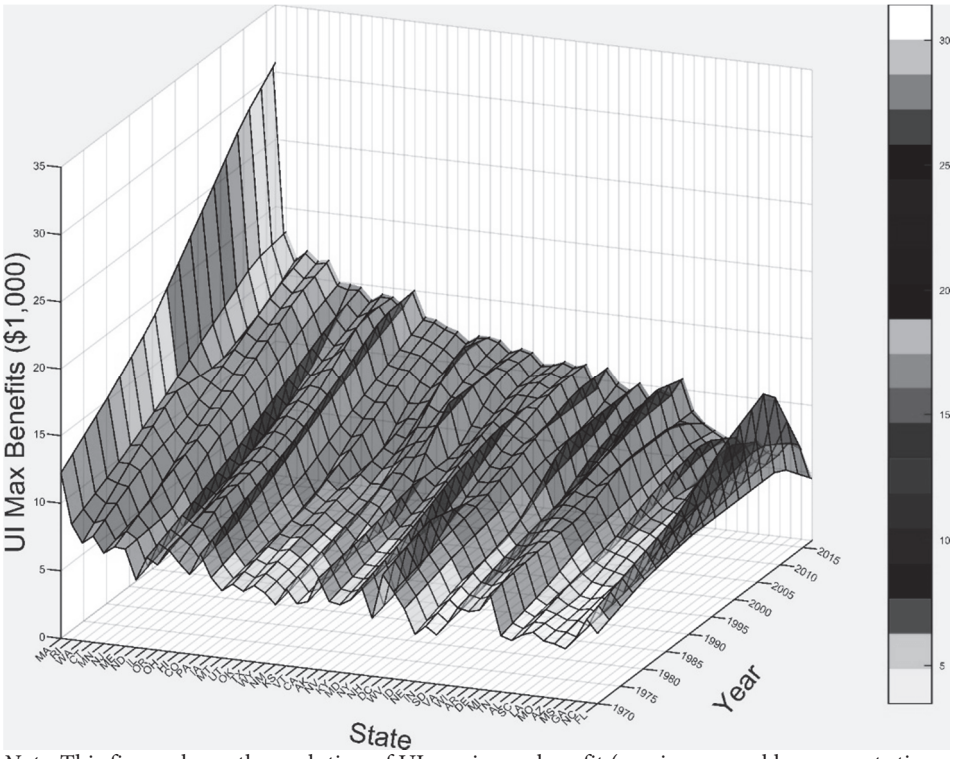
To have a consistent level of aggregation, we collapse the final sample of Natality data into the state, year and month of birth, age, education, race, and marital status. We then merge the collapsed Natality data with the generated 'predicted eligibility' data and UI benefits based on state, demographic group, and year and month of birth.

[1] The CPS asks each person who is in the labour force and currently claims to be unemployed the reason for being unemployed. These reasons are categorized as: job-losers on lay off, other job losers, temporary job ended, job leaver, re-entrant, new entrant.

Since embryos are susceptible to external shocks during the in-utero period, the UI transfers might be effective during pregnancy. Therefore, a better approach requires the UI benefits to be assigned during pregnancy, which is usually nine months, rather than their contemporaneous values. We thus calculate the average of UI benefits and 'predicted eligibility' over the nine months prior to each month and year of birth.

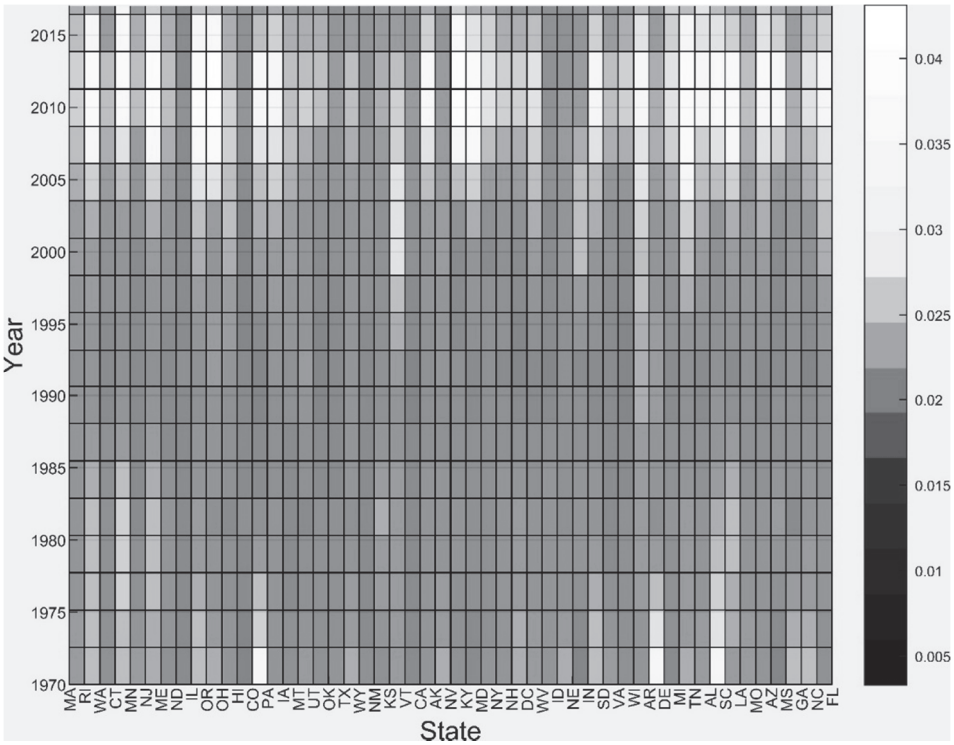
Summary statistics of the final sample are reported in Table 1. On average, about 10% of births are categorized as low birth weight. Roughly 1.4% of mothers are eligible for benefits.

Figure 1: Maximum UI benefits across states and over time



Note: This figure shows the evolution of UI maximum benefit (maximum weekly payments times maximum duration of pay) for each state (in x-axis) across the years 1970–2019 (y-axis). The colour palette on the right refers to the levels of UI maximum benefit (z-axis), with warmer and darker colors showing larger amounts. Massachusetts (the far-left state on the x-axis) experienced the largest increases in UI benefits over the years 1970–2019 and Florida (the far-right state on the y-axis) experienced the lowest increases.

Figure 2: Average predicted UI eligibility within mothers' demographic cells, across states and over the years



Note: The variable 'predicted eligibility' is the share of women in monthly CPS files who are unemployed and identified as job losers or on lay-off in each month, year, state, and for the following demographic characteristics: age, education, race, and marital status. It represents the imputed value of mothers who are likely to receive UI benefits. This figure shows the distribution of 'predicted eligibility' across states (x-axis) and over the years 1970–2019 (y-axis). The lighter colours show higher values and the darker colours show lower values.

Table 1: Descriptive Statistics

	Mean	SD	Median
Infants' Characteristics			
Birth Weight (Grams)	3200.18	320.24	3234.13
Full-Term Birth Weight (Grams)	3349.56	224.08	3356.90
Gestational Age-Adjusted Birth Weight (Grams)	3294.61	217.47	3333.13
Low Birth Weight	0.09	0.14	0.07
Small for Gestational Age	0.13	0.15	0.11
Foetal Growth	83.82	6.84	84.28
Sex (Female=1)	0.49	0.21	0.49
Gestational Age (Weeks)	38.69	1.52	38.91
Preterm Birth	0.20	0.18	0.18
Apgar Score (1–10)	8.74	0.59	8.85
Delivery Method (Vaginal=1)	0.69	0.22	0.72
Mothers' Characteristics			
Predicted Eligibility	0.014	0.020	0.00
Age	27.66	5.87	26.21
Education: Missing	0.21	0.41	0.00
Education: Less Than High School	0.02	0.07	0.00
Education: High School	0.36	0.46	0.00
Education: Some College	0.20	0.30	0.00
Education: Bachelor Degree	0.12	0.19	0.00
Education: Master – PhD	0.08	0.15	0.00
Race: White	0.53	0.50	1.00
Race: Black	0.27	0.38	0.00
Race: Indian	0.05	0.17	0.00
Ethnicity: Hispanic	0.07	0.15	0.01
Married	0.51	0.50	1.00
Prenatal Visits	11.31	2.17	11.50
No. of Cigarettes Smoked	1.00	2.10	0.22
Smoker	0.11	0.17	0.04
State Unemployment Insurance Figures			
Duration (Weeks)	25.91	1.61	26.00
Maximum Weekly Pay (Nominal, $1,000)	0.36	0.13	0.33
Maximum Benefit (Nominal, $1,000)	9.24	3.75	8.55
Maximum Benefit (Real, $1,000)	11.89	3.82	11.38
Observations:		577,978	

Note: US dollar values are in 2019 dollars. The panel covers the years 1970–2019. Each observation is a demographic (based on mothers' education, race, marital status, and age)–state–year cell.

4. EMPIRICAL STRATEGY

Although the main source of exogeneity in the identification strategy is the state–time changes in UI benefits, the 'predicted eligibility' generates another dimension of variation within each state and time. The identification strategy takes advantage of space–time variation in UI laws as well as the extent to which each group of mothers is likely to be eligible for the treatment; i.e., their 'predicted eligibility'. This strategy can be summarized in the following difference-in-difference-in-difference (hereafter DDD) estimation strategy:

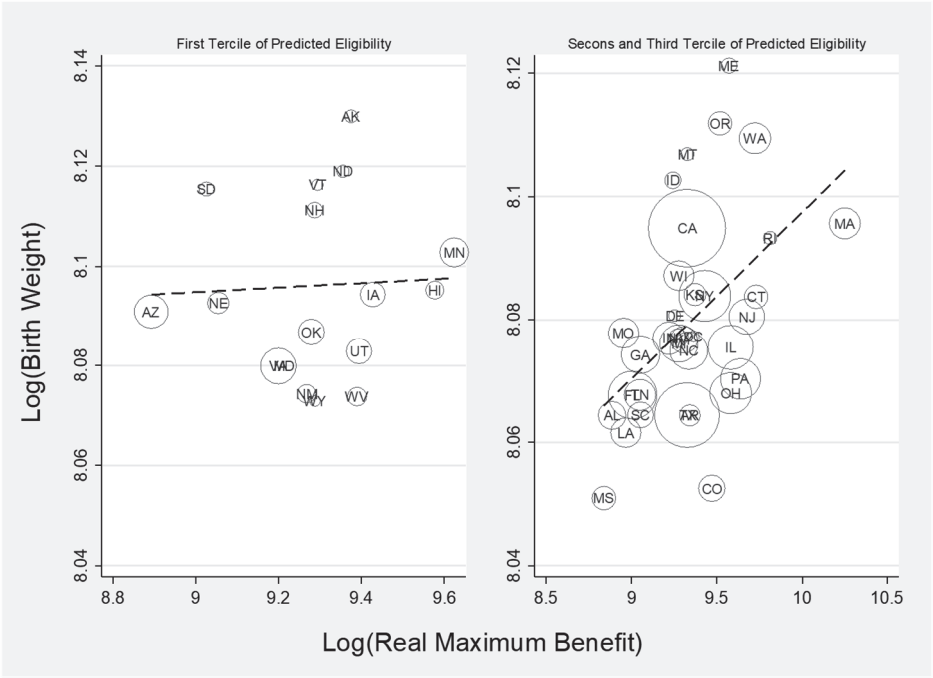
$$\begin{aligned} y_{aermst} = {} & \alpha + \delta MaxBen_{st} \times PredElig_{aerm} + \beta MaxBen_{st} + \theta PredElig_{aerm} \\ & + \vartheta X_{aerm} + \gamma Z_{st} + \mu_a + \phi_e + \kappa_r + \zeta_m + \pi_t + \tau_s \times t + \varepsilon_{ist} \end{aligned} \quad (1)$$

where y is the average birth outcome of mothers in age group a, education group e, race r, with marital status m, in state s and time (month–year) t. $MaxBen$ is maximum UI benefits; i.e., maximum weekly payments × maximum number of weeks of payments, measured in 2019 thousand dollars except where explicitly stated otherwise. X is a vector of mother and father characteristics (father's age and race dummies, mother's delivery method dummies, and mother's use of prenatal care); Z is a vector of state-by-year controls (share of different age groups in the population, share of different race groups in the population, income per capita, minimum wage, expenditure per capita on Medicaid, and unemployment rate); μ, ϕ, κ, and ζ are a series of fixed effects for age, education, race, and marital status, respectively; π is time (month–year) fixed effects; $\tau_s \times t$ is a state-specific time trend included in some specifications. Finally, ε is a disturbance term. All regressions are weighted using the birth counts in each cell.

5. MAIN RESULTS

We start with a visual depiction of the relationship between benefits, eligibility, and birth outcomes. Among mothers in the top two terciles of 'predicted eligibility' there is a strong unconditional correlation between birth weight and UI Maximum Benefit (shown in the right panel of Figure 3). At the same time, there is no visual correlation between UI benefits and birth weight among mothers in the first tercile of predicted eligibility (left panel of Figure 3).

Figure 3: UI maximum benefits and birth weight across terciles of predicted eligibility



In order to empirically explore the visually positive association between UI benefits and birth outcomes, we run different specifications of Equation 1. The results are reported in Table 2. 'Predicted eligibility' is negatively correlated with birth weight, while the 'maximum benefit' has a positive but insignificant correlation. The signs of the main effects comply with our prior expectations that being laid off restricts the mothers' necessary resources during pregnancy, while cash transfers mediate such difficulties.

The DDD term, δ (reported in the third row), suggests a positive effect on birth outcomes. The estimated coefficient of column 1 implies that a $3,828 increase in benefits, a standard deviation of benefits over the sample period, increases birth weight by roughly 110.3 grams, a 3.4% increase in the mean of birth weight.

Moreover, a one-standard-deviation increase in 'maximum benefit' is associated with roughly 41.2 hours longer gestational age, a 0.6% increase in the mean of gestational age.

The interaction coefficient implies a marginal effect of an 89-basis-point reduction in 'low birth weight' (birth weight < 2,500 g) for a $1,000 change in 'maximum benefit', or an 8.9% reduction in the mean of low birth weight (compared to a 0.8% increase in the mean of birth weight). The effect is similar when we look at the low tails (bottom 10%) of birth weight distribution within each week of gestation. The marginal effect of –1.0 percentage points on 'small for gestational age' (column 2) implies a reduction of 7.7% for each additional $1,000 rise in benefits. The DDD coefficient of full-term birth weight (birth weight for infants with gestational age between 38 and 42 weeks, column 3) is smaller than that of mean birth weight in column 1. Furthermore, the DDD term implies a 123-basis-points reduction in preterm birth (gestational age less than 37 weeks), equivalent to a 6.2% reduction in the mean of preterm birth (column 4). These results suggest that the UI benefits are more helpful for poorer mothers who are at the risk of having a child with low birth weight or a preterm child.

Children who are in utero for a longer time have higher birth weight, and those who are born prematurely are born with low birth weight. In a full specification regression based on the final sample of this paper, the elasticity of birth weight with respect to gestational weeks is 1.5. Therefore, an interesting question is whether or not the positive effects of UI benefits on birth weight are merely the results of having a longer gestational period. To investigate this we use another measure of health at birth, 'foetal growth', which is defined as birth weight divided by gestational weeks. The DDD term of 0.62 (p-value<0.01) implies an increase of 0.7% in the mean of 'foetal growth' as a response to a $1,000 rise in 'maximum benefits' (column 6). Comparing this rise with 0.8% for the birth weight and 0.15% for the gestational age (marginal effect of 0.06 for a mean of 38.6), one can conclude that the positive effects on birth weight are mainly driven by faster intrauterine growth of the foetus rather than a longer gestational period.

Another measure of health at birth is the five-minute Apgar score (varies between 1 and10). While there is a positive interaction term that points to an improvement in Apgar score, the estimate is imprecise. However, the DDD term on all other

outcomes (columns 1–7) is economically large and statistically significant at the 1% level.

The estimated coefficients are comparable to other studies. For instance, Hoynes et al. (2015) find that a treatment-on-the-treated $1,000 raise in income through the extension of earned income tax credit increases birth weight by about 6 grams for the entire population of recipients and by about 18.7 grams for blacks, a 0.2% and 0.6% rise in the mean of birth weight, respectively. In another study, Almond, Hoynes, and Schanzenbach (2011) explore the health effects of the introduction of the Food Stamp Program (FSP) during the 1970s on birth outcomes. They find that food stamps lead to an increase in the mean birth weight of about 0.06%. These positive externalities also hold in the case of developing countries. Amarante, Manacorda, Miguel, and Vigorito (2016) show that participation in PANES, a government welfare programme in Uruguay targeted at the poorest 10% of the country, is associated with roughly 30 grams higher birth weight, and about 165 grams higher birth weight among premature children.

Table 2: Maximum UI benefits and infants' birth outcomes

	Birth Weight	Low Birth Weight	Small for Gestational Age	Full-Term Birth Weight	Preterm Birth	Foetal Growth	Gestational Age	Apgar Score
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predicted UI Eligibility	−498.44***	0.1573***	0.1738***	−379.90***	0.2063***	−10.610***	−1.17***	−0.7686**
	(93.30)	(0.0241)	(0.0395)	(87.67)	(0.0038)	(2.222)	(0.27)	(0.3819)
Maximum benefit ($1,000)	0.481	0.0001	−0.0001	0.6479	−0.0002	0.0081	0.001	0.0006
	(0.659)	(0.0001)	(0.0002)	(0.4921)	(0.0004)	(0.0128)	(0.002)	(0.0039)
Predicted UI Eligibility × Maximum Benefit ($1,000)	28.83***	−0.0089***	−0.0101***	23.597***	−0.0123***	0.6213***	0.064***	0.0356
	(6.08)	(0.0015)	(0.0021)	(5.938)	(0.0038)	(0.1356)	(0.023)	(0.0230)
R^2	0.78	0.50	0.58	0.78	0.17	0.08	0.58	0.52
Observations	577,978	577,978	577,978	577,978	577,978	577,978	577,978	339,987
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Full Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by the number of birth counts in the cell. Standard errors, clustered on the state, are reported in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

6. HETEROGENEITY ANALYSIS

In this section we explore the heterogeneity in the effects across subsamples based on some observable characteristics. In Table 3 we show the triple-interaction coefficient for a selected set of outcomes and across subsamples. The effects are largest among low-educated and unmarried mothers. For instance, a $1,000 increase in benefits among eligible versus non-eligible mothers is associated with 56 grams higher birth weight in unmarried-mother samples. This effect is about 6.7 grams in the married-mother sample. The effects are also larger in counties with a higher share of blacks compared to counties with a lower share of blacks. Overall, the results suggest that the effects are more concentrated in more vulnerable populations and point to larger externalities among low-educated, unmarried, and black mothers.

7. EXTENDED BENEFITS AND INFANT HEALTH

During periods of high unemployment, states may extend the duration of UI payments for those who have exhausted their regular benefit and remained unemployed. Two federal programmes cover such extensions. The Extended Benefit (EB) programme provides an additional 13 weeks of UI payments and is triggered when the unemployment rate goes above 5% and is 20% higher than the two-year average of the state-level unemployment rate. The Emergency Unemployment Compensation (EUC) Act of 2008, modified by the Middle-Class Tax Relief and Job Creation Act of 2012, categorizes claimants into four tiers based on the state-level three-month seasonally adjusted unemployment rate. It provides 20, 14, 13, and 6 weeks of additional benefits for tiers one through four. The cumulative additional benefits can add up to 53 weeks. The EUC expired in December 2013.

These extended benefits provided an unprecedented additional cash transfer that varied across states based on their contemporaneous unemployment rate. In Table 4 we explore the possible effects of extended benefits on infant health outcomes for the period 2000–2014.[2] For birth weight, both the main effect of 'maximum benefit' and the DDD coefficient are positive and significant (column 1). For 'predicted' eligible mothers versus 'predicted' non-eligible mothers, a one-

[2] These extended UI payments started around 2002 and ended in 2013.

standard-deviation rise in 'maximum benefits', equivalent to a $12,574 increase, is associated with 28.2 grams-higher birth weight. The implied marginal effects for low birth weight and preterm birth are –0.12 and –0.14 percentage points (columns 2 and 8, respectively). These effects are substantially lower than those in the main results for regular UI benefits. One possible explanation is that extended benefits are for those who have exhausted their regular payments and are still unemployed. These potential eligible mothers might be systematically different from others in unobservable ways that are correlated with their birth outcomes and lead to a bias in the estimated coefficients. Another reason could be the fact that extended benefits (especially EUC) are paid in times of extremely high unemployment rates. A deep recession may generate a harsher environment for pregnant mothers and may mitigate the positive effects of cash transfers.

The results also suggest a positive effect of extended benefits on other birth outcomes, such as small for gestational age, full-term birth weight, Apgar score, foetal growth, and gestational age. However, they are imprecisely estimated and quite small in magnitude.

Table 3: Heterogeneity of results across subsamples

Sample	Outcomes				
	Birth Weight	Low Birth Weight	Gestational Weeks	Preterm Birth	Apgar Score
Mother Education ≤ 12	31.81***	–0.0098***	0.0936**	–0.0140**	0.0785**
	(6.28)	(0.0019)	(0.0041)	(0.0057)	(0.0326)
R^2	0.71	0.44	0.55	0.47	0.18
Observations	306,143	306,143	306,143	306,143	168,706
Mother Education > 12	19.21***	–0.0046***	0.0422*	–0.0087***	0.0017
	(11.81)	(0.0015)	(0.0231)	(0.0029)	(0.0261)
R^2	0.80	0.50	0.63	0.47	0.20
Observations	210,142	210,142	210,142	210,142	117,003
Mother Unmarried	55.77***	–0.0180***	0.1470***	–0.0270***	0.0554
	(9.667)	(0.0032)	(0.0445)	(0.0070)	(0.0358)
R^2	0.70	0.46	0.54	0.45	0.18
Observations	247,419	247,419	247,419	247,419	137,125
Mother Married	6.776**	–0.0031***	0.0149	–0.0044*	0.0182
	(3.242)	(0.0010)	(0.0131)	(0.0022)	(0.0141)
R^2	0.72	0.35	0.55	0.38	0.19
Observations	267,866	267,866	267,866	267,866	148,584
Below-Median Blacks	27.14***	–0.0060**	0.0583*	–0.0144***	0.0195
	(7.41)	(0.0022)	(0.0345)	(0.0052)	(0.0199)
R^2	0.78	0.51	0.58	0.51	0.19
Observations	277,276	277,276	277,276	277,276	153,991
Above-Median Blacks	30.10***	–0.0098***	0.0483*	–0.0100	–0.0034
	(7.58)	(0.0024)	(0.0264)	(0.49)	(0.0179)
R^2	0.77	0.49	0.56	0.49	0.19
Observations	238,009	238,009	238,009	238,009	131,718

Note: Each cell represents a separate regression. All regressions are weighted by the number of birth counts in the cell. Standard errors, clustered on the state, are reported in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 4: UI extended benefits (EB+EUC) and infants' birth outcomes

	Birth Weight	Low Birth Weight	Small for Gestational Age	Full-Term Birth Weight	Apgar Score	Foetal growth	Gestational Weeks	Preterm Birth
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predicted UI Eligibility	−198.78*** (59.44)	0.0699*** (0.0161)	0.0731*** (0.0253)	-135.07*** (52.36)	−0.5249** (0.2559)	−4.103*** (1.344)	−0.5566*** (0.1561)	0.0633*** (0.0206)
Maximum benefit ($1,000)	0.2999*** (0.0506)	−0.00005** (0.00002)	−0.0001*** (0.00003)	0.2299*** (0.0577)	−0.0010 (0.0006)	0.0066*** (0.0014)	0.0005 (0.0003)	−0.00004 (0.00004)
Predicted UI Eligibility × Maximum Benefit ($1,000)	2.243** (1.027)	−0.0012*** (0.0003)	−0.0006 (0.0005)	1.577* (0.9368)	0.0081 (0.0082)	0.0414 (0.0269)	0.0092* (0.0050)	−0.0014** (0.0006)
R^2	0.76	0.49	0.58	0.78	0.17	0.55	0.52	0.48
Observations	158,185	158,185	158,126	153,381	156,576	158,126	158,126	158,126
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by the number of birth counts in the cell. Standard errors, clustered on the state, are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

8. CONCLUSION

This paper examined the effects of temporary cash transfer through the Unemployment Insurance programme on an untargeted population: infants. We extended previous studies on this topic by showing that UI payments benefit mothers and new-borns. In addition, we provide evidence that these benefits are more pronounced among black mothers, uneducated mothers, and unmarried mothers.

The nontrivial effects of UI benefits on birth outcomes offer an unplanned externality that policymakers can use to re-evaluate the benefit components of the programme and re-design the optimum benefit schedule. The importance of these externalities lies in the long-term effect of health endowment at birth, and specifically the lifetime costs of adverse birth outcomes such as low birth weight.

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UNCERTAINTY AND BANK FUNDING LIQUIDITY RISK IN VIETNAM

ABSTRACT: *This paper examines the impact of uncertainty on bank funding liquidity risk. Based on a sample of Vietnamese commercial banks from 2007 to 2019, we show evidence that micro uncertainty in the banking sector leads to higher funding liquidity risk, as proxied by lower deposit ratios. Additional analyses reveal that this nexus widely depends on bank heterogeneity. More precisely, various bank-specific forces that improve banks' financial strength (i.e., an increase in bank return, loan quality, capitalization, liquid assets, and bank size) tend to mitigate the adverse impact of uncertainty on bank funding liquidity risk. Our findings are robust to changes in multiple combinations of regressors, different key bank-level variables to calculate the dispersion of shocks as banking uncertainty measures, and alternative econometric approaches.*

KEY WORDS: *bank deposits, bank-specific characteristics, dynamic models, funding liquidity risk, uncertainty*

JEL CLASSIFICATION: D81, E50, G21, G32

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1. INTRODUCTION

Uncertainty has become a topic of great interest for academics and policymakers, especially since the 2008 global crisis. Accordingly, many harmful consequences of uncertainty have been found, from cutting investment/consumption and increasing unemployment (Aaberge et al., 2017; Caggiano et al., 2017; Drobetz et al., 2018; Gulen & Ion, 2016; Yizhong Wang et al., 2014) to reducing gross national product (Baker et al., 2016; Bloom et al., 2018). Notably, existing studies in the banking literature have also shown adverse effects of uncertainty. For example, in the context of uncertainty, banks are more likely to lose market values (He & Niu, 2018), take on more risk (Chi & Li, 2017; Karadima & Louri, 2021; Wu et al., 2020), experience higher financial instability (Bilgin et al., 2021; Phan et al., 2021), and restraint loan growth (Bordo et al., 2016; Buch et al., 2015; Danisman et al., 2020; Hu & Gong, 2019; Valencia, 2017).

In two recent empirical papers, Berger et al. (2020) and Ashraf (2020) have explored changes in banks' liquidity hoarding behaviours in response to uncertainty shocks. Berger et al. (2020) concentrate on all liquid banking items on and off the balance sheets of US banks, while Ashraf (2020) examines banks' pure liquid asset holdings in 21 major countries, in an identical effort to link economic policy uncertainty with bank liquidity hoarding. They conclude that banks hold more liquidity – with the main emphasis on increased asset liquidity – as a precautionary motive to protect themselves against increased risks of liquidity shortages and funding difficulties that might occur as a result of uncertainty.

Overall, although there has been much analysis of the impact of uncertainty on the banking sectors, some even highlighting bank asset liquidity, the existing literature exploring bank funding liquidity risk in the face of uncertainty is still limited. Funding liquidity has a special role in providing funds that allow banks to repay their due liabilities. Funding liquidity risk describes the inability of a bank to acquire funds as needed with efficiency (Dahir et al., 2018). It can also be defined as a bank's failure to settle obligations immediately (Drehmann & Nikolaou, 2013). While asset liquidity risk relates to the asset side of banks' balance sheets, funding liquidity risk deals with the liability side. Funding liquidity risk is regarded as a critical factor that leads to bank runs (Drehmann & Nikolaou, 2013). Problematic deposit-taking exposes banks to funding liquidity

risks that may predict bank runs (Diamond & Dybvig, 1983). In addition, funding liquidity risk, as denoted by lower deposit ratios, is expected to hamper bank lending activities (Acharya & Naqvi, 2012; Ivashina & Scharfstein, 2010). Therefore, understanding how bank funding liquidity risk reacts to uncertainty is extremely important. In this paper, we fill a gap in the literature by testing whether bank funding liquidity risk is sensitive to a high level of uncertainty.

Uncertainty is expected to influence bank funding liquidity risk through competing routes. On the one hand, in a period of high uncertainty, banks are seen as 'safe shelters' for depositors' assets due to deposit insurance and government guarantees that encourage investors to prefer bank deposits to other investment opportunities (Gatev & Strahan, 2006). When this mechanism dominates, banks can raise more deposits and avoid funding liquidity risk in times of heightened uncertainty. On the other hand, depositors may demand greater deposit rates as a risk premium when they face adverse shocks in uncertain times (Pástor & Veronesi, 2012). If banks cannot afford this demand they are forced to cut their core funds, and thus suffer greater funding liquidity risk. Overall, we could expect the impact of uncertainty on bank funding liquidity risk to be theoretically ambiguous: an increase in uncertainty can lead to a decrease or an increase in bank funding liquidity risk. This ambiguity makes this link an interesting empirical topic to be explored.

Within this framework, we explore the impact of uncertainty on bank funding liquidity risk in the panel dataset of Vietnamese commercial banks for the period 2007–2019. Following most prior studies on bank funding liquidity risk, we proxy it via the ratio of deposits to total assets, greater deposits indicating lower funding liquidity risk. While previous papers have looked at aggregate uncertainty (i.e., economic policy uncertainty) or its subcomponents (e.g., monetary uncertainty or financial uncertainty) (see Al-Thaqeb and Algharabali 2019 for a thorough review), our work considers the uncertainty aspect associated explicitly with the banking sector (Buch et al., 2015). The use of this micro measure which directly displays the uncertainty level in banking could constitute an outstanding supplement to the existing literature on the link between uncertainty and bank activities. Moreover, computation of a banking uncertainty measure based on the cross-sectional dispersion of shocks to bank-level variables may yield multiple advantages. Typically, and unlike market-based measures, it does not demand

market data with a high frequency (Buch et al., 2015), and unlike text-based uncertainty proxies it does not face vulnerability in assuring the reliability and accuracy of newspapers (Baker et al., 2016). In line with Buch et al. (2015), we consider the dispersion of shocks to key bank-level variables, including total assets, short-term funding, and bank profitability. These alternative variables strengthen the conclusions of the paper.

In analysing the impact of uncertainty on funding liquidity risk, we further focus on the different responses of heterogeneous banks. The fact that uncertainty is a common factor to all banks in the same market implies that heterogeneous banks, associated with different financial strengths and bank-specific characteristics, may be driven more or less by uncertainty. Such heterogeneity in banks' reaction to uncertainty could tell us more about the underlying mechanisms behind the impact under investigation. This idea has been well documented in the related literature on the nexus between uncertainty and bank lending. Many studies have shown that this link is extensively moderated by bank capital (Bordo et al., 2016; Buch et al., 2015; Valencia, 2017), asset liquidity (Bordo et al., 2016; Buch et al., 2015; Valencia, 2017), bank size (Bordo et al., 2016), bank risk (Hu & Gong, 2019; Nguyen et al., 2020), and bank profitability (Nguyen et al., 2020). Moreover, in another well-established literature strand on how bank lending responds to monetary shocks, multiple authors consistently claim that banks with weak balance sheets are more sensitive to monetary shocks because of their limited access to alternative funding (e.g., Kashyap & Stein, 1995; Kishan & Opiela, 2000). Therefore, it is of interest to explore the evolution of bank-specific characteristics that shape the link between uncertainty and funding liquidity risk. We do this by empirically interacting uncertainty with a rich set of key bank-specific variables inspired by the existing literature, including bank credit risk, bank return, capitalization, asset liquidity, and bank size.

As a prominent representative of emerging economies, Vietnam offers favourable characteristics for conducting the analysis. Due to the absence of advanced financial instruments to absorb risk, the unfavourable effects of uncertainty may be more completely exposed in emerging markets (Nguyen et al., 2020). Moreover, Vietnam's financial sector depends extensively on the banking system, which plays a vital role in fuelling economic growth (Dang & Dang, 2020). Thus, any excessive funding liquidity risk in Vietnamese banks is more likely to produce

detrimental consequences than in less bank-dependent markets. In recent years, banking uncertainty in Vietnam has experienced a period of sizable fluctuation as a result of multiple forces, such as the 2008 global financial crisis, the bad debt boom in 2012, and even the continuous policy reforms to upgrade the banking system's risk management to international standards (Batten & Vo, 2019). The banking reforms have strongly influenced and significantly modified most of the banks in the system, leading to an important divergence in bank-specific characteristics across individual banks (Dang & Huynh, 2021).

Our paper contributes to the understanding of how uncertainty affects bank operations. We introduce the first evaluation of the impact of uncertainty on bank funding liquidity risk. The theory offers conflicting predictions about how uncertainty drives bank funding liquidity risk; however, to date no empirical analysis has been performed to directly shed light on this link. We also aim to understand the underlying mechanism behind the relationship between uncertainty and funding liquidity risk by exploring how this relationship depends on bank-specific characteristics. We do this by interacting uncertainty with a wide range of bank variables in order to target the right group of banks in the specific contexts. In addition, we conduct our regressions using advanced econometric approaches that work well for dynamic panel models; namely, the generalized method of moments (GMM) estimator and the least squares dummy variable corrected (LSDVC) technique. These estimation methods deal effectively with potential endogeneity and small sample bias, as witnessed in this study. We thereby contribute to a growing body of empirical research that makes use of both GMM and LSDVC regressions as perfect complements (Bogliacino et al., 2012; Boukhatem & Djelassi, 2020; Dahir et al., 2019; Yiwei Wang et al., 2019).

The rest of the paper is organised as follows. Section 2 introduces the methodology and data employed for the empirical analysis. Section 3 presents the main estimation results and robustness checks. Finally, section 4 concludes the paper with relevant implications and future research directions.

2. EMPIRICAL METHODOLOGY AND DATA

2.1 Empirical methodology

We explore the impact of uncertainty on bank funding liquidity risk by regressing the baseline model specification as follows:

$$FLR_{i,t} = \alpha_0 + \alpha_1 \times FLR_{i,t-1} + \alpha_2 \times Uncertainty_{t-1} + \alpha_3 \times BC_{i,t-1} + \alpha_4 \times MC_{t-1} + \varepsilon_{i,t} \quad (1)$$

where *i* is a bank, and *t* denotes a year. The dependent variable FLR is the ratio of total deposits to total assets. In line with many previous papers (Acharya & Naqvi, 2012; Dahir et al., 2019; Khan et al., 2017; Rokhim & Min, 2018; Smaoui et al., 2020), we understand banks with more deposits as banks that have less funding liquidity risk. We insert the lagged dependent variable as an important regressor, since bank funding liquidity risk is likely influenced by its past value. The independent variable of primary interest is *Uncertainty*. To better explain bank funding liquidity risk, we allow for various controls (Hoque & Pour, 2018; Umar & Sun, 2016). *BC* is a set of bank-level controls, including bank return (the return-on-asset ratio), bank credit risk (the ratio of loan loss provisions to gross loans), capital (the equity-to-asset ratio), asset liquidity (the ratio of liquid assets to total assets), and bank size (the natural logarithm of total assets). *MC* is a vector of macroeconomic controls, containing policy rates (refinancing rates established by the central bank) and economic cycles (the annual change in GDP). $\varepsilon_{i,t}$ is the error term. We lag all independent variables to reduce reverse-causality problems and emphasize lagged bank responses.

We estimate the above dynamic model using the two-step system GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998). This technique effectively addresses endogeneity issues via the lags of regressors employed as instruments. To validate the GMM regression, we need to limit the number of instruments created (Roodman, 2009) and rely on some diagnostic tests. All of them are carefully described when we report the estimation results.

As mentioned previously, in this paper we utilize bank-level data that carries information regarding banking-market-specific uncertainty. Consistent with Buch et al. (2015), the uncertainty in banking is captured by the cross-sectional dispersion of shocks to assets, short-term funding, and bank profitability. To

obtain such dispersion, we start with the following equation to predict bank-year-specific shocks for each of our key bank-level variables:

$$X_{i,t} = \alpha_i + \beta_t + \varepsilon_{i,t} \tag{2}$$

where $X_{i,t}$ is the bank-level variable selected (total asset growth rate, short-term funding growth rate, and profitability level, separately) for bank *i* at year *t*. The use of all three bank-level variables at the same time helps strengthen the robustness of our work. α_i is bank fixed effects, and β_t is time fixed effects. The residual component $\varepsilon_{i,t}$ is a shock estimation, which is then used in the second step to obtain the cross-sectional dispersion across all bank-specific shocks. Concretely, the standard deviation (*SD*) of the residuals is employed to form the uncertainty measure for the entire banking system in year *t* as follows:

$$Uncertainty_t = SD(\varepsilon_{i,t}) \tag{3}$$

Our uncertainty measure in the banking sector could serve as a good proxy for micro uncertainty stemming from noisy private signals, which is close in spirit to that applied for manufacturing firms by Bloom et al. (2018). Prior authors claim that the cross-sectional dispersion of US firm-level features reveals idiosyncratic differences in information signals across firms.

We go a step further in analysing the effect of uncertainty on bank funding liquidity risk by testing whether the effect is strengthened or weakened under particular conditions. To this end, we reformulate our baseline model as follows:

$$\begin{aligned} FLR_{i,t} = {} & \alpha_0 + \alpha_1 \times FLR_{i,t-1} + \alpha_2 \times Uncertainty_{t-1} + \alpha_3 \times Uncertainty_{t-1} \times BC_{i,t-1} \\ & + \alpha_4 \times BC_{i,t-1} + \alpha_5 \times MC_{t-1} + \varepsilon_{i,t} \end{aligned} \tag{4}$$

where *BC* captures multiple aspects of bank-specific characteristics, as elaborated earlier. The coefficients on the interaction term $Uncertainty \times BC$ indicate whether the effect of uncertainty on bank funding liquidity risk depends on bank heterogeneity. Our approach in this regard sheds light on how uncertainty is translated into bank funding liquidity risk.

2.2 Data

We collected bank-level data from the annual financial reports of 31 commercial banks in Vietnam for the period 2007–2019, subject to data availability. We only kept in our sample the banks that published more than four consecutive years of data. Banks with missing data for the main variables were also eliminated. Apart from bank-level data, we sourced macroeconomic data from the World Development Indicators and the State Bank of Vietnam.

Table 1 displays the summary statistics of our sample. The deposits-to-assets ratio has a mean of 64.05%, implying that on average the deposits of the sample banks equal 64.05% of their total assets. The statistical distributions via the extreme values and the standard deviations of uncertainty measures suggest a substantial fluctuation in uncertainty in the banking system over the years. Other variables also possess considerable volatility.

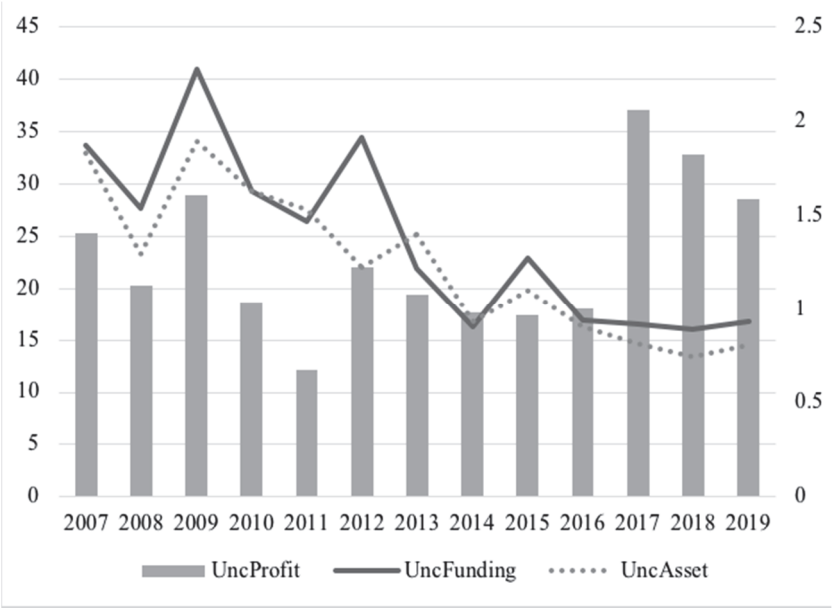
Table 1: Statistics summary

	Mean	Standard deviation	Min	Max
Bank-level characteristics				
Funding liquidity	64.05	13.75	33.22	88.19
Return	1.570	0.868	0.171	3.769
Provision	0.959	0.703	0.035	2.806
Capital	9.984	4.741	4.464	23.831
Asset liquidity	17.347	9.777	5.168	42.289
Size	32.015	1.249	29.879	34.573
Uncertainty measures and macroeconomic factors				
UncAsset	21.936	6.747	13.427	34.091
UncFunding	24.226	7.890	15.995	40.931
UncProfit	1.273	0.386	0.674	2.058
Policy rate	8.021	2.536	6.000	15.000
Economic cycle	6.245	0.640	5.247	7.130

Note: Table 1 summarizes the distribution of all used variables. The sample comprises 31 Vietnamese commercial banks and 383 observations from 2007– 2019. *Funding liquidity* is the ratio of deposits to total assets (%). *Return* is the return-on-asset ratio (%). *Provision* is the ratio of loan loss provisions to gross loans (%). *Capital* is the equity-to-asset ratio (%). *Asset liquidity* is the ratio of liquid assets to total assets (%). *Size* is the natural logarithm of total assets. *UncAsset, UncFunding,* and *UncProfit* are the uncertainty measures for the banking system, calculated by estimating the dispersion of bank shocks to assets, short-term funding, and profitability, respectively. *Policy rate* captures refinancing rates established by the central bank (%). *Economic cycle* reflects the annual change in GDP (%).

Figure 1 displays the changes in uncertainty levels over the years 2007–2019. Asset and funding uncertainty and profitability uncertainty reached their all-time high in 2009. After 2009 the trend of all three uncertainty proxies was downward as a whole, implying a decrease in the level of uncertainty in Vietnam. Interestingly, profitability uncertainty exhibited a slightly different pattern compared to asset and funding uncertainty.

Figure 1: Changes in uncertainty levels, 2007–2019



3. ESTIMATION RESULTS

3.1 Baseline results

Table 2 presents our baseline results for the association between uncertainty and bank funding liquidity risk. As a robustness check, columns 1–3 report the results without macroeconomic factors, while columns 4–6 extend the model by incorporating macroeconomic factors. Alternative measures of uncertainty in banking are also employed. The diagnostic tests (Hansen and AR(1)/AR(2)) and the number of instruments reported ensure that the two-step system GMM estimation is valid to determine the link between uncertainty and bank funding liquidity risk.

Table 2: Baseline regressions

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.570***	0.545***	0.616***	0.674***	0.686***	0.708***
	(0.032)	(0.032)	(0.029)	(0.044)	(0.046)	(0.042)
Uncertainty	–0.320***	–0.202***	–2.549***	–0.110***	–0.172***	–1.796***
	(0.058)	(0.033)	(0.383)	(0.035)	(0.039)	(0.447)
Return	–2.175***	–1.866***	–2.583***	–2.788***	–2.415***	–3.086***
	(0.456)	(0.379)	(0.234)	(0.312)	(0.331)	(0.292)
Provision	0.958**	1.443***	1.514***	1.391***	1.325***	1.528***
	(0.441)	(0.403)	(0.389)	(0.324)	(0.336)	(0.303)
Capital	0.482***	0.124	0.122	0.230***	0.201**	0.290***
	(0.167)	(0.081)	(0.076)	(0.084)	(0.086)	(0.104)
Asset liquidity	0.158***	0.071*	0.056	0.055	0.079	0.053
	(0.040)	(0.040)	(0.041)	(0.044)	(0.055)	(0.042)
Size	4.105***	2.285***	2.470***	2.324***	2.167***	2.468***
	(0.797)	(0.353)	(0.262)	(0.299)	(0.375)	(0.360)
Policy rate				0.693***	0.713***	0.551***
				(0.123)	(0.123)	(0.116)
Economic cycle				1.641***	1.069***	2.097***
				(0.259)	(0.299)	(0.317)
Constant	–100.720***	–38.634***	–49.556***	–65.678***	–56.906***	–74.605***
	(27.591)	(10.978)	(9.155)	(8.301)	(9.959)	(9.854)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	26	26	26	28	28	28
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.115	0.289	0.261	0.605	0.550	0.451
Hansen test	0.131	0.116	0.105	0.124	0.123	0.129

Note: The table presents results from estimating the baseline model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. ***, **, and * indicate significance at the 1%, 5%, and 10% level respectively.

Across all regressions, we observe that the coefficient on uncertainty, our primary variable of interest, is negative and statistically significant. Given that banks with greater deposits have lower funding liquidity risk and the deposit ratio is our dependent variable, our result suggests that banks tend to engage in higher funding liquidity risk in periods of uncertainty in the banking sector. This linkage is also economically significant. For instance, a standard deviation increase of 1 in the uncertainty measure (6.747 for *UncAsset*, 7.890 for *UncFunding*, or 0.386 for *UncProfit*) is associated with a drop in the deposit ratio of 2.159 (6.747*0.320, column 1), 1.594 (7.890*0.202, column 2), or 0.984 (0.386*2.549, column 3) percentage points, respectively. Such changes are reasonable given that the mean value of the deposit ratio is 64.05%.

In sum, our finding shows that bank funding liquidity deteriorates with banking uncertainty. This evidence is consistent with the argument that due to the greater adverse shocks in periods of uncertainty, depositors may require higher funding premiums from their banks, which leads to an increase in funding costs and a potential decrease in the amount of deposits that banks obtain (Pástor & Veronesi, 2012). Our evidence is the first in the literature on the uncertainty–banking institutions nexus to indicate the linkage between uncertainty and bank funding liquidity risk.

3.2 Heterogeneity across banks

As discussed earlier in the paper, banks with different characteristics, such as bank size, capitalization, asset liquidity, and risk-return profiles, may respond differently to uncertainty shocks. In this section we shed light on this possibility by expanding the baseline model with interaction terms between uncertainty and various bank-specific characteristics. Before considering the results for the interaction terms of main interest reported in Tables 3–7, we should pay attention to results from the standalone uncertainty measures, which consistently indicate negative and significant signs. This pattern implies that the adverse impact of uncertainty on bank funding liquidity risk firmly holds.

Table 3 reports the funding liquidity risk regression results highlighting the interaction term between uncertainty and bank return, *Uncertainty*Return*. All coefficients on the interaction term are positive and statistically significant. The significantly negative coefficient on the standalone uncertainty measure, which is

opposite to those observed for the interaction term, shows that bank return introduces a mitigating effect on the association between uncertainty and bank funding liquidity risk. In other words, more profitable banks are likely to suffer less funding liquidity risk than their less profitable peers if the dispersion of shocks to critical bank-level variables surges. Next, Table 4 presents estimates of the interaction term between uncertainty and bank credit risk, captured by loan loss provisions. Interestingly, we observe negative and significant coefficients on estimates of the interaction *Uncertainty*Provision*. In contrast to the positive interaction estimate witnessed for bank return above, this negative estimate suggests that bank credit risk boosts the link between uncertainty and bank funding liquidity risk. In other words, amid uncertainty a deterioration in a bank's asset portfolio quality tends to increase the funding liquidity risk more than an improvement.

Table 3: Augmented regressions with the moderating role of bank return

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.493***	0.429***	0.448***	0.670***	0.676***	0.608***
	(0.030)	(0.043)	(0.049)	(0.040)	(0.046)	(0.055)
Uncertainty	–0.650***	–0.298***	–2.372***	–0.581***	–0.636***	–17.905***
	(0.107)	(0.075)	(0.902)	(0.150)	(0.169)	(3.416)
Uncertainty*Return	0.297***	0.078***	1.382***	0.308***	0.351***	11.487***
	(0.063)	(0.026)	(0.500)	(0.082)	(0.096)	(2.580)
Return	–9.823***	–11.013***	–11.306***	–10.982***	–13.892***	–20.178***
	(1.466)	(1.284)	(1.237)	(1.996)	(2.632)	(3.898)
Provision	2.315***	1.985***	1.818***	2.389***	2.830***	2.746***
	(0.410)	(0.301)	(0.296)	(0.289)	(0.309)	(0.515)
Capital	0.130*	0.588***	0.507***	0.273**	0.371***	0.237*
	(0.077)	(0.087)	(0.089)	(0.114)	(0.118)	(0.128)
Asset liquidity	0.063**	0.104**	0.069	0.074**	0.093**	0.000
	(0.026)	(0.044)	(0.045)	(0.032)	(0.043)	(0.048)
Size	2.790***	4.708***	4.840***	2.788***	3.056***	2.630***
	(0.402)	(0.466)	(0.415)	(0.371)	(0.458)	(0.369)
Policy rate				0.783***	0.972***	1.117***
				(0.135)	(0.146)	(0.185)
Economic cycle				1.533***	1.818***	2.992***
				(0.311)	(0.360)	(0.266)
Constant	–41.197***	–100.856***	–108.526***	–70.163***	–79.797***	–59.408***
	(12.579)	(14.166)	(11.158)	(12.487)	(13.422)	(13.219)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	27	27	27	29	29	29
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.380	0.626	0.416	0.514	0.364	0.257
Hansen test	0.194	0.361	0.377	0.198	0.106	0.144

Note: Table 3 presents results from estimating the augmented model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. ***, **, and * indicating significance at the 1%, 5%, and 10% levels respectively.

Table 4: Augmented regressions with the moderating role of bank credit risk

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.547***	0.485***	0.606***	0.699***	0.706***	0.722***
	(0.027)	(0.035)	(0.029)	(0.043)	(0.053)	(0.049)
Uncertainty	–0.083	–0.188***	–1.315***	–0.081**	–0.140***	–1.495***
	(0.056)	(0.037)	(0.456)	(0.036)	(0.033)	(0.487)
Uncertainty*Provisio n	–0.237***	–0.086***	–1.128***	–0.117***	–0.160***	–0.894***
	(0.053)	(0.021)	(0.330)	(0.041)	(0.038)	(0.326)
Return	–2.132***	–2.493***	–4.324***	–2.710***	–2.235***	–3.077***
	(0.378)	(0.242)	(0.457)	(0.388)	(0.404)	(0.398)
Provision	8.767***	1.931***	9.282***	1.703***	4.923***	1.718***
	(1.161)	(0.442)	(0.775)	(0.363)	(0.978)	(0.299)
Capital	0.082	0.161*	0.119	0.329***	0.152	0.293**
	(0.102)	(0.097)	(0.113)	(0.097)	(0.115)	(0.122)
Asset liquidity	0.108***	–0.073	0.156***	0.057	0.106*	0.025
	(0.039)	(0.046)	(0.045)	(0.042)	(0.059)	(0.049)
Size	1.790***	2.900***	1.519***	2.653***	1.969***	2.500***
	(0.284)	(0.338)	(0.278)	(0.306)	(0.489)	(0.415)
Policy rate				0.849***	0.994***	0.615***
				(0.122)	(0.152)	(0.132)
Economic cycle				1.412***	1.079***	2.161***
				(0.344)	(0.332)	(0.330)
Constant	–28.440***	–50.722***	–25.248**	–77.420***	–55.321***	–76.554***
	(10.840)	(11.444)	(10.322)	(8.742)	(16.202)	(14.115)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	27	27	27	29	29	29
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.219	0.325	0.205	0.393	0.493	0.415
Hansen test	0.194	0.177	0.381	0.135	0.140	0.174

Note: Table 4 presents results from estimating the augmented model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

In addition to return-risk profiles, other standard bank-level factors also matter. Table 5 displays the effect of banking uncertainty on funding liquidity risk, conditional on banks' capital ratio. The interaction term *Uncertainty*Capital* is positive and significant in most columns, implying that given an increase in uncertainty, the funding liquidity risk of better-capitalized banks increases less. In uncertain periods, these better-capitalized banks can partially shield their funding liquidity against shocks. Similarly, in Table 6, the coefficient of the interaction term *Uncertainty*Asset liquidity* is positive and statistically significant in most columns, confirming that when uncertainty in the banking sector is high, banks hoarding more liquid assets may experience a smaller decline in deposits than banks with less liquid assets. Finally, we examine whether bank size can alter the adverse effect of uncertainty on bank funding liquidity risk. Consistently, our results show that the estimate for the interaction term *Uncertainty*Size* in Table 7 is positive and highly significant, suggesting that funding liquidity risk is less pronounced in larger banks during times of high uncertainty.

Table 5: Augmented regressions with the moderating role of bank capital

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.585***	0.613***	0.634***	0.780***	0.804***	0.782***
	(0.029)	(0.026)	(0.031)	(0.041)	(0.042)	(0.045)
Uncertainty	–0.382***	–0.194***	–4.994***	–0.514***	–0.395***	–5.323***
	(0.043)	(0.036)	(0.674)	(0.054)	(0.047)	(0.695)
Uncertainty*Capital	0.005*	0.017***	0.591***	0.007**	0.013***	0.462***
	(0.003)	(0.004)	(0.075)	(0.003)	(0.003)	(0.074)
Return	–1.888***	–2.676***	–3.319***	–2.335***	–2.610***	–3.555***
	(0.386)	(0.362)	(0.347)	(0.299)	(0.235)	(0.315)
Provision	1.225***	1.438***	1.333***	0.850**	0.967***	1.127***
	(0.445)	(0.507)	(0.495)	(0.342)	(0.345)	(0.384)
Capital	0.192*	–0.046	–0.157	0.250*	0.108	0.005
	(0.104)	(0.084)	(0.097)	(0.133)	(0.119)	(0.114)
Asset liquidity	0.125***	0.067*	0.086**	0.179***	0.154***	0.082*
	(0.035)	(0.037)	(0.038)	(0.045)	(0.030)	(0.045)
Size	2.640***	2.931***	3.356***	2.409***	2.425***	2.963***
	(0.263)	(0.271)	(0.284)	(0.447)	(0.477)	(0.382)
Policy rate				1.013***	1.213***	0.703***
				(0.118)	(0.164)	(0.123)
Economic cycle				0.100	1.633***	1.950***
				(0.271)	(0.251)	(0.275)
Constant	–51.974***	–64.999***	–79.466***	–64.129***	–78.262***	–93.113***
	(10.080)	(10.136)	(10.386)	(14.305)	(13.621)	(11.431)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	27	27	27	29	29	29
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.159	0.178	0.226	0.160	0.296	0.387
Hansen test	0.132	0.111	0.106	0.130	0.142	0.154

Note: Table 5 presents results from estimating the augmented model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table 6: Augmented regressions with the moderating role of bank asset liquidity

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.545***	0.508***	0.490***	0.813***	0.635***	0.615***
	(0.026)	(0.044)	(0.029)	(0.055)	(0.058)	(0.040)
Uncertainty	–0.300***	–0.190***	–13.588***	–0.353***	–0.146***	–13.274***
	(0.064)	(0.038)	(0.899)	(0.078)	(0.046)	(1.009)
Uncertainty*Asset liquidity	0.007***	0.006***	0.949***	0.010***	0.003	0.835***
	(0.001)	(0.001)	(0.059)	(0.003)	(0.002)	(0.076)
Return	–1.921***	–6.884***	–2.483***	–4.757***	–8.993***	–2.955***
	(0.456)	(1.250)	(0.261)	(0.897)	(0.811)	(0.374)
Provision	4.180***	4.038***	1.306***	8.106***	6.002***	1.480***
	(0.965)	(1.053)	(0.402)	(1.399)	(1.016)	(0.400)
Capital	0.258**	0.601***	–0.045	0.257	0.848***	0.157
	(0.125)	(0.219)	(0.074)	(0.290)	(0.200)	(0.104)
Asset liquidity	0.351***	0.289***	1.155***	-0.122	0.094	0.971***
	(0.031)	(0.105)	(0.066)	(0.101)	(0.086)	(0.081)
Size	1.022**	3.559***	2.414***	0.296	4.136***	2.556***
	(0.425)	(0.690)	(0.315)	(1.177)	(0.314)	(0.375)
Policy rate				1.290***	0.327	0.350***
				(0.133)	(0.219)	(0.123)
Economic cycle				1.937***	1.711***	2.386***
				(0.468)	(0.480)	(0.383)
Constant	3.061	–74.222***	–23.135**	–16.619	–121.276***	–55.951***
	(15.197)	(24.434)	(10.863)	(41.559)	(11.616)	(9.641)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	27	27	27	29	29	29
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.171	0.637	0.191	0.163	0.816	0.255
Hansen test	0.136	0.149	0.155	0.181	0.191	0.148

Note: Table 6 presents results from estimating the augmented model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. *** and ** indicate significance at the 1% and 5% levels respectively.

Table 7: Augmented regressions with the moderating role of bank size

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.536***	0.590***	0.634***	0.679***	0.711***	0.699***
	(0.029)	(0.036)	(0.037)	(0.043)	(0.050)	(0.051)
Uncertainty	–4.837***	–5.522***	–74.585***	–3.445*	–4.686***	–50.450**
	(0.500)	(0.561)	(14.036)	(1.818)	(1.328)	(23.204)
Uncertainty*Size	0.145***	0.167***	2.223***	0.105*	0.142***	1.498**
	(0.016)	(0.017)	(0.427)	(0.057)	(0.041)	(0.712)
Return	–1.621***	–1.384***	–2.447***	–2.504***	–2.083***	–2.834***
	(0.367)	(0.420)	(0.248)	(0.530)	(0.514)	(0.469)
Provision	1.135***	0.943**	1.531***	1.125***	0.994***	1.577***
	(0.428)	(0.436)	(0.390)	(0.381)	(0.372)	(0.328)
Capital	0.085	0.151*	0.063	0.251***	0.230**	0.203
	(0.086)	(0.086)	(0.080)	(0.087)	(0.101)	(0.127)
Asset liquidity	0.070*	0.088*	0.069	0.065	0.083	0.056
	(0.037)	(0.046)	(0.047)	(0.043)	(0.058)	(0.049)
Size	–0.970*	1.911***	–0.551	0.020	–1.401	0.340
	(0.538)	(0.676)	(0.742)	(1.459)	(1.332)	(1.224)
Policy rate				0.617***	0.646***	0.464***
				(0.131)	(0.124)	(0.134)
Economic cycle				1.842***	1.350***	1.857***
				(0.270)	(0.340)	(0.343)
Constant	65.954***	91.644***	47.140**	6.549	53.254	–2.613
	(17.622)	(20.334)	(22.365)	(48.002)	(41.641)	(41.017)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31
Instruments	27	27	27	29	29	29
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.632	0.485	0.404	0.755	0.754	0.543
Hansen test	0.113	0.123	0.112	0.129	0.125	0.126

Note: Table 7 presents results from estimating the augmented model using two-step GMM. The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Standard errors are given in parentheses. Diagnostic tests are displayed with p-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Overall, the estimation results in Tables 3–7 reveal that an increase in bank return, capitalization, asset liquidity, and bank size may help alleviate the link between uncertainty and bank funding liquidity risk, while an increase in bank credit risk tends to exacerbate the detrimental effect of uncertainty. All of our results remain unchanged when alternative uncertainty measures are used and a series of different regressors are included. Overall, our findings show that in Vietnam, stronger banks may be less affected by the dispersion of bank shocks. In this regard, the funding liquidity risk of the more profitable, less risky, better capitalized, more liquid, and larger banks in periods of high uncertainty will be smaller. Market participants underestimate financially weaker banks (Jayaratne & Morgan, 2000). Consequently, depositors may realize greater adverse shocks when involved with these banks and therefore demand a much greater funding premium during times of high uncertainty, which may amplify the funding liquidity risk. Our results are broadly in line with the literature showing that banks with weak balance sheets are more subject to macroeconomic shocks due to their more limited funding access (Kashyap & Stein, 1995; Kishan & Opiela, 2000). All in all, our findings with conditional patterns shed light on the potential mechanism through which uncertainty drives bank funding liquidity risk.

3.3 Robustness tests

Thus far, our findings are not sensitive to different uncertainty measures and different sets of regressors. However, a sensitivity check with an alternative econometric technique needs to be conducted, as the recent literature claims that the GMM estimator may work poorly when the data panel is small (Bogliacino et al., 2012; Boukhatem & Djelassi, 2020), as in our case. To solve this problem, we re-estimate our dynamic models using the LSDVC approach, which is proven to be highly effective when the sample of cross-section units is small and the panel data are strongly unbalanced (Bruno, 2005). Following prior studies, we display bootstrapped standard errors with 50 times replication while performing the LSDVC estimator (Bogliacino et al., 2012; Boukhatem & Djelassi, 2020).

Tables 8–9 present the robustness check results from LSDVC regressions. We only show LSDVC (Anderson-Hsiao) estimates; other LSDVC regressions (Anderson-Hsiao and Blundell-Bond) yielded similar patterns but are not shown for brevity. Though the significance level of our estimates slightly decreases with the alternative econometric approach, our key findings remain unaltered. The negative coefficients on standalone uncertainty measures point to the detrimental

effect of uncertainty on bank funding liquidity risk. The same conditionality is detected as found previously, under which banking uncertainty modifies funding liquidity risk heterogeneously.

Table 8: Robustness checks with the moderating roles of bank credit risk and return

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit
Lagged dependent variable	0.725***	0.710***	0.651***	0.714***	0.717***	0.772***
	(0.040)	(0.044)	(0.033)	(0.051)	(0.053)	(0.051)
Uncertainty	–0.260*	–0.208	–1.288**	–0.017	–0.097**	–1.596***
	(0.136)	(0.134)	(0.596)	(0.039)	(0.042)	(0.487)
Uncertainty*Return	0.152*	0.086	0.859**			
	(0.085)	(0.083)	(0.346)			
Uncertainty* Provision				–0.125***	–0.116**	–1.524***
				(0.046)	(0.047)	(0.426)
Return	–7.530***	–6.259***	–10.518***	–3.295***	–2.762***	–3.464***
	(2.188)	(2.384)	(0.975)	(0.518)	(0.543)	(0.502)
Provision	2.304***	2.341***	4.601***	2.215***	4.300***	2.394***
	(0.363)	(0.458)	(1.155)	(0.392)	(1.040)	(0.363)
Capital	0.353***	0.340***	0.654***	0.376***	0.198*	0.372***
	(0.115)	(0.108)	(0.179)	(0.129)	(0.118)	(0.122)
Asset liquidity	0.114***	0.133***	0.183***	0.069	0.118**	0.064
	(0.037)	(0.050)	(0.056)	(0.045)	(0.057)	(0.046)
Size	2.774***	2.677***	4.403***	2.700***	2.036***	2.550***
	(0.338)	(0.369)	(0.423)	(0.354)	(0.462)	(0.316)
Policy rate	0.623***	0.638***	0.373**	0.713***	0.770***	0.571***
	(0.118)	(0.120)	(0.155)	(0.097)	(0.128)	(0.119)
Economic cycle	1.756***	1.628***	2.154***	1.488***	1.275***	2.290***
	(0.259)	(0.265)	(0.476)	(0.328)	(0.280)	(0.307)
Constant	–81.553***	–77.614***	–131.763***	–80.895***	–58.850***	–82.464***
	(11.233)	(11.622)	(11.906)	(12.992)	(16.543)	(11.560)
Observations	352	352	352	352	352	352
Banks	31	31	31	31	31	31

Note: Table 8 presents results from estimating the augmented model using LSDVC (Anderson-Hsiao). The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Bootstrapped standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. Other LSDVC estimates (Arellano-Bond and Blundell-Bond) yield similar patterns, but are not reported for brevity.

Table 9: Robustness checks with the moderating roles of bank capital, asset liquidity, and bank size

	(1) UncAsset	(2) UncFunding	(3) UncProfit	(4) UncAsset	(5) UncFunding	(6) UncProfit	(7) UncAsset	(8) UncFunding	(9) UncProfit
Lagged dependent variable	0.776***	0.782***	0.828***	0.812***	0.706***	0.678***	0.718***	0.726***	0.722***
	(0.048)	(0.049)	(0.051)	(0.054)	(0.043)	(0.043)	(0.043)	(0.049)	(0.052)
Uncertainty	−0.371***	−0.320***	−5.558***	−0.174**	−0.108**	−10.681***	−3.151	−4.586***	−45.718*
	(0.059)	(0.054)	(0.816)	(0.080)	(0.051)	(1.061)	(2.048)	(1.295)	(24.894)
Uncertainty*Capital	0.009**	0.013***	0.396***						
	(0.004)	(0.004)	(0.085)						
Uncertainty*Asset liquidity				0.011***	0.001	0.599***			
				(0.003)	(0.003)	(0.086)			
Uncertainty*Size							0.098	0.141***	1.354*
							(0.063)	(0.040)	(0.765)
Return	−2.831***	−2.892***	−3.918***	−5.307***	−8.843***	−3.454***	−3.046***	−2.527***	−3.183***
	(0.544)	(0.482)	(0.451)	(0.980)	(0.770)	(0.453)	(0.714)	(0.673)	(0.587)
Provision	1.261***	1.329***	1.791***	9.473***	5.652***	1.873***	1.608***	1.460***	1.896***
	(0.407)	(0.418)	(0.346)	(1.377)	(1.033)	(0.394)	(0.459)	(0.432)	(0.359)
Capital	0.347**	0.174	0.104	0.136	0.950***	0.161	0.319**	0.272**	0.207
	(0.139)	(0.151)	(0.124)	(0.318)	(0.245)	(0.112)	(0.132)	(0.129)	(0.146)
Asset liquidity	0.169***	0.145***	0.114***	−0.133	0.209*	0.648***	0.092**	0.104*	0.098*
	(0.041)	(0.041)	(0.044)	(0.101)	(0.109)	(0.094)	(0.042)	(0.057)	(0.051)
Size	2.775***	2.601***	2.803***	0.237	4.349***	2.347***	0.197	−1.443	0.485
	(0.579)	(0.461)	(0.373)	(1.209)	(0.681)	(0.343)	(1.788)	(1.346)	(1.274)
Policy rate	0.741***	0.883***	0.622***	0.921***	0.342	0.380***	0.502***	0.514***	0.374***
	(0.105)	(0.162)	(0.113)	(0.117)	(0.231)	(0.112)	(0.114)	(0.103)	(0.113)
Economic cycle	0.512*	1.503***	1.929***	2.211***	1.660***	2.224***	1.923***	1.487***	1.887***
	(0.290)	(0.227)	(0.290)	(0.434)	(0.467)	(0.339)	(0.247)	(0.312)	(0.294)
Constant	−79.572***	−80.985***	−90.715***	−16.333	−135.067***	−56.136***	−3.572	51.921	−8.927
	(21.278)	(13.910)	(13.165)	(43.196)	(20.776)	(11.530)	(58.911)	(42.223)	(42.912)
Observations	352	352	352	352	352	352	352	352	352
Banks	31	31	31	31	31	31	31	31	31

Note: Table 9 presents the results from estimating the augmented model using the LSDVC (Arellano-Bond). The dependent variable is the ratio of deposits to total assets (reverse funding liquidity risk). Uncertainty measures employed in each regression (including *UncAsset, UncFunding,* and *UncProfit*) are shown at the top of each column. Bootstrapped standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4. CONCLUSION

Employing a sample of Vietnamese commercial banks for the period 2007–2019, this paper investigates the effect of uncertainty on bank funding liquidity risk. We measure uncertainty in the banking sector using the dispersion of shocks to key bank-level variables and capture funding liquidity risk via the deposit ratio. Though there is much empirical analysis on how banks react to uncertainty, our paper is the first to focus on funding liquidity risk in the context of uncertainty. Our findings show that uncertainty in banking increases funding liquidity risk. Inspired by previous authors, we also explore whether bank-specific characteristics can weaken or intensify how banks respond to uncertainty shocks. Our findings across different aspects of bank characteristics tend to converge toward a uniform pattern that shows that greater financial strength of banks, captured by an increase in bank return/loan quality/capital/asset liquidity/bank size, can weaken the impact of uncertainty on bank funding liquidity risk. Not only are our findings robust to different combinations of regressors, but they also remain unchanged when different key bank-level variables are employed to calculate the dispersion of bank shocks as banking uncertainty measures or different estimation approaches are adopted, such as dynamic GMM and LSDVC.

Our findings have certain policy implications. Banking uncertainty is an essential factor explaining banks' funding liquidity risk, which regulatory authorities should keep it in mind when issuing policies that can alter the level of uncertainty. Given that funding liquidity risk may adversely affect bank operations and, further, the real economy, actions to reduce uncertainty and stabilize the banking sector should be prioritized. Another caveat highlights the importance of focusing on certain groups of banks as a bonus policy to mitigate the detrimental impact of uncertainty on funding liquidity risk. In other words, a consistent framework to improve the financial strength of banks should be considered.

Our analysis has some limitations. It only features one market and a modest database, and in this market we only consider banking uncertainty computed by bank-level data as a single kind of uncertainty. Due to data limitation, we only focus on bank deposits as a whole, though different deposit sources (e.g., demand deposits and saving deposits) may differ significantly. Future research could expand our work to other markets using different forms of uncertainty and a further breakdown of deposit structure. It would also be interesting to separate

periods of low uncertainty from periods of high uncertainty in order to examine the link between uncertainty and bank operations.

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PRODUCT DIFFERENTIATION AND EXPORT INCENTIVE SCHEMES: A GAME THEORY APPROACH

ABSTRACT: *In order to improve economic growth, many governments use public policies to promote their countries' degree of internationalisation. When designing optimal public incentive schemes for internationalisation it is fundamental to consider the characteristics of export markets, such as size, competition degree, tax system, and product differentiation. This paper analyses whether product differentiation has any impact on optimal internationalisation incentive policies, focusing on export subsidy schemes. We develop a two-stage game for three different scenarios: (1) no subsidy, (2) a fixed-subsidy scheme, and (3) a subsidy-per-quantity-exported scheme. Using numerical analysis, we revisit the analysis of schemes designing optimal public incentives for internationalisation and conclude that for export markets with low product differentiation a subsidy-per-quantity exported scheme is best at stimulating internationalisation, while for export markets with high product differentiation a fixed-subsidy scheme is the preferable policy.*

KEY WORDS: *export subsidy schemes, internationalisation, product differentiation, game theory.*

JEL CLASSIFICATION: D43, F19, L13

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1. INTRODUCTION

Many governments provide support to their industries and firms. They do so for a variety of reasons, namely (1) to support fragile industries or regions, (2) to compensate for exceptional situations, (3) to foster national industries to compete in either the European or the global market, (4) to provide goods or services in the event of market failure, and (5) to promote internationalisation and R&D (Lin, 2021; OECD, 2021). In general, the aim of government support is to increase social welfare (Wilkinson & Brouthers, 2006). This type of government intervention gained momentum after the financial crisis at the end of the first decade of the 21st century and it has been argued that it has given industrial policy a new life; however, research on its effects and functioning is lacking (Criscuolo et al., 2019).

One of the areas of governmental support is internationalisation. Politicians have traditionally supported internationalisation because of its benefit to the economy and the difficulties firms face during the internationalisation process. Promoting internationalisation involves developing measures to address the lack of skills and internal resources and mitigate the economic and political risk to which firms are exposed (Zaheer, 1995; Bannò & Sgobbi, 2010). Therefore, governments introduce political measures that provide financial or knowledge resources to assist and enhance firms 'capacity to handle the specificities related to the internationalisation process (Varum & Piscitello, 2011; Bannò & Sgobbi, 2010; Ciszewska-Mlinarič, 2018). Government intervention is justified by market failures, the achievement of social equality, and the distribution of income and welfare (Alcântara et al., 2013; Krugman et al., 2012). From a public policy perspective, the aim is to enable businesses to exploit existing possibilities under better conditions (Maeseneire & Claeys, 2007).

In recent years more than 70% of policies and programmes to support internationalisation have been export-related. Since 1980 many studies have used game theory to examine trade policy focusing on exports (European Commission, 2014). Eaton and Grossman (1983) discuss the effects on social welfare of a commercial and industrial policy under an oligopoly industrial structure, and identify the ideal form of intervention through qualitative analysis. The authors conclude that a production subsidy and an export tax added to the production subsidy can increase national welfare. Dixit and Grossman (1986)

analyse the effect of an export subsidy. Starting from a duopoly as in Cournot, they show that an export subsidy transfers profits from the government to the domestic firm, increasing social welfare. Comparing a domestic firm and a foreign firm, and assuming that both use the same factor of production and that the economy is perfectly competitive, the authors find improvements in national well-being. Brander and Spencer (1985) analyse the impact of the application of a specific export subsidy on welfare. They consider a domestic and a foreign firm operating as in Cournot and producing for a third market with entry barriers (high fixed costs), with homogeneous products, and without domestic consumption. They show that when applying a subsidy to the quantity exported the marginal costs of the domestic firm decrease, while its exports increase. As a result, the subsidy moves the Cournot-Nash equilibrium, reducing the foreign firm's earnings. Hwang et al. (2015) introduce the cost of welfare from distorted taxation in the framework of Brander and Spencer (1985) and use it to compare welfare levels under specific export subsidies and ad valorem subsidies. They find that well-being under the specific subsidy scheme is higher (lower) than in the ad valorem subsidy scheme if the social cost of 'taxation distortion' is low (high). In addition, the signs of the two optimal subsidies are also dependent on this social cost, being positive (negative) if the social cost is low (high). According to Beenhakker (2001), defenders of the application of export subsidies believe that they deter investment and production by foreign firms, which can increase the profits of the national firm in a greater proportion than the subsidy and consequently increase social well-being. He shows that export subsidies can affect the structure of the game between a small number of either domestic or foreign firms (oligopoly) to allow the subsidized firm to profit from exports at the expense of foreign competitors. For Dobre (2008), strategic trade policies aim to promote exports in specific sectors to increase a nation's well-being. Therefore, she questions whether government intervention can increase national well-being by shifting oligopoly income from abroad to national firms. The author shows that, in principle, government policies such as export subsidies can serve the strategic objective of changing the subsequent incentives of firms acting as a deterrent to foreign competitors.

In general, most studies consider a homogeneous product market and do not consider a differentiated product market or explore whether product differentiation impacts the incentive policy chosen by governments. The present

paper is the first to explore, through game theory, the conditions under which the degree of product differentiation affects decisions regarding the most appropriate internationalisation incentive. This study is relevant to the extent that innovation and internationalisation strategies develop conjointly, and government policies aim to provide the means to help firms to compete internationally through both. In Portugal the government's incentive policy stresses the importance of firms investing in the development of their products before addressing foreign markets, in order to differentiate themselves from other firms, thus supporting the need to analyse the impact of product differentiation. To the best of our knowledge, no previous work analyses the influence of different degrees of product differentiation on internationalisation incentive policies. Therefore, regarding export subsidies, we developed a two-stage game for three different scenarios: (1) no subsidy, (2) a subsidy for investment in internationalisation, and (3) a subsidy based on the quantity exported. Using numerical analyses, we explore which internationalisation subsidy is more effective for different degrees of product differentiation and show that the degree of export market product differentiation has an impact on the optimal internationalisation incentive policy. Moreover, we explore how demand, cost, and other model parameters affect this analysis.

The paper is structured as follows. The next section presents the theoretical background to this study. The third section develops the model and presents the main results. Finally, the conclusion summarizes the principal results and derives policy implications.

2. THE MODEL

The model consists of a foreign market where there is an external firm (E) and where the domestic firm (D) will enter. In the country of the domestic firm the government seeks to help firm D enter the foreign market. Using a two-stage game the model will assume that first, the domestic firm chooses how much it is willing to invest to enter the foreign market (θ) and second, after observing the choice of firm D, both firms (E and D) choose prices simultaneously. Therefore, in this game we have complete and perfect information.[1]

[1] The choice of the domestic company is observable by the foreign company. Only after the domestic company chooses θ do the companies choose prices.

To define the demands of the foreign market and introduce product differentiation, we use the inverse demand functions proposed by Dixit (1979):

$$\begin{cases} p_D = a - bq_D - dq_E \\ p_E = a - bq_E - dq_D \end{cases}$$

where, a, b, and d are positive constants, q_D and q_E are the quantities of each product offered by the domestic and foreign firm respectively, and p_D and p_E are the prices fixed by each firm. The parameter $d \in [0, b]$ measures the degree of differentiation between the two products. When $d \to b$ the products become homogeneous, and when $d \to 0$ the products are completely differentiated.

Since in the first stage of the game the domestic firm chooses how much it is willing to invest to enter the foreign market, we decided to introduce a parameter in the demand function of firm D that measures the internationalisation effort made by the domestic firm. To define this parameter, we adapted the model developed by Liu and Li (2014) and considered θ as an indicator of the expense/effort that company D performs ex ante, that is, before starting its internationalisation process.

Studies in the literature highlight the importance of domestic firms making the necessary investment before entering foreign markets in order to overcome the difficulties it will face (see Wilkinson & Brouthers, 2006). Thus, in our model, θ is seen as an investment that better prepares the firm to face international markets.[2]

This internationalisation investment indicator will be influenced by a positive constant (r) that measures the impact of this investment on individual foreign country demand (see Banker et al. 1998, which addresses a quality competition framework). The inverse functions of market demand are given by:

[2] To better justify the use of this argument we refer to the Portuguese case, where the government's internationalisation incentive represents a percentage of the investment/cost that the company has to bear before exporting. When approving applications, the responsible entities analyse whether the investment made has resulted in marketing innovation or organizational innovation. If neither of these improvements has occurred, the application is refused.

$$\begin{cases} p_D = a + r\theta - bq_D - dq_E \\ p_E = a - bq_E - dq_D \end{cases}$$

For simplicity, we assume that the costs of this investment are $I\theta^2$, which ensures that the profit function is concave at θ. Thus, it is guaranteed that it is not optimal to choose an infinitely high θ to infinitely expand the demand. The marginal production costs of the two firms are constant and given by c_D and c_E for the domestic and foreign firms, respectively, where $c_D > 0$ and $c_E > 0$. We assume that the domestic firm costs are larger than the foreign firm costs.

Solving the system, in order of quantities, we obtain the following market demand functions:

$$\begin{cases} q_D = \frac{a(b-d)}{b^2-d^2} + \frac{br\theta}{b^2-d^2} - \frac{b}{b^2-d^2}p_D + \frac{d}{b^2-d^2}p_E \\ q_E = \frac{a(b-d)}{b^2-d^2} - \frac{dr\theta}{b^2-d^2} + \frac{d}{b^2-d^2}p_D - \frac{b}{b^2-d^2}p_E \end{cases} \quad (1)$$

Accordingly, we have the following profit functions for both firms:

$$\begin{cases} \pi_D = (p_D - c_D)q_D - I\theta^2 \\ \pi_E = (p_E - c_E)q_E \end{cases}$$

Finally, we also consider that $a > c_D$, $a > c_E$, $c_D > 0$.

In the sections that follow we find the subgame perfect equilibrium by considering three scenarios:

(1) Base scenario. No subsidy scheme, where the domestic firm exports without any type of government support.
(2) Scenario 1. Fixed subsidy scheme, where a lump sum subsidy covers part of the investment that the firm makes to achieve internationalisation.
(3) Scenario 2. Quantity-exported subsidy scheme, where a subsidy for the quantity exported is applied.

2.1. Base scenario: No subsidy

In the base scenario, the firm starts the export process without any government support. Using backward induction, we start by maximizing π_D and π_E as a function of p_D and p_E, simultaneously:

$$Max\pi_D = (p_D - c_D)q_D - I\theta^2$$

where q_D is the demand function D given in (1). Computing the first order condition:

$$\frac{\partial \pi_D}{\partial p_D} = 0 \Leftrightarrow p_D = \frac{a(b-d)}{2b} + \frac{br\theta}{2b} + \frac{d}{2b}p_E + \frac{b}{2b}c_D$$

And also, from:

$$Max\pi_E = (p_E - c_E)q_E$$

where q_E is the demand function E given in (1), we compute:

$$\frac{\partial \pi_E}{\partial p_E} = 0 \Leftrightarrow p_E = \frac{a(b-d)}{2b} - \frac{dr\theta}{2b} + \frac{d}{2b}p_D + \frac{b}{2b}c_E$$

Solving the system with the two first order conditions, we achieve:

$$\begin{cases} p_D = \frac{a(b-d)(2b+d)}{4b^2-d^2} + \frac{r\theta(2b^2-d^2)}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_E + \frac{2b^2}{4b^2-d^2}c_D \\ p_E = \frac{a(b-d)(2b+d)}{4b^2-d^2} - \frac{dr\theta}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_D + \frac{2b^2}{4b^2-d^2}c_E \end{cases} \quad (2)$$

Using backward induction, we now focus on the domestic firm's decision regarding the investment θ_D^B, by replacing the expressions obtained in (2) in the profit function of the domestic firm:

$$\pi_D = (p_D - c_D)q_D - I\theta^2 \Leftrightarrow$$

$$\pi_D = \left(\frac{a(b-d)(2b+d)}{4b^2-d^2} + \frac{r\theta(2b^2-d^2)}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_E - \frac{2b^2-d^2}{4b^2-d^2}c_D\right)\left(\frac{ab(b-d)(2b+d)}{(b^2-d^2)(4b^2-d^2)} + \frac{r\theta b(2b^2-d^2)}{(b^2-d^2)(4b^2-d^2)} + \frac{db^2}{(b^2-d^2)(4b^2-d^2)}c_E - \frac{b(2b^2-d^2)}{(b^2-d^2)(4b^2-d^2)}c_D\right) - I\theta^2$$

Thus, we maximize π_D by calculating the first order condition:

$$\frac{\partial \pi_D}{\partial \theta} = 0 \Leftrightarrow \theta_D^B = \frac{rb(2b^2-d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2-d^2)c_D]}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

Replacing θ_D^B in $p_D$and p_E we have the perfect Nash equilibrium of prices in all subsets, which are given by:

$$p_D^B = \frac{I(b^2-d^2)(4b^2-d^2)[a(b-d)(2b+d) + dbc_E + 2b^2c_D] - br^2(2b^2-d^2)^2c_D}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

$$p_E^B = \frac{a(b^2-d^2)[(b-d)(2b+d)I(4b^2-d^2) - br^2(2b^2-d^2)]}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2} + \frac{b^2[I(b^2-d^2)(4b^2-d^2) - br^2(2b^2-d^2)]c_E}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2} + \frac{dbI(b^2-d^2)(4b^2-d^2)^2c_D}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

and also, we achieve:

$$q_D^B = \frac{Ib(4b^2-d^2)[a(b-d)(2b+d) + dbc_E - (2b^2-d^2)c_D]}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

$$\pi_D^B = (p_D - c_D)q_D - I\theta^2 \Leftrightarrow \pi_D^B = \frac{Ib[(a(b-d)(2b+d) + dbc_E - (2b^2-d^2)c_D]^2}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

2.2. Scenario 1: Fixed subsidy scheme

We consider the introduction of a lump sum subsidy that covers part of the investment in internationalisation. As stated before, $I\theta^2$ is the investment cost that better prepares the firm to face international markets. Our subsidy will be a percentage of the expense spent on internationalisation. This subsidy of investment costs covers expenses associated with, for example, conducting market studies, participating in international fairs, and directing the firm's marketing to the chosen markets. The government's support in the form of a subsidy is given by $sI\theta^2$, while $(1-s)I\theta^2$is the domestic firm's investment cost.

Using backward induction we follow the above reasoning, starting by maximizing π_D and π_E as a function of p_D and p_E (as in the base scenario), and obtain:

$$Max\ \pi_D = (p_D - c_D)q_D - (1-s)I\theta^2$$

$$p_D = \frac{a(b-d)}{2b} + \frac{br\theta}{2b} + \frac{d}{2b}p_E + \frac{b}{2b}c_D$$

and

$$Max\ \pi_E = (p_E - c_E)q_E$$

$$p_E = \frac{a(b-d)}{2b} - \frac{dr\theta}{2b} + \frac{d}{2b}p_D + \frac{b}{2b}c_E$$

Thus, the equilibrium prices do not change:

$$\begin{cases} p_D = \frac{a(b-d)(2b+d)}{4b^2-d^2} + \frac{r\theta(2b^2-d^2)}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_E + \frac{2b^2}{4b^2-d^2}c_D \\ p_E = \frac{a(b-d)(2b+d)}{4b^2-d^2} - \frac{dr\theta}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_E + \frac{2b^2}{4b^2-d^2}c_D \end{cases} \quad (3)$$

It remains to computeθ_D^1 by maximizing the profits of firm D in this scenario:

$$Max\ \pi_D = (p_D - c_D)q_D - (1-s)I(\theta_D^1)^2$$

$$\theta_D^1 = \frac{rb(2b^2 - d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$$

Replacing θ_D^1 in the equilibrium prices we reach the perfect equilibrium prices:

$$p_D^1 = \frac{(1-s)I(b^2 - d^2)(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E + 2b^2c_D] - br^2(2b^2 - d^2)^2c_D}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$$

$$p_E^1 = \frac{a(b^2 - d^2)[(b-d)(2b+d)(1-s)I(4b^2 - d^2) - br^2(2b^2 - d^2)]}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2} + \frac{b^2[(1-s)I(b^2 - d^2)(4b^2 - d^2) - br^2(2b^2 - d^2)]c_E}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2} + \frac{db(1-s)I(b^2 - d^2)(4b^2 - d^2)^2c_D}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$$

For scenario1 we also achieve:

$$q_D^1 = \frac{(1-s)Ib(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$$

$$\pi_D^1 = (p_D - c_D)q_D - (1-s)I\theta^2 \Leftrightarrow \pi_D^1 = \frac{(1-s)Ib[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]^2}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$$

Lastly, the government expenditure on this subsidy is given by:

$$G_D^1 = sI\theta^2$$

$$\Leftrightarrow$$

$$G_D^1 = sI\big(br(2b^2 - d^2)\big)^2\left[\frac{(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}\right]^2$$

2.3. Scenario 2: Quantity-exported subsidy scheme

Finally, we consider the introduction of a subsidy per quantity exported. In this scenario the government applies a subsidy *e* for each exported unit, which changes the profit function of the domestic firm to:

$$\pi_D = (p_D - c_D + e)q_D - I\theta^2$$

$$\Leftrightarrow \pi_D = (p_D - c_D + e)\left(\frac{a(b-d)}{b^2-d^2} + \frac{br\theta}{b^2-d^2} - \frac{b}{b^2-d^2}p_D + \frac{d}{b^2-d^2}p_E\right) - I\theta^2$$

Solving the game by backward induction, we start by maximizing π_D as a function of p_D and obtain:

$$Max\ \pi_D$$

$$p_D = \frac{a(b-d)}{2b} + \frac{br\theta}{2b} + \frac{d}{2b}p_E + \frac{b}{2b}(c_D - e)$$

whereas Max π_E calculation remains unchanged. Thus, the subgame perfect Nash equilibrium prices are:

$$\begin{cases} p_D = \frac{a(b-d)(2b+d)}{4b^2-d^2} + \frac{r\theta(2b^2-d^2)}{4b^2-d^2} + \frac{db}{4b^2-d^2}c_E + \frac{2b^2}{4b^2-d^2}(c_D - e) \\ p_E = \frac{a(b-d)(2b+d)}{4b^2-d^2} - \frac{r\theta bd}{4b^2-d^2} + \frac{db}{4b^2-d^2}(c_D + e) + \frac{2b^2}{4b^2-d^2}c_E \end{cases} \quad (4)$$

Computingθ_D^2, from $Max\pi_D$:

$$\frac{\partial \pi_D}{\partial \theta_D^2} = 0 \Leftrightarrow \theta_D^2$$
$$= \frac{rb(2b^2-d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2-d^2)(c_D - e)]}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

Finally, the subgame perfect equilibrium of scenario 2 is given by:

$$p_D^2 = \frac{I(b^2-d^2)(4b^2-d^2)[a(b-d)(2b+d) + dbc_E + 2b^2(c_D - e)] - br^2(2b^2-d^2)^2(c_D - e)}{I(b^2-d^2)(4b^2-d^2)^2 - br^2(2b^2-d^2)^2}$$

$$p_E^2 = \frac{a(b^2-d^2)[(b-d)(2b+d)I(4b^2-d^2)-br^2(2b^2-d^2)]}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2} + \frac{b^2[I(b^2-d^2)(4b^2-d^2)-br^2(2b^2-d^2)]c_E}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2} + \frac{dbI(b^2-d^2)(4b^2-d^2)^2(c_D+e)}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}$$

For scenario2 we also achieve:

$$q_D^2 = \frac{Ib(4b^2-d^2)[a(b-d)(2b+d)+dbc_E-(2b^2-d^2)(c_D-e)]}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}$$

$$\pi_D^2 = (p_D - c_D + e)q_D - I\theta^2 \Leftrightarrow \pi_D^2 = \frac{Ib[(a(b-d)(2b+d)+dbc_E-(2b^2-d^2)(c_D-e)]^2}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}$$

Finally, the government expenditure is given by:

$$G_D^2 = eq_D^2 = eIb(4b^2-d^2)\left[\frac{(a(b-d)(2b+d)+dbc_E-(2b^2-d^2)(c_D-e)}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}\right]$$

3. DISCUSSION

To ensure non-negativity equilibrium conditions, i.e., such that guarantee that p, q, and θ are positive in all scenarios, we must assume:

$$\begin{cases} (1-s)I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2>0 \\ a(b-d)(2b+d)+dbc_E-(2b^2-d^2)c_D>0 \end{cases}$$

$$\begin{cases} a(b-d)(2b+d)-dr\theta+dbc_D+2b^2c_E>0 \\ a(b-d)(2b+d)-dr\theta+dbc_D-(2b^2-d^2)c_E>0 \end{cases}$$

Under these conditions, Table 1 summarizes the main results of the scenarios presented.

Table 1: Main results for the three scenarios

	Quantities
Base Scenario	$q_D^B = \frac{Ib(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 1	$q_D^1 = \frac{(1-s)Ib(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 2	$q_D^2 = \frac{Ib(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)(c_D - e)]}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
	Prices
Base Scenario	$p_D^B = \frac{I(b^2 - d^2)(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E + 2b^2c_D] - br^2(2b^2 - d^2)^2c_D}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 1	$p_D^1 = \frac{(1-s)I(b^2 - d^2)(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E + 2b^2c_D] - br^2(2b^2 - d^2)^2c_D}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 2	$p_D^2 = \frac{I(b^2 - d^2)(4b^2 - d^2)[a(b-d)(2b+d) + dbc_E + 2b^2(c_D - e)] - br^2(2b^2 - d^2)^2(c_D - e)}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
	Profits
Base Scenario	$\pi_D^B = \frac{Ib[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]^2}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 1	$\pi_D^1 = \frac{(1-s)Ib[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]^2}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 2	$\pi_D^2 = \frac{Ib[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)(c_D - e)]^2}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
	θ
Base Scenario	$\theta_D^B = \frac{rb(2b^2 - d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 1	$\theta_D^1 = \frac{rb(2b^2 - d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D]}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
Scenario 2	$\theta_D^2 = \frac{rb(2b^2 - d^2)[(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)(c_D - e)]}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}$
	Subsidies
Scenario 1	$G_D^1 = sI\left(br(2b^2 - d^2)\right)^2\left[\frac{(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)c_D}{(1-s)I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}\right]^2$
Scenario 2	$G_D^2 = eIb(4b^2 - d^2)\left[\frac{(a(b-d)(2b+d) + dbc_E - (2b^2 - d^2)(c_D - e)}{I(b^2 - d^2)(4b^2 - d^2)^2 - br^2(2b^2 - d^2)^2}\right]$

Comparison of the domestic firm's investments in internationalisation (θ)

Proposition 1: $\theta_D^1 > \theta_D^B$ and $\theta_D^2 > \theta_D^B$ Proof: See Appendix.

Both investments are higher under export subsidy schemes. Moreover, we show that:

$$\theta_D^1 > \theta_D^2 \text{ for } e < \frac{sI(b^2-d^2)(2b^2-d^2)(4b^2-d^2)[a(b-d)(2b+d)+dbc_E-(2b^2-d^2)c_D]}{(2b^2-d^2)[(1-s)I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2]}.$$

This result indicates that θ_D^2 is not always greater than θ_D^1. For a given *s*, when *e* is low, the domestic firm's investment in internationalisation is greater in scenario 1 than in scenario 2 for a large subset of product differentiation degrees. Thus, the investment depends on the degree of product differentiation.

Comparison of quantities exported

Proposition 2: $q_D^1 > q_D^B$ and $q_D^2 > q_D^B$ Proof: See Appendix

The domestic firm exports more with the existence of a subsidised export scheme than without the application of any subsidy. Additionally, $q_D^1 > q_D^2$ only when:

$$e < \frac{sbr^2(2b^2-d^2)[a(b-d)(2b+d)+dbc_E-(2b^2-d^2)c_D]}{(1-s)I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}$$

For a given *s*, for high levels of *e*, scenario 1 is no better than scenario 2 in terms of subsidy for the quantity exported. However, for low levels of *e*, for a given *s*, the quantity exported in scenario 1 is higher than in scenario 2 per degree of low product differentiation.

Comparison of subsidy expenses

In terms of the comparison of subsidies expenses, we conclude that $G_D^1 > G_D^2$ when *e* is lower than:

$$\frac{a(b-d)(2b+d)+dbc_E-(2b^2-d^2)c_D}{(1-s)I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2}\sqrt{\frac{sbr^2(2b^2-d^2)[I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2]}{(4b^2-d^2)}}$$

For a fixed value of *s*, it turns out that for low levels of *e*, public expenditure in scenario 1 is higher than in scenario 2. However, for high levels of *e*, given a fixed value of *s*, public expenditure in scenario 2 is higher than in scenario 1. Table 2 summarizes the main results.

Table 2: Comparison of scenario results

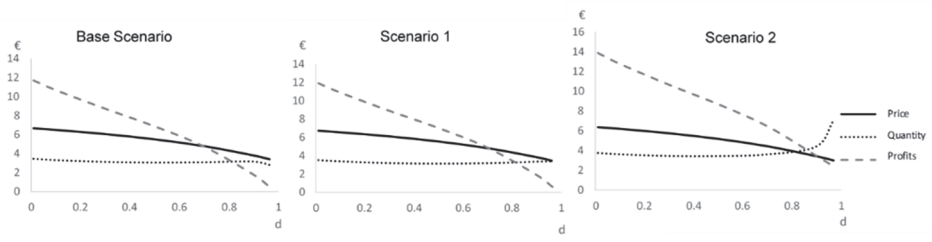
	Base Scenario	Subsidy supporting investment to internationalise	Export-quantity subsidy	Scenario 1 vs. Scenario 2
Quantity	q_D^B	$q_D^1 > q_D^B$	$q_D^2 > q_D^B$	$q_D^1 \lessgtr q_D^B$
$\boldsymbol{\theta}$	θ_D^B	$\theta_D^1 > \theta_D^B$	$\theta_D^2 > \theta_D^B$	$\theta_D^1 \lessgtr \theta_D^B$
Subsidy	$\emptyset$	$sI\theta_1^*$	eq_D^*	$G_D^1 \lessgtr G_D^2$

The analysis of the impact of the degree of product differentiation comparing the subgame perfect Nash equilibrium in the three scenarios proved to be complex. Thus, we resort to a numerical analysis that enables us to explore how product differentiation impacts the better incentive policy to increase exports.

3.1. Numerical Analysis

In this simulation, the value of some parameters of the model is fixed. We assume that b = 1 (standard in the literature) and s = 0.45 (to capture the reality in Portugal, where the government subsidizes 45% of domestic firms' internationalisation investment costs). We assume the following parameters: e= 0.6, a = 10, r = 0.4, I = 1.8, c_D=3.2, and c_E=3. We proceed with the simulation showing the impact on the prices, quantities, and profits of firm D under the three scenarios considered for different degrees of product differentiation (Figure 1).

Figure 1. Comparison of prices, quantities and profits



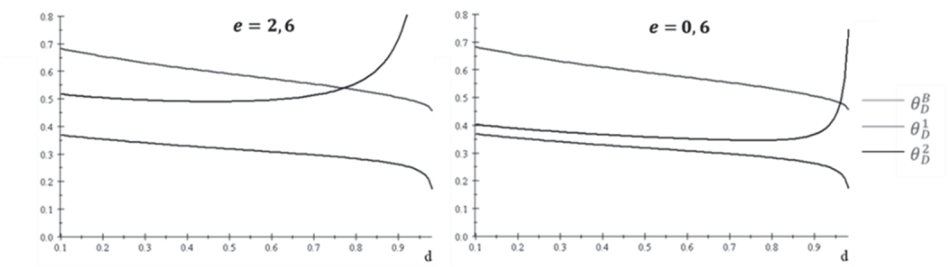
As shown in the previous results, in all the scenarios, product differentiation has a positive impact on the results of the domestic firm. The more differentiated the product is in the foreign market, the better the achieved results. Conversely, the more homogeneous the products are in the foreign market (as d → 1), the more competitive the market becomes and the lower the profits of firm D.

Comparison of the domestic firm's investment in internationalisation (θ)

Figures 2 to 4 show the behaviour of $\theta_D^B, \theta_D^1,$ and θ_D^2 under different degrees of product differentiation for the previously defined parameter values.

Given a decrease in the degree of product differentiation (i.e., the more homogeneous the goods) the internationalisation investment is greater in scenario 2 than in scenario 1 (θ_D^2 is higher than θ_D^1), since the impact of the fixed-subsidy incentive scheme (s) is almost null as d approaches 1. Thus, Figure 2 shows that the degree of product differentiation has an impact on the firm's investment in internationalisation. With higher product differentiation the internationalisation investment becomes greater in scenario 1 than in scenario 2. The use of a fixed-subsidy incentive scheme leads to stronger incentives, since with a high degree of product differentiation, competition is not so fierce, and thus a lump-sum outweighs the incentives of a quantity-subsidy scheme.

Figure 2. Comparison of θ for different levels of e

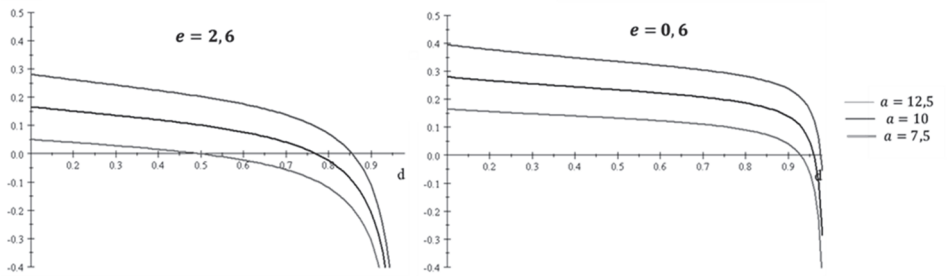


With a decrease in the subsidy per quantity exported (e) and keeping everything else constant, we find that θ_D^2 approaches θ_D^B, making scenario 1 usually superior to scenario 2, for all degrees of product differentiation. Thus, our results show that θ_D^2 is a preferable policy for low degrees of product differentiation and also for more degrees of product differentiation when e increases, since $\theta_D^2 > \theta_D^1$ for a

larger interval of product differentiation degrees; i.e., increasing *e* makes the scenario 2 incentive preferable for a large range of degrees of product-differentiated markets, not only those with a very low degree of product differentiation. Therefore, our model illustrates that with a low degree of product differentiation $\theta_D^2>\theta_D^1$ is always attained, but when the degree of product differentiation starts to increase there is always $\theta_D^2<\theta_D^1$, for all *e*.

To better understand the impact of the degree of product differentiation, the evolution of θ_D^1- θ_D^2 for different demand parameters (a) was explored (still considering $r = 0.4$ / $I = 0.8$ / $c_D = 3.2$ / $c_E = 3$). As concluded in the previous figure, product differentiation has an impact on the domestic firm's investment in internationalisation (θ), since when products become more differentiated θ_D^1- $\theta_D^2$is positive, but when they are more homogeneous θ_D^1- $\theta_D^2$is negative. Additionally, Figure 3 illustrates that the demand parameter (a) also has an impact on this comparison.We conclude that the higher the demand, for every degree of product differentiation the difference between $\theta_D^1$and θ_D^2 is higher and the range where θ_D^1- $\theta_D^2$is positive increases with a. When *e = 2.6* this condition is satisfied for $d > 0.5$, but when *e = 0.6* it is satisfied for *d* higher than 0.9. Moreover, increasing *e* decreases the impact of the demand on θ_D^1- θ_D^2, since it outweighs part of the positive effect that increasing demand has on θ_D^1- θ_D^2.

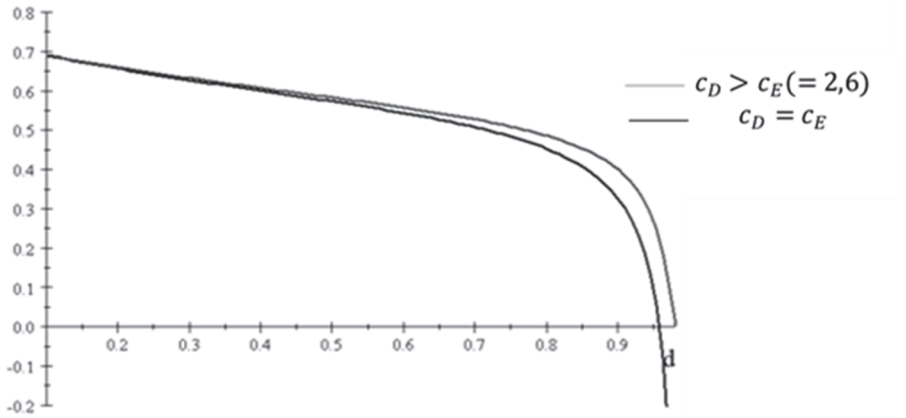
Figure 3. Evolution of $\theta_D^1 - \theta_D^2$ for different values of *a*



We also highlight the impact of the proximity of firms' costs (still considering $r = 0.4$ / $I = 0.8$ / $c_D = 3.2$ and for $e = 1.5$ / $a = 20$).Figure 4 shows that product differentiation has a higher impact on θ_D^1- θ_D^2 when firms have different production costs (namely, when $c_D > c_E$). Thus, when the domestic firm has a cost disadvantage, scenario 1 leads to higher levels of internationalisation investment,

since, for a given *e*, scenario 2 does not outweigh the cost disadvantage as scenario 1 does. Moreover, when firms are more similar, for lower levels of the degree of product differentiation, θ_D^2 starts to be better than θ_D^1.

Figure 4. Evolution of $\theta_D^1 - \theta_D^2$ for different values of c_E



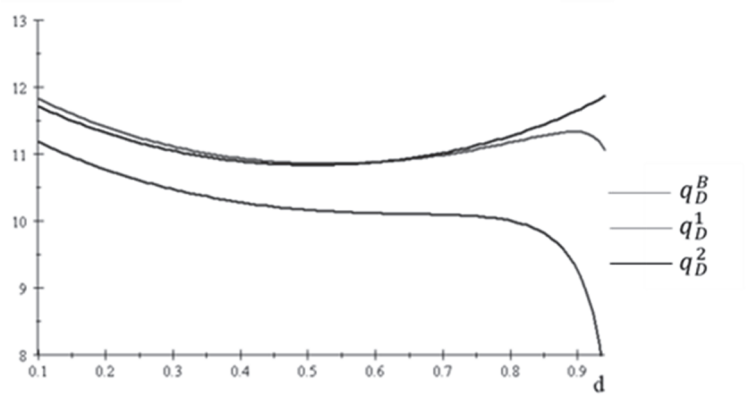
Comparison of quantities exported

We explore the behaviour of q_D^B, q_D^1, and q_D^2, for different degrees of product differentiation, assuming the following parameters: e= 1, a = 30, r = 1, I = 4, c_D=8, and c_E=6 (Figures 5 – 7).

A comparison of the different scenarios allows us to conclude that the degree of product differentiation also has an impact on the quantity exported (Figure 5).

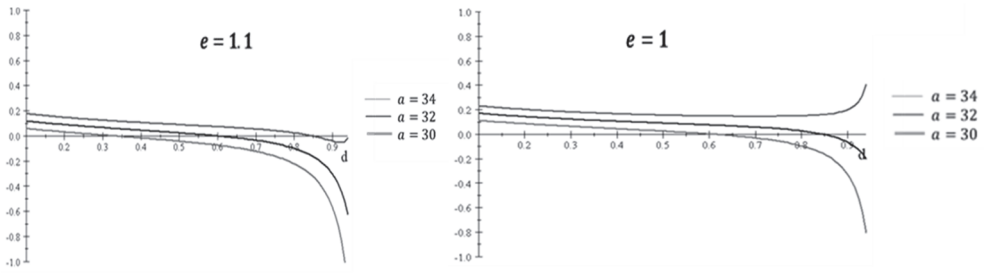
When products are more homogeneous, d→1, the preferable policy to encourage internationalisation is the incentive scheme in scenario 2, given that $q_D^2 > q_D^1$. However, when the degree of product differentiation is higher, the preferable policy to promote internationalisation is the incentive scheme in scenario 1. The use of fixed-subsidy incentive schemes leads to slightly stronger incentives to increase the quantity exported when the degree of product differentiation is high, whereas the opposite occurs with a low degree of product differentiation, since the impact of the lump-sum fixed-subsidy scheme decreases the quantity exported, q_D^1, more than when there is a subsidy per unit exported.

Figure 5. Comparison q_D



Additionally, to better understand the impact of the degree of product differentiation on the quantity exported, we decided to graphically analyse the evolution of q_D^1- q_D^2 for different parameters of the demand (a) (Figure 6).

Figure 6. Evolution of $q_D^1 - q_D^2$ for different values of a



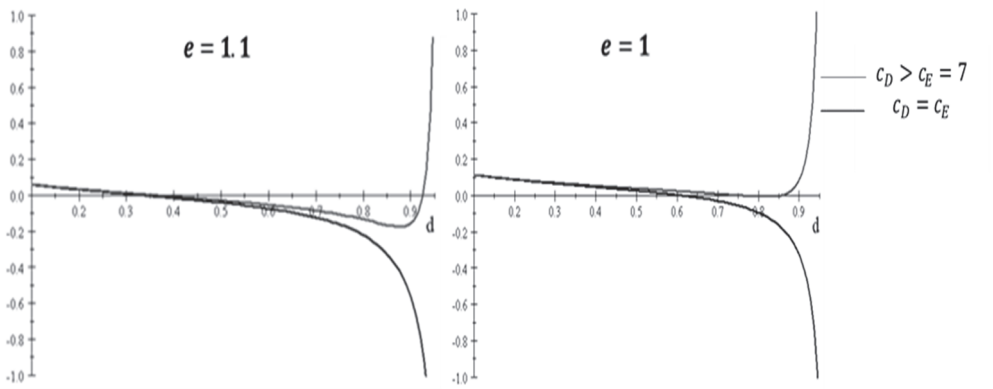
For different parameters of the demand, we find that for the three scenarios there is always some degree of product differentiation that causes $q_D^2 > q_D^1$.

We conclude that for every degree of product differentiation, the higher the demand, the higher q_D^1- q_D^2, and the range where $q_D^1 - q_D^2$ is positive increases with a. For low levels of demand (such as a = 30), q_D^1- q_D^2 is negative for d > 0.3; i.e., when demand is low the range of the degree of product differentiation is wider where the lump-sum fixed-subsidy scheme leads to a lower quantity

exported, q_D^1, than q_D^2. For high demand levels, only for almost homogeneous goods, we get $q_D^2 > q_D^1$. With a decrease of *e*, we observe that for higher levels of demand the condition $q_D^1 > q_D^2$ is verified for every possible degree of product differentiation; thus the preferable policy is always scenario 1. Last, we analyse the impact of the similarity of firms' production costs, but now considering $q_D^1 - q_D^2$.

Figure 7 presents the results for e = 1.1 and e = 1, respectively. For high *e*, the impact of the degree of product differentiation on whether or not firms' production costs affect q_D^1 and q_D^2 is different. There are always some degrees of product differentiation for which $q_D^2 > q_D^1$ regardless of $c_D > c_E$ or $c_D = c_E$. When the domestic firm has a cost disadvantage, scenario 1 leads to a higher quantity exported since, for low *e*, scenario 2 does not outweigh the cost disadvantage as scenario 1 does.

Figure 7. Evolution of $q_D^1 - q_D^2$ for different values of c_E



3.2. Discussion of the numerical analysis

The results obtained from the numerical analysis show that product differentiation has an impact on the incentive policy that the government uses to support the internationalisation of domestic firms, increasing their exports or their internationalisation investment. Product differentiation itself has an impact on the firms' results: a differentiated product means better results for the domestic firm, and a decreasing trend of these results is quite evident the more homogeneous the product becomes. Our results reinforce the idea that product

differentiation has an impact on the preferable incentive policy for encouraging internationalisation, through higher exports or higher internationalisation efforts. This is also true when analysing different demands or even when discussing the firms 'similar cost structure when the values of subsidies allocated by the government are changed. Therefore, we find that the use of a fixed-subsidy scheme (scenario 1) is better for the internationalisation of domestic firms when the degree of export markets' product differentiation is high or intermediate. When the degree of export markets' product differentiation is low, we conclude that the use of a subsidy per quantity exported (scenario 2) is more effective in increasing the levels of internationalisation than that in scenario 1. Thus, we find that for different markets, in terms of their degree of product differentiation, the incentive policies to promote internationalisation may differ.

4. CONCLUSION

This paper explores whether product differentiation has an impact on policy that incentivises internationalisation via exports. To encourage internationalisation, governments can make financial resources available or contribute to reducing asymmetric information and economic and political risk by providing, for example, technical advice. The present study focuses on the two most common export incentives in Portugal: a subsidy to finance a part of firms' internationalisation costs and a subsidy based on each unit of product exported.

The existing literature does not consider models that incorporate product differentiation and there is a gap concerning the impact of product differentiation on policies that incentivise internationalisation. Using a game theory model, we compare different incentive policies to promote exports, highlighting and discussing the impact of the degree of product differentiation on the results of different incentive policies. We develop a product differentiation model and explore the subgame of perfect Nash equilibrium, in three scenarios: (1) a domestic firm exports products with no government support; (2) a domestic firm receives an investment subsidy to pay for part of the costs of the internationalisation process, and (3) a domestic firm receives a subsidy per quantity exported. Through numerical analysis, we conclude that product differentiation has an impact on the incentive policy that the government uses to increase the exports of domestic firms.

We find that using a fixed subsidy that covers part of the cost of investing in internationalisation is preferable for the domestic firm as long as the export market's degree of product differentiation is high. When the export market's degree of product differentiation is low, the policy that applies a subsidy per quantity exported generates greater internationalisation.

We have revisited and extended the literature on export incentive schemes, and here present some avenues for future research. In our game we focus on a market with two firms, one domestic and one foreign; in future research it would be useful to extend the analysis to several firms in the market. Additionally, in our game everything that the domestic firm produces is for export and the country's domestic consumption is not taken into account; in future research it would be useful to investigate the composition of domestic consumption.

Disclosure statement

No potential conflict of interest was reported by the authors.

The authors declare that this work is original and has not been published elsewhere nor is it currently under consideration for publication elsewhere.

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APPENDIX

Proof of proposition 1: $\theta_D^1 > \theta_D^B$ and $\theta_D^2 > \theta_D^B$

since both numerators are the same and the denominator of θ_D^1 is lower than the denominator of θ_D^B. And also since the numerator of θ_D^2 is greater than the numerator θ_D^B and both denominators are the same.

Proof of proposition 2: $q_D^1 > q_D^B$ and $q_D^2 > q_D^B$

Since

$$\frac{br^2(2b^2-d^2)[a(b-d)(2b+d)+dbc_E-(2b^2-d^2)c_D]}{[I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2][(1-s)I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2]} \text{ and}$$

$$\frac{Ib(4b^2-d^2)(2b^2-d^2)e}{I(b^2-d^2)(4b^2-d^2)^2-br^2(2b^2-d^2)^2} \text{ are always positive.}$$

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SUSTAINABLE LEAN IMPLEMENTATION: A STUDY OF SERBIAN COMPANIES

ABSTRACT: *We aim to identify and analyse the key success factors of sustainable lean implementation and investigate the changes in management accounting and performance measurement systems after lean implementation. We analyse four large, publicly traded Serbian companies that have implemented lean. To introduce diversity into our sample we choose companies from different industries and with different competitive and organizational characteristics. We use a multiple case study method to analyse the motives behind, barriers to, and implications of lean implementation and to examine the management accounting and performance measurement systems of companies implementing lean. Our results suggest that the key factors of sustainable lean implementation are continuous communication of the objectives and importance of the lean project, continuous improvement of soft skills, development of teamwork and employee motivation, dedicated management, a supportive work environment, and continuous monitoring of the implemented changes and results. Our results also point to the importance of changes and improvements in the management accounting and performance measurement systems during and after lean implementation.*

KEY WORDS: *lean implementation, lean sustainability, performance measurement, management accounting.*

JEL CLASSIFICATION: M11, M41, L25

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1. INTRODUCTION

Lean has rapidly grown in popularity during recent decades and an increasing number of manufacturing and service companies have embraced lean principles to improve performance. More recently, however, some authors have noted that besides Toyota, only a few companies have been truly successful at becoming lean (Kiran, 2022; Loyd et al., 2020; Vanichchinchai, 2021). Lean implementation is far from problem-free and companies may experience difficulties in sustaining lean. There are several reasons for lean failure, including failure to manage the process of change (Nordin et al., 2012), focusing only on the short-term application of lean tools rather than on the implementation of deeper overall changes (Dombrowski & Mielke, 2014), and a lack of focus on the development of lean capabilities amongst organization members (Jorgensen et al., 2007). Due to these and other reasons, in many companies the improvements decline over time (Dombrowski & Mielke, 2014).

We aim to identify and analyse the key success factors of sustainable lean implementation and to investigate changes in management accounting and performance measurement after lean implementation. We use a multiple case study method to analyse the motives behind, barriers to, and implications of lean implementation and to examine the management accounting and performance measurement systems of companies implementing lean. Our study is of importance for researchers and practitioners in the areas of production and lean management, performance management, management accounting, and cost accounting. We emphasise that the sample companies operate in Serbia's transitional and developing economy. However, our study does not consider the direct impact of a specific economic environment on lean implementation and can be beneficial to companies in similar economies to that of Serbia.

Most lean research is not grounded in any theory (Danese et al., 2018). Ahlstrom et al. (2021) conclude that "lean is not a theory but has plenty of theoretical underpinnings" and acknowledge "the importance of lean theory for external validity and generalizability, and for the topic to progress in a systematic and scientific manner". Boer et al. (2015) note that in the field of operations management, "theory is the fundamental engine that drives the creation of knowledge". In the field of lean this is also necessary, but very problematic. The

problem is how to draw a "theory" for a practice-driven phenomenon such as lean. Nevertheless, our study contributes to the literature in several ways.

The most important theoretical contributions of our study are a comprehensive and analytical review of existing lean experiences and a critical analysis of positive and negative phenomena in the lean implementation process. Our results suggest that some of the key factors of sustainable lean implementation are the continuous communication of the objectives and importance of the lean project; the continuous improvement of soft skills, teamwork development, and employee motivation; dedicated management; a supportive work environment; and continuous monitoring of the implemented changes and results. Our results also indicate some of the key barriers to lean implementation. The identification, understanding, and overcoming of these barriers enable the successful implementation of lean and improvement of company performance. Our results can therefore contribute to raising awareness about the need to identify and manage these factors and barriers.

Most of the experts who deal with lean are of technical (production) orientation. Our research contributes to the integration of knowledge and the learning process of experts from various fields. This more holistic view of lean implementation and the analysis of the interrelationship between lean implementation and lean effects point to the need to apply innovative cost accounting methodologies such as TDABC, and to the importance of these innovations in improving company performance. Thus, our research on the experiences of lean companies also contributes to the development of lean theory in the fields of lean, operations management, and management accounting.

The structure of our paper is as follows. The next section presents the theoretical background and literature review. The third section presents the research methodology, while the fourth and fifth sections present our results and their discussion. The sixth section presents our conclusions.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

Lean is defined in many ways. The absence of a clear definition has several consequences for practitioners seeking to implement lean, as well as researchers trying to capture the essence of the lean concept. Karlsson and Ahlstrom (1996)

point out that the lack of a precise definition can lead to difficulties in determining whether or not changes made in an organization are consistent with lean, and consequently difficulties in evaluating the effectiveness of the concept itself. Shah and Ward (2007), on the other hand, argue that a definition of lean is necessary for theory development, while Ahlstrom et al. (2021) argue that the multitude of different lean definitions is one of the reasons making it difficult to understand lean as a theory.

Pettersen (2009) stresses that lean is usually defined in operational terms by pointing to the most frequently mentioned characteristics of lean: time reduction and continuous improvement, just-in-time production, pull system, failure prevention, and production levelling. This list of characteristics is unsurprising given that lean originated in the Toyota Production System (TPS), which relies on two pillars: just-in-time (JIT) and Jidoka ('autonomation' or automation with human intelligence) and aims at achieving the highest quality, shortest lead time, and lowest cost (Bhamu & Singh Sangwan, 2014; Jasti & Kodali, 2015; Lean Enterprise Institute, 2022a; Shah & Ward, 2007).

Lean is generally described as a way of thinking ('lean thinking') about guiding principles and overarching goals, and as a practice ('toolbox lean' or 'lean practice') that relies on a set of management practices, tools, or techniques (Lean Enterprise Institute, 2022b; Petersen, 2009; Shah & Ward, 2007; Womack et al., 1990). Bhamu and Singh Sangwan (2014) summarize that lean may be understood as a way, a process, a set of principles, a set of tools and techniques, an approach, a concept, a philosophy, a practice, a system, a programme, a manufacturing paradigm, or a model aimed at reducing costs and time to delivery, levelling the production schedule, improving quality at low cost, removing waste from the system, maximizing capacity and minimizing inventory, improving productivity and quality, achieving agility, etc.

There have been several important attempts to define lean. Shah and Ward (2007) define lean as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability". Hopp and Spearman (2021) broadly describe lean as efficiency management and offer four narrower definitions to describe four lenses through which lean can be viewed: process (pursuit of waste elimination), flow

(minimizing the cost of excess inventory, capacity, or time), network (a systematic process of reducing the cost of waste), and organization (an organizational culture that encourages the continual reduction of the cost of waste). Lean is studied mostly in the fields of operations and general management (Ahlstrom et al., 2021), psychology (Balzer et al., 2019), accounting (Maskell & Kennedy, 2007), and information technology (Mrugalska & Wyrwicka, 2017), etc.

2.1. Benefits and factors of lean implementation

In recent decades an increasing number of manufacturing and service companies have embraced lean principles as a way to improve performance. Lean is seen as a business method that promotes efficiency and elimination of waste, as well as focusing on customer needs (Bhamu & Singh Sangwan, 2014; Shah & Ward, 2007). It is seen as an instrument to improve product development processes and reduce the time to market of new products with better quality and manufacturability. Lean can also help a company develop a competitive advantage (Hartini & Cipromulyono, 2015; Kosky et al., 2021; Natarajan et al., 2017; Shah & Ward, 2003, 2007; Swank 2003; Wood et al., 2004). Lean can be implemented in companies of all types, sizes, and industries that strive to improve their competitive advantage, operations, and profits in regional and global markets (Alkhoraif et al., 2019). Lean is expected to contribute to the development of a positive and fulfilling work environment through employee involvement in and ownership of problem-solving and improvement activities (Bocquet et al., 2019; Neirotti, 2018).

Lean manufacturing relies on empowering employees (Todorović & Čupić, 2017). Vidal (2007) argues that employees' empowerment increases their responsibilities and abilities and increases their job satisfaction and performance. Employees' ideas regarding changes and improvements create a competitive advantage that is more sustainable (Robinson & Schroeder, 2006). This is especially important for companies in transition economies like Serbia's, which in addition to a lack of motivation and resistance to change faces a problematic low level of employee involvement in the processes of continuous improvement. The low level of awareness about the need to present ideas and opinions is the consequence of a specific socio-economic pre-transition period, with passive employees, collective responsibility, and strict adherence to hierarchy (Janjić et. al., 2020). It is therefore necessary to ensure continuous communication of the

objectives and significance of lean implementation; i.e., it is necessary to prepare and motivate people (Antony, 2014). The failure of many companies' change programmes can be attributed directly to employees' resistance to change (Allaoui & Benmoussa, 2019). That is why it is important to understand why employees adopt/accept change, i.e., lean initiative (Keyser et al., 2016).

Companies have difficulties sustaining lean over time for several reasons. One of the most important reasons is that managers lack a real understanding of lean principles and therefore focus on the short-term application of isolated tools rather than on deeper changes. The various lean techniques are very effective for achieving short-term improvements, but after a few years many companies' lean programmes no longer meet expectations (Dombrowski & Mielke, 2014). For many companies, the kaizen[1] event has become the primary and, in some cases, the exclusive vehicle for lean improvement (Nicholas & Soni, 2005). Veech (2004) notes that up to 90% of the benefits of kaizen events disappear within six months. Another reason for lean failure is a lack of focus on developing the capabilities of employees that make them progressively better at doing lean, and on creating a learning environment that supports a lean culture. A continuous learning process and building lean culture are key assumptions for achieving long-term sustainable results (Jorgensen et al., 2007). Another main reason for lean failure is inadequate management of the change process during the lean transformation (Nordin et al., 2012).

2.2. Management accounting and performance measurement

The efficiency and effectiveness of lean management are determined by many factors, but one of the most important is the performance measurement system which allows evaluating processes and the impact of new concepts or changes on process efficiency. Cherrafi et al. (2019) argue that performance measurement permits organizations to identify process issues, evaluate the effectiveness of an action plan, and monitor progress towards goals. Some studies (Norreklit & Mitchell, 2007; Searcy, 2009) analyse the existence of the time lag between early operational improvements and delayed financial results, which can be misinterpreted as an indication of lean failure. Searcy (2009) notes that this

[1] Kaizen (Continuous Improvement) is a strategy where employees at all levels of a company work together proactively to achieve regular, incremental improvements to the manufacturing process.

misinterpretation reflects "the overemphasis on costs early in a lean implementation and the disregard of the time lag inherent in the financial results".

Jorgensen et al. (2007) stress that assessment tools are critical to successful lean implementation and that lean assessment tools must include a technical perspective that reflects performance, methods, and tools related to the company's strategic scope, and an organizational perspective which reflects management, organizational, and human capabilities, culture, and learning. Changes to performance measurement, management accounting, and management reporting systems are often found to be necessary for lean sustainability (Searcy, 2009; Kaplan & Anderson, 2007; Nordin et al., 2012; Norreklit & Mitchell, 2007; Todorović & Čupić, 2017). Lean sustainability also requires the use of different financial and non-financial performance measures. Fullerton and Wempe (2009) find that managers who implement lean manufacturing without utilizing supportive non-financial manufacturing performance measures may experience disappointing financial results.

There are many studies investigating the importance of management accounting and cost accounting for performance measurement and management reporting in the context of continuous improvement programme implementation (Kaličanin & Knežević, 2013; Kaplan & Anderson, 2007; Nordin et al., 2012; Todorović & Čupić, 2017). The choice of an adequate methodological approach for cost accounting is very important. The most common choices in the context of lean implementation are Value Stream Accounting (VCA) and Activity Based Costing (ABC). Leading authors in the field of management accounting argue that Time-Driven Activity Based Costing (TDABC) can be beneficial for lean implementation (Kaplan & Anderson, 2007). TDABC can contribute to lean management, especially when it comes to waste identification, selection of appropriate measures for waste elimination, and application of corrective measures to improve efficiency (Demeere et al. 2009; Everaert et al., 2012; Hoozee & Bruggeman, 2010; Kaplan & Anderson, 2007).

Todorović (2013) finds that 19.4% of accountants in a sample of Serbian companies are familiar with the lean concept, while only 5.6% of companies apply lean. She also finds that as many as 80.5% of accountants are unfamiliar with

TDABC, while only 8.33% of accountants are familiar with both lean and TDABC and only 1.39% of accountants implement lean and know TDABC. In a study of the effects of 5S implementation on the operational and financial performance indicators of one Serbian company, Todorović and Čupić (2017) find that the implementation of 5S only contributes to the performance of an organization in the short and medium term. They also point to the importance of management accounting system improvements after implementation of the continuous improvement programme.

3. RESEARCH METHODOLOGY

3.1. Research method and instruments

We use a multiple case study method to examine the motives behind, barriers to, and effects of lean implementation and to investigate the changes in management accounting and performance measurement systems after lean implementation. The case study method is often used to illustrate an emerging theory (Keating, 1995). It is also used to research unknown subjects (Bogićević Milikić & Janićijević, 2009) and to get an in-depth and first-hand understanding of a particular situation (Yin, 2014). The case study is widely used because it can offer insights that might not be achieved with other approaches (Rowley, 2002). Yin (2014) defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between the phenomenon and the context are not evident, using multiple sources of evidence. Eisenhardt (1989) points out that case studies are an excellent research method for generating creative, testable, and empirically valid theories.

Unlike single case studies, multiple case studies permit replication and extension between individual cases, which helps researchers to more easily understand patterns, to eliminate chance associations, and to form a better theoretical structure. Multiple case studies depend on proper case selection. While there is no ideal number of cases, a number between four and ten usually works (Eisenhardt, 1989). We analyse four large companies which have experience with lean. Like Chen and Guliang (2009) and Kennerly and Neely (2002), to introduce diversity into our sample we intentionally choose companies from different industries and with different competitive and organizational characteristics.

The multiple case method has been used in several studies on operations management, management accounting, corporate governance, and performance measurement (Bogićević Milikić & Janićijević, 2009; Chen & Guliang, 2009; Everaert et al., 2012; Kennerly & Neely, 2002; Stancic et al., 2012). Scapens (2006) emphasises that a case study method can be used "to understand how accounting practices which are in use have emerged in specific organisations". He further explains that "the organisations do not have to be representative of some population; simply organisations in which management accounting practices are changing".

Akkermans and Helden (2002) point out that the case study method can pose problems ensuring rigour and reliability, given that the conclusions can be based on accidental circumstances and researchers' own biases, instead of on careful observations of reality. Following Akkermans and Helden (2002), we take steps to limit our personal biases by using several independent perspectives and data sources. Independent perspectives were obtained by sending the questionnaire to members of the sample companies with different backgrounds: PR manager, Chief Financial Officer (CFO), and production manager. We also interviewed them to supplement the information gathered from the questionnaires that they completed. We used additional sources of data, including company and official institutions reports, to cross-check and supplement the data and information collected from the questionnaire and interviews. Following Everaert et al. (2012), we support the reliability of our conclusions by combining qualitative data from the interview with data from different sources.

Our questionnaire comprises three groups of questions. The first group aims to identify implemented lean techniques, the process of and the key barriers to lean implementation, and the motivation behind and expectations and effects of lean implementation. The second group of questions aims to determine the implications of implemented lean techniques on management accounting and cost accounting; i.e., to determine changes in the cost accounting methodology and performance measurement system. The third group of questions aims to identify the implications of the implemented lean techniques for the company's organization, production, and overall business processes.

3.2. Sample

Our sample consists of the four companies presented in Table 1. The success of the implementation of any particular management practice frequently depends on organizational characteristics, and not all companies can or should implement the same set of practices. All companies in our sample are publicly traded and large, according to the Serbian Law on Accounting of 2019. Large companies generally have better access to the capital and human resources necessary for the adoption and implementation of lean practices (Dombrowski et al., 2010; Bhamu & Singh Sangwan, 2014). The sample companies are from different industries and they all have foreign capital in the ownership structure. They implemented different lean techniques, but they all implemented 5S as one of the best-known and most widely used. Companies A, B, and C implemented the Quality Management System (QMS), the Environmental Management System (EMS), and the Occupational Health and Safety Advisory Service (OHSAS) as integral parts of the Integrated Management System (IMS). Companies A and B implemented ISO-22000, while company A also has a HALAL certificate.

Table 1: Features of selected companies

Company	Primary activity	Implemented lean techniques	Implemented standards
A	Production of bakery products and pasta	Total Productive Maintenance (TPM), Single-Minute Exchange of Die (SMED), 5S	Integrated Management System (IMS) based on ISO-9001 (QMS), ISO-14001 (EMS), ISO-18001 (OHSAS), and ISO-22000 (HACCP); HALAL
B	Production of tobacco	5S, Visual Management	ISO 22000 (HACCP)
C	Production of footwear	TPM, SMED, 5S, Six Sigma	IMS based on ISO-9001 (QMS), ISO-14001 (EMS), and ISO-18001 (OHSAS)
D	Production of drinks	TPM, SMED, 5S, Six Sigma, Visual Management	IMS based on ISO-9001 (QMS), ISO-14001 (EMS), and ISO-18001 (OHSAS).

The Serbian economic environment is specific. Serbia is a developing and transition economy in the process of accession to the European Union (EU). One of the consequences of this process is the continuous intensification of competition due to market liberalization. This is especially important, given that about 80% of company A's revenues and over 60% of company D's revenues are realized in the domestic market. Company C holds about a 75% market share in Serbia, and exports more than 60% of its products to the EU, the United States, and Canada. The level of competition, especially price competition, in the European markets is very high and the producers are forced to focus on production costs. Strong competition is also an important factor in companies' efforts to implement continuous improvements and eliminate waste. The sample companies implemented lean as one of the solutions to these problems.

4. ANALYSIS OF THE LEAN IMPLEMENTATION

4.1. Understanding of lean and motives for its implementation

Table 2 presents the understanding of lean and motives for its implementation in the sample companies. An adequate understanding of lean and avoiding focusing on short-term lean techniques is crucial for its sustainability (Dombrowski & Mielke, 2014). Companies B and D have formalized their commitment to lean implementation and understand lean in the broadest sense, as a business philosophy and concept. These companies do not focus only on lean techniques. Company D treats lean as an integral part of the corporate culture. On the other hand, companies A and C focus only on individual lean techniques, meaning that lean is understood more narrowly.

Table 2: The understanding of lean and motives for its implementation

Company	Understanding of lean	Motives of lean implementation
A	- Little experience - Focus on lean techniques - There is no formal commitment to lean principles	- Increasing process efficiency - Cost reduction - Higher employee motivation and participation - Elimination of non-value-adding work
B	- There is a formal project to introduce lean	- Sales increase and cost reduction - Better product quality - Reduction of unproductive work - Strengthening staff motivation and development - Encouraging teamwork
C	- Focus on techniques, not on lean concept	- Cost reduction and productivity increase - Reduction of delivery time - Improving process efficiency - Better customer satisfaction
D	- Formal corporate decision on lean implementation	- Cost reduction and productivity growth - Reducing the number of complaints - Strengthening employee motivation and development

Table 2 shows that the most common motives for lean implementation are cost reduction, greater employee development and participation, and improved customer satisfaction. Similar to previous studies, we find that lean is associated with the creation of a positive work environment and greater employee participation and involvement (Bocquet et al., 2019; Neirotti, 2018). Lean is also expected to reduce costs, shorten lead times, and provide the best staff safety and highest morale (Jainury et al., 2012; Shah & Ward, 2003, 2007; Wood et al., 2004). Although the sample companies understand lean differently, there is a significant degree of similarity regarding their motives. The question is whether the companies' expectations regarding lean will be met, given their different approaches to lean understanding.

4.2. The phases of and barriers to lean implementation

Table 3 presents the phases of and barriers to lean implementation in the sample companies. The vision, mission, and objectives of company A indicate that the lean principles are accepted (Table 3 and Table 4). Company B uses a project approach to lean implementation, meaning that lean implementation is an organized, coordinated, structured, and managed process. There is no formal project of lean implementation in company C; however, the promoted core values indicate that this company informally accepts lean principles. Company D started to implement lean after a corporate decision to improve processes and employees. When asked how long the implementation process took, one of the managers of this company answered:

> "*Lean implementation is an ongoing process. It cannot be said how long this process will take. The process is still ongoing.*"

Employees in company D who underwent training abroad were the leaders of lean implementation. Employees in the department that has already implemented lean train the employees in the department where the implementation is just beginning. Monitoring is of great importance for project sustainability in company D. It involves continuous control and regular follow-ups on the current situation and its development towards the defined aims. Follow-up 1 involves verification of the lean effects. One of the managers stated:

> *"The purpose of follow-up 1 is not just in the monitoring of quantitative performance, given that significant improvements are still expected. Follow up 1 should instead enable the analysis of business processes and check if they are implemented in an intended way."*

Follow-up 2 and all other follow-ups aim to ensure lean sustainability. Company D emphasises that to ensure the success of its implementation, lean needs to become part of the corporate culture. This requires time, continuous work, and top management's absolute support, commitment, and understanding of lean. Top management should be supported by special teams whose basic task is continuous improvement. Other factors are employees, continuous investment in employees, and the development of a culture of process and employee improvement.

Table 3: Issues relevant to lean implementation

Company	Phases of lean Implementation	Barriers to lean implementation
A	- Reviewing the situation - Employee training - Monitoring implementation - Organizational changes to comply with lean principles - Communication of objectives and significance of lean implementation	- Lack of employee knowledge, skills, and competencies - Employees' resistance to and distrust of the results, usually caused by the time lag between implementation and results
B	- Project approach to implementation	- Employee inertia and resistance to change
C	- Defining and planning improvements in the plant, equipment, and employees - Measuring and analysing implemented changes to achieve defined objectives - Launching production after the implementation of improvements - Continuous control of the implemented improvements and taking corrective action when needed	- Seasonal workforce with lower levels of competency - Conflict between management at different hierarchical levels - Lack of defined business policies and procedures related to implementation
D	- Reviewing the actual situation - Defining the future situation with a top-down approach (when targets are set by top management) or a bottom-up approach (when areas where improvements are needed are first identified and then targets are defined) - Development of activity plan and project management - Implementation - Follow up at multiple levels and stages	- Duration (improvement process is a continuous process) - Difficulties in accepting change, especially due to job rotation

One of company D's objectives is to increase employees' motivation. To achieve this, different methods of measuring employee motivation and engagement are developed, including the ratio of the number of reported problems to the number of ideas for improvement suggested by employees, and the ratio of the number of employees who suggest ideas to the total number of employees. The purpose of

encouraging initiatives and ideas from employees is to implement them as simply as possible with the employees' support.

It can be concluded that employees at all levels of the hierarchy are a critical success factor in lean implementation and sustainability in the sample companies. The human factor is the critical success factor of lean implementation (Janjić & Todorović, 2019), but it is often also the reason for its failure, due to a lack of real understanding of lean principles and a focus on the short-term application of lean tools (Nordin et al., 2012), a lack of employee involvement (Bocquet et al., 2019; Neirotti, 2018), a lack of focus on developing employees' lean capabilities (Jorgensen et al., 2007), and an inappropriate style of governance (Hoozee & Bruggeman, 2010). Our study also indicates that the most common problems in lean implementation related to employees are lack of knowledge, skills, and competencies; inertia; resistance to change; and management conflict at different hierarchical levels. Resistance to change is usually found to be due to low commitment and inadequate training (Nordin et al., 2012), weak support from top management (Tiwari et al., 2020), and lack of communication and participant involvement during change (Canning & Found, 2015).

Ford et al. (2008) argue that resistance to change is usually caused by the actions or inactions of change agents. Top management and change agents of companies implementing lean sustainability need to continuously work on improving employees, encouraging their participation, and building a supportive work environment. AlManei et al. (2018) find that one of the major challenges of lean implementation is managing the changes in structure, system, process, and employees, as defined in the implementation plan. They add that lean implementation is not a one-off project but a continuous process affecting processes and people. Top management and strong leadership styles and an effective change-agent system are critical aspects of lean implementation. Nordin et al. (2012) argue that the role of a lean-change agent is very important in implementing behavioural and mindset changes, given that the employees are often not familiar with the lean work environment. Ahlstrom et al. (2021) argue that future studies should examine the roles of different hierarchical levels in sustainable lean implementation, as well as the deeper emotional, change-management side of lean implementation, including the psychological hurdles of continuous improvement and behavioural change.

4.3. The effects of lean implementation

Table 4 presents the business characteristics after lean implementation and the financial and non-financial benefits of lean implementation in the sample companies. Company A introduced 160 new products over the three years following lean implementation. The production of such a large number of new products requires the organization of flexible production in small batches, which in turn requires well-trained employees and flexible equipment allowing frequent tool changes and more frequent cleaning of the production line. Food quality and consumers' health and safety are ensured through the implementation of HACCP and HALAL for over 80 products. Company A focuses on identifying defective products at each stage of production and at at least two workplaces before the final packaging. Employees should identify, mark, and inform the management about defects, but also eliminate defects. Company A productivity, measured as the ratio of total production volume to hours spent per worker, increased by 2% in the first year and by 40% over the five years after lean implementation.

Employee innovations are constantly encouraged in company B: employees are expected to identify problems and present ideas for improvements directly to their superiors or at regular meetings related to continuous improvements. After the implementation of 5S, impressive results were achieved. In just one year, the number of unnecessary elements per department was drastically reduced – from 179 to 31 in factory 1, from 85 to 14 in factory 2, and from 56 to 0 in factory 3. In addition, significant water savings were achieved: over a period of three years, water consumption was reduced by more than 70%. The reject ratio, as a percentage of discarded products or components in relation to the total number of processed products, was reduced from 3.8 to 1.6 in four years. Implemented continuous improvement techniques resulted in productivity growth of 52% and a decrease in scrap of 57%.

Table 4: Effects of lean implementation

Company	Business characteristics after lean implementation	Benefits of lean implementation
A	- Creating value for customers - Flexible production in small batches - Focus on quality assurance	- Development of 160 new products - Productivity growth by 40% over five years after lean implementation
B	- Focus on continuous improvements - Increasing employee participation, responsibility, and innovation - Commitment to quality	- Productivity growth by 52% - Waste reduction by 43%, where scrap is reduced by 57% and water consumption by more than 70% - Technical efficiency growth
C	- Greater investments - Job rotation and employee empowerment	- Cost reduction - 150 new products
D	- Innovations and investments in production - Investments in employees (3% of profits are invested in employees' education) - Work in small groups - Job rotation and employees' safety	- Cost reduction - Reduced number of defective products - Reduced number of injuries at work

Company C invests in the development of new products and new and alternative materials to improve product performance. More than 150 products were developed over the three years after lean implementation. They strive to optimize the cost of goods sold through productivity growth. Monthly production plans are prepared according to sales requirements; i.e., production is realized in accordance with defined monthly plans, total stocks of finished products, and available preproduction stocks. The company applies job rotation according to process requirements, resulting in highly qualified and skilled employees.

Employees of company D work in small groups, which increases the level of employees' complex knowledge, the creation of rotation opportunities, and the responsibility and flexibility of employees. The rotation of employees and management is carried out every 1 to 2 years, which improves the flexibility of the employee structure and understanding of the entire business. Visual management involves setting up boards to present problems and new ideas, visual instructions, and machinery operation. As a result, company D has improved the transparency of monitoring machinery operation, improved internal communication between shifts, reduced the number of errors, and facilitated monitoring of reported problems. The innovations in company D led to productivity improvements and employee development and education. Investments in human resources or soft capital proved to be extremely profitable, given their very quick payback.

In summary, the sample companies increased investments in new technology, production, and new products. They invest in the education and development of employees; they also rotate employees and increase their flexibility. Teamwork, participation, and increased accountability lead to increased motivation. Employees are encouraged to present problems resulting from and ideas for continuous improvements. The companies pay great attention to the safety and protection of employees, and they all have similar objectives regarding quality assurance. The common characteristics of the sample companies are investment and innovation, education, and product quality.

5. ANALYSIS OF CHANGES IN THE PERFORMANCE MEASUREMENT SYSTEM

In the second part of our research we analyse changes in the performance measurement system and management reporting after lean implementation. We analyse the measurement process itself, and not the results of that process. Company B considered these issues to be a business secret and is therefore not included in the analysis.

The accounting information system (AIS) organization, accounting methodology, and performance measurement system of company A did not change significantly after lean implementation. The company uses absorption costing, where overhead costs (about 40% of the total) are allocated according to the value of the work order. Given that company A has experience in monitoring and measuring time, and the fact that TDABC relies on time measurement,

changes in the accounting system could include TDABC implementation. This is especially important given that the managers of lean companies usually have greater information needs and require performance measures based on time.

The implementation of lean techniques in company A required the introduction of the following performance measures: mean time between failures (MTBF) and mean time between repairs (MTBR). MTBF represents the time between failures during system operation. It can be calculated as a statistical mean; i.e., average time. However, its definition depends on how the failures are defined or understood. Failures are most often those conditions and unforeseen circumstances that put the system out of operation. MTBR reflects the average time between repairs. Company A also relies on the Overall Equipment Effectiveness (OEE) index to measure production effectiveness. This indicator is considered crucial for lean production and is determined by production capacity availability, results, and quality. Each of these OEE elements can be improved. Capacity availability is measured as the ratio of the actually available work time to the maximum possible time. The results are measured in several ways; for example, as the ratio of the actual number of products produced to the maximum possible number of products, and the ratio of the ideal cycle time to the quotient of the time actually spent and the number of products produced. Quality is measured as the ratio of the number of products whose production has been completed to the number of products whose production has started or as the ratio of the number of valid products to the total number of products.

Company C has radically changed its accounting methodology. It uses time-driven activity-based costing (TDABC) for cost accounting, which allows creating information and reports important and useful for efficient decision making and control after the lean implementation. It also allows detailed analysis of the efficiency and capacity utilization of business processes and the introduction of production productivity and efficiency measures. Implementation and utilization of TDABC make possible a more precise allocation of indirect costs (about 15% of the total) based on the time needed for the production of one unit of product. Productivity is measured as the ratio of production volume to the number of employees, while efficiency is measured as the degree of capacity utilization or by using the productivity index (ratio of labour productivity in the current compared to the previous period).

Company D applies traditional cost accounting approaches but has made significant methodological improvements. Different types of costs are calculated and monitored in relation to the time variable. There are no significant changes in the performance measurement system. The OEE index is considered to be very important. It is used in production, and with certain modifications in other parts of the company. Cycle time is also important. It reflects the total time from the beginning to the end of the process. The cycle-time ratio is calculated as the ratio of standard to actual cycle time. To measure quality assurance and control, the rejection rate is calculated. The reject ratio is calculated as the ratio of the number of products rejected to the total number of products.

Based on the results of the analysis, we draw several conclusions. First, a lean environment changes the management's information needs, the performance measurement system, and management reporting. These changes are a prerequisite for ensuring lean sustainability. However, the scope and depth of changes in the sample companies differ as a consequence of their different understanding of lean. Second, no changes in financial reporting were identified, but there were organizational and methodological changes in the management accounting system. Third, lean implementation increases the importance of measuring productivity and efficiency. Fourth, the importance of non-financial performance measures, especially those related to the environment and environmental costs, is growing. Fifth, time measurement has become more important and is included in various calculations. Instead of partial use of time, possible further improvements for companies A and D include the implementation of TDABC as one of the most effective instruments for valorising lean effects (Kaplan & Anderson, 2007; Everaert et al., 2012).

6. CONCLUSIONS

In this paper we have identified and analysed the key success factors of sustainable lean implementation and investigated the changes in management accounting and performance measurement after lean implementation. Lean sustainability means that the momentum of improvement is maintained after the initial implementation steps are completed. Jorgensen et al. (2007) argue that lean sustainability involves the continuous development of lean implementation capabilities among employees and requires a focus on both performance improvement and capability development. The company is not lean when it uses

some lean techniques, but when it establishes a culture of continuous improvement of processes and employees.

The human factor is often found to be a key success factor in lean implementation. It is often also the reason why lean fails. In the sample companies we identified several barriers to lean implementation related to employees: lack of knowledge, skills, and competencies; inertia; resistance to change; and management conflict at different levels of the hierarchy. These are the reasons why the sample companies pay great attention to employees and continuous employee improvement. They all invest heavily in employee education and development and encourage employee initiatives and innovations. Working in small groups and employee rotation increase employees' level of complex knowledge, the flexibility of employee structure, and employees' understanding of the entire business process.

In the sample companies the employees are invited to present ideas and suggest improvements. The sample companies also tend to create a supportive work environment where employees feel empowered and have the necessary tools to own the product and process. The work environment should encourage change and transformation. An integral element of such an environment is dedicated, professional, and supportive management at all hierarchical levels. Management is also responsible for a good relationship with employees and the development of the concept of "respect for people" (Natarajan et al., 2017).

The sample companies improved their performance measurement and management accounting systems. They all measure and monitor time in different contexts. One sample company has implemented time-driven activity-based costing (TDABC) to create the information and reports important for decision-making and control in a lean environment. The other two companies still need to work on improving their accounting methodology. The performance measurement system should allow continuous monitoring of the implemented changes. This is especially important because of the time lag between lean implementation and performance (Alkhoraif et al., 2019). One of the sample companies emphasises the existence of a time lag in performance and the importance of monitoring.

Our paper has significant theoretical and practical implications related to the theoretical background, literature review, and results. We have identified, analysed, and emphasised barriers to sustainable lean implementation as well as its key success factors. Our results suggest that some of the key success factors of sustainable lean implementation are the continuous communication of the objectives and importance of the lean project, the continuous improvement of soft skills, the development of teamwork and employee motivation, a dedicated management, a supportive work environment, and continuous monitoring of the implemented changes and results. Our results contribute to raising management awareness of the need to identify and manage these factors. Management should be supported by specialist teams whose task is continuous improvement. Finally, change management and lean transformation should become part of the corporate culture. Lean is just one continuous improvement programme, but the results of this study can also be used to improve the sustainability of other programmes. We therefore expect that our study will contribute to a wider application of the lean concept, more efficient lean implementation, and the achievement of long-term sustainable results.

Finally, our paper has several limitations. The multiple case study method has limitations stemming from the fact that the analysed cases may be unusual and therefore cannot be used to draw general conclusions. It is a data-driven rather than theory-driven approach and it does not allow the use of statistical or econometrical analyses. Some data on the sample companies (e.g., understanding lean and lean effects) cannot be compared using statistical methods. The sample is small and the data are qualitative. However, we limit our personal biases by using several independent perspectives and data sources and believe our study offers useful insights into lean implementation and its effects.

The paper has introduced some questions and dilemmas for the consideration of future researchers. The key question is how to build a lean accounting model. A larger sample and the use of quantitative data should enable the application of advanced statistical methodology.

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VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN RAJASTHAN

ABSTRACT: *Climate change is a globally challenging phenomenon that is particularly distressing for the agricultural sector, as agricultural products and productivity depend on the climate. This study analyses agricultural households' perception of climate change and the adaption strategies undertaken to mitigate it. A purposive random sampling technique is used to collect primary data from a survey conducted in the arid and semi-arid regions of Rajasthan, India. The study employs logistic regression to identify the determinants of the perception of climate change and adaptation strategies, while a livelihood vulnerability index is constructed to indicate households' degree of vulnerability, focusing especially on adaptive capacity. Out of the total sample of 600 households analysed, 534 perceive a long-term change in the climate. Farmers' adaptation strategies include crop diversification, mixed cropping, crop rotation, and farm ponds. The major factors affecting adaptation are the educational status of the household head, farming experience, type of financial support, agricultural training, land size, access to agricultural institutions, distance between the household and farmland, and storage. The livelihood vulnerability index shows that most of the households are moderately vulnerable. The study recommends an efficient weather forecasting system and effective government policies to improve credit availability, financial support, and agricultural mechanization.*

KEY WORDS: *climate change, perception, adaptation, vulnerability, agricultural households, Rajasthan*

JEL CLASSIFICATION: Q54, Q12, Q18

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1. INTRODUCTION

Climate change is a major developmental challenge (Adzawla et al., 2020), whose adverse impacts are being felt all over the world. It is becoming warmer, rainfall is erratic, the sea level is rising, and extreme weather events are more frequent and intense. Climate variability generating an irregular precipitation pattern and an unfavourable rise in temperatures affects lives in most developing countries. Poor people and poor-income countries are exposed and vulnerable to climate shocks, including natural disasters, drought, crop failure, a spike in food prices, and extreme weather conditions (Hallegate et al., 2016). Though every sector of the economy is affected by climate change the impact is notably higher in agriculture due to its climate-sensitive nature, resulting in low or poor agricultural productivity (Narayanan & Sahu, 2016). The concern is exceptionally high for countries like India that are highly dependent on agriculture. With nearly half of its population and nearly 20% of its GDP depending on agriculture, India is one of the country's most vulnerable to climate change risks.

Vulnerability is a function of exposure, sensitivity, and adaptation capacity regarding a specific risk (IPCC, 2007). A system is less vulnerable if it is less exposed, less sensitive, or has a strong adaptive capacity (Smit and Wandel, 2006). Adaptation is an adjustment in the socio-ecological and economic system in response to actual and expected change in climate (Smit & Pilifosova, 2003), and a planning and decision-making process to mitigate the problems caused by any hazards (Ahmed et al., 2021). For example, to cope with changes in climate, farmers adopt adaptation choices such as planting new crop varieties, changing planting dates, using pest-resistant varieties (Suresh et al., 2021, Webber et al., 2014), water conservation (Boyer et al., 2021; Meckonnen et al., 2021), selling off livestock (Kehler & Birchall, 2021), changing crop composition (Schlingmann et al., 2021), and applying fertilizers (Erbas & Solakoglu, 2017; Wing et al., 2021). Over the years, adaptation to climate change has evolved as the most effective tool in mitigating adverse climatic effects (Chattopadhyay & Hulme, 1997).

Adaptation depends on adaptive capacity, which depends on the socio-economic attributes of households vulnerable to climate change. Poor households in rural areas that depend on agriculture face many social and institutional constraints, such as poor education, lack of information, lack of agricultural extension services, social incompatibility, no access to credit, and inadequate capital,

which act as barriers to adaptation and limit the capacity to adapt, leaving them highly vulnerable to climate change. Adaptation also depends on another significant factor: perception. Bryant et al. (2000) find that how the perception of climate change is translated into agricultural decision-making constitutes adaptation in agriculture, so it is crucial to include farmers' perception of climate change in adaptation studies (Maddison, 2007; Banerjee, 2015; Waibel et al., 2018). The perception of climate change helps to negotiate the need for adaptation and explain the most efficient and effective strategy to minimize risks and future losses. The major factors influencing perception are socio-political events, economic factors, and individual factors, including views and ideas (Whitmarsh & Capstick, 2018).

Formulating effective policies to address the climate vulnerability of agricultural households requires an understanding of adaptation strategies, barriers to adaptation, and households' perception of climate change. Besides presenting an overview of agricultural households' perception of and vulnerability to climate change and the adaptation strategies employed, this study attempts to unravel the socio-economic factors that influence these perceptions and adaptations. The objectives of the study are:

1) To study agricultural households' perception of climate change and the factors influencing it.
2) To analyse the factors influencing agricultural households' adaptation strategies.
3) To calculate a livelihood vulnerability index of households in the arid and semi-arid regions of Rajasthan.

Several studies have addressed these issues globally but studies relating to the desert state of Rajasthan are lacking. Rajasthan is the largest state in India, with 10.4 % of the total geographical area. The climate is very harsh: it receives scanty rainfall with high air and soil temperatures, intense solar radiation, and high wind velocity. In India nearly 317,090 sq. kms. are arid, of which 2,46,790 sq. kms. are hot arid areas, and roughly 80% of the hot arid areas is in Rajasthan. The arid and semi-arid areas are more vulnerable to climate change due to their dependence on sensitive sectors such as agriculture, fisheries, forestry, and water (Prasad et

al., 2014). This paper deals exclusively with agricultural households in these semi-arid and arid regions of Rajasthan.

The remaining sections of the paper are organized as follows. Section 2 reviews the related literature. Section 3 provides the methodology and Section 4 discusses the results. Section 5 presents a summary and conclusions.

2. LITERATURE REVIEW

Several studies have examined farmers' perception of climate risks and the adopted adaptation strategies and have identified factors constraining adaptation to climate change. Using a bottom-up approach, Gbetibouo (2009) examines farmers' perception of climate change and variability in South Africa and finds that although they accept secondary data on climate variability, only half of them make adjustments in response to climate change. The main adaptation strategies are changing crop varieties and planting dates, switching crops, and increasing irrigation. Farm size, household size, farming experience, wealth, extension services, and access to credit are found to be significant determinants of adaptation strategies.

Bose (2014) assesses farmers' perception of climate variability in the semi-arid region of north-eastern Nigeria using secondary climate data. Employing a questionnaire survey and non-parametric Mann-Kendall test, the author finds that farmers perceive long-term changes in temperature and precipitation that match the recorded data on annual temperatures and adopt different strategies to reduce the effects of climate change, such as changing planting dates and improving crop seedlings, irrigation, and soil conservation.

Limantol et al. (2016) examine farmers' perception of and adaptation to climate change in the Vea catchment of northern Ghana between 1972 and 2012. They find that the farmers adopted different strategies to cope with the perceived climate change. The farmers fell into two groups, one relying exclusively on rain-fed agriculture and the other adopting a mix of rain-fed and irrigation strategies. The farmers using a mixed strategy kept using fertilizers while the rain-fed group were inclined to vary crop type as their adaptation strategy.

Nhemachena & Hassan (2018) investigate farmers' perception of long-term changes in temperature and precipitation, farm-level adaptation strategies, and barriers to adaptation in Southern Africa. A multivariate discrete choice model is used to identify the determinants of adaptation. The results show that most farmers perceive a long-term increase in temperatures and that the region is getting drier, with pronounced changes in rainfall patterns and drought frequency. Access to credit and extension services and awareness of climate change are found to be the most important determinants of adaptation choices.

In the Indian context, Das (2010) analyses farmers' perception of climate change in villages in Andhra Pradesh and Maharashtra and finds that most farmers have observed the increase in temperature, decline in the level of precipitation, and more erratic rainfall. The farmers have adopted strategies such as migration, taking credit, selling off assets, diversifying livelihoods, using savings, and shifting from cereal to non-cereal crops.

Dhaka et al. (2010) uses a questionnaire to collect data from 500 farmers on perception of and adaptation to climate change in the Bundi district of Rajasthan. Most farmers perceive that temperatures have increased, the climate is getting drier, and the timing of rains and frequency of droughts is changing. They have adapted by integrating farming systems, changing planting dates, and changing crop sequences and rotation.

Prasad et al. (2014) examine farmers' perception of climate change and adaptation options in the Panna district of Madhya Pradesh. The results show that farmers are well aware of the changing climatic conditions and realize their impact on agriculture. The farmers have adapted by planting trees, changing planting dates, and adopting agroforestry.

Varadan & Kumar (2014) study the perception of climate change and adaptation strategies of dryland farmers. The farmers realize that there is an urgent need to devise appropriate adaptation strategies to cope with the negative effects of climate change and have adapted strategies such as manipulating sowing dates, changing cropping patterns, reducing fertilizer use, and diversifying crops. Their adaptation strategies are supported by the farming experience of elderly people, access to irrigation, and availability of livestock.

Dhanya & Ramachandran (2016) explore farmers' perceptions of climate change in South India's semi-arid region using both quantitative and qualitative data. They find that most farmers are aware of climate variability and use adaptation strategies such as cultivating short-duration pulses and fruits, and flowers and vegetables.

Banerjee et al. (2013) examine barriers to adaptation, based on a qualitative survey. They find that although farmers perceive the changes in climate, they face many constraints that limit their capacity to adapt, including lack of access to information, finance, technological inputs, and infrastructure. Small farmers and women are most affected by the lack of resources and improper implementation of government schemes.

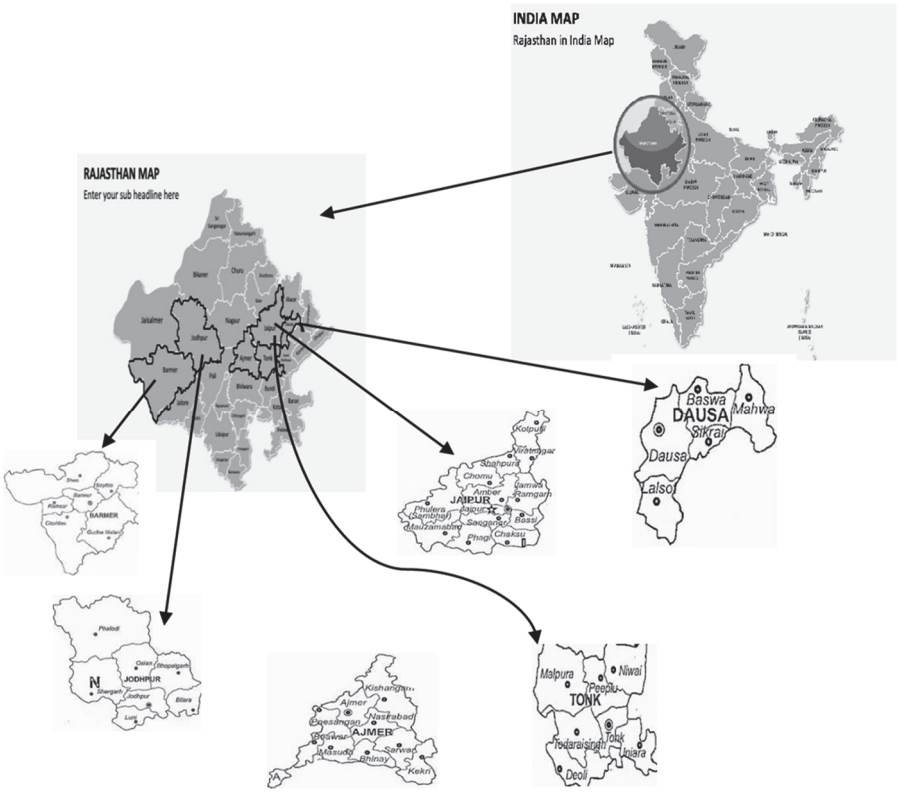
Based on primary and secondary data in Maharashtra, Udmale et al. (2014) find that farmers recognise the impact of drought on their livelihoods and use various drought preparedness and adaptation measures to mitigate its effect. Lack of education, low income, and small landholding size act as major constraints on adaptation.

3. METHODOLOGY

3.1 Area of study

Rajasthan has 10 agro-climatic zones. The arid region covers 4.74 million hectares and the semi-arid region 2.96 million hectares. These regions have low, erratic rainfall and high mean maximum temperatures (Manga et al., 2015), resulting in unexpected losses and poor income. This study was conducted among agricultural households in two arid regions of Rajasthan, Barmer and Jodhpur, and four semi-arid regions, Ajmer, Jaipur, Tonk, and Dausa.

Figure 1: Map of study area



3.2 Sampling technique and data collection

Purposive random sampling was used to collect data from agricultural households. The sample size was set at 600: two administrative blocks from each district were selected for data collection and five villages were selected from each tehsil. The study used a structured household questionnaire, focus group discussions, and personal interviews. Focus group discussions were conducted to review farmers' perception and understanding of climate change and their general opinion regarding interventions to mitigate climate change. Each group consisted of 8 to 10 members from similar localities. Officials and heads of Farmer Producer Organisations (FPOs) and other agricultural extension services were

interviewed to attain a general understanding of the area and the standard of living.

3.3 Conceptual Framework

3.3.1 Perception and adaptation

The major factors governing agricultural households' perception of climate change were determined using binary logistic regression. The logistic regression model helps to analyse events given the probability of occurrence. The mathematical model for the logistic regression is represented below:

$$p/1-p \;=\; e\hat{}y \tag{1}$$

where *y* is the independent variable.

Here, *p/1-p* is the odds ratio which calculates the ratio of the probability of success to the probability of failure. The logistic regression model uses the natural logarithm of the odds ratio, given as:

$$log\ (p/1-p) \;=\; y \tag{2}$$

This study employed a binary logistic regression model to analyse the determinants of farmers' perception. . Each category was regressed separately using the logistic regression and the marginal effects were calculated to interpret the data. The major changes perceived by the farmers include increased temperature, decreased rainfall events, decreased rainfall intensity, and decrease in rainfall duration. Binary logistic regression was run for each response category to find the determinants and eliminate the possibility of error due to multiple responses. This is expressed mathematically as:

$$\Pr\left(Y=\frac{a}{X}\right)=\frac{e^{\mathrm{XiBA}}}{\left(1+e^{XiB2}+e^{XiB3}+e^{XiB4}+\cdots..e^{XiBA}\right)} \tag{3}$$

Here the dependent variable *a* can take the value of either 1 or 0, where *a*=0 when the farmers have not perceived the change and *a*=1 when the farmers have perceived the change. XB_1, XB_2……XB_G show the independent variable or the characteristics of household *i*. The household characteristics considered in the model are gender of the household head, social responsibility of the household

head, literacy status and educational status of the household head, number of years involved in farming, household size, access to institutions, and visit of extension services.

The study employed a binary response model to analyse the factors determining agricultural households' adaptation to climate change. Since the farmers employed more than one strategy to mitigate the effects, binary logistic regression was used to analyse the factors determining the adoption of each strategy. The major strategies were using a variety of crops, mixed cropping, selling livestock, planting trees, crop rotation, and construction of farm ponds. The variables used were educational status of the household head, number of years involved in farming, external support, agricultural training, land size, agricultural income, agricultural institutions, farmland distance, and storage.

$$\Pr\left(Y=\frac{m}{X}\right)=\frac{e^{\mathrm{XiBJ}}}{\left(1+e^{XiB2}+e^{XiB3}+e^{XiB4}+\ldots..e^{XiBJ}\right)} \quad (4)$$

Here m takes two values, 0 and 1. If m=0 it indicates that the farmer has not adopted any specific strategy and if m=1 it indicates that the farmer has adopted the strategy. XB_1, XB_2…...XB_J show the independent variable or the characteristics of household i .

3.3.2 Vulnerability index calculation

A livelihood vulnerability index was constructed to analyse the households' vulnerability to climate change. The vulnerability index has 8 sub-indices: economic wellbeing and stability (EW), gender discrimination (GD), dependency burden (DB), interconnectivity (IC), susceptibility to environmental change (SE), housing quality (HQ), awareness level (AL), and institutional and infrastructural environment (IE). Each sub-index contains several indicators and each was assigned a weight. Once the weights were assigned, each indicator was standardized as an index using the formula:

$$IndexR_d = R_d - R_{dmin}/(R_{dmax} - R_{dmin})$$

Here R_d is an indicator of the major component M_d, and $R_{d\,max}$ and $R_{d\,min}$ are the maximum and minimum values of the indicator. Once the indicators were

standardized, they were averaged together to find the value of their respective major components using the following equation:

$$M_d = \sum_{i=1}^{n} R_{di} / n$$

Here M_d is the major component. Index R_{di} is the standardized indicator of the major component M_d, where i take the values 1, 2, or 3 according to the number of indicators the major component has. n is the total number of indicators in the major component M_d. The other major components are also calculated using the above equation. Once the values of the major components are calculated, the livelihood vulnerability index is calculated using the following equation:

$$LVI = \frac{[n1(EW) + n2\,(GD) + = n3\,(DB) + n4(IC) + n5(SE) + n6\,(HQ) + n7(AL) + n8(IE)]}{n1 + n2 + n3 + n4 + n5 + n6 + n7 + n8}$$

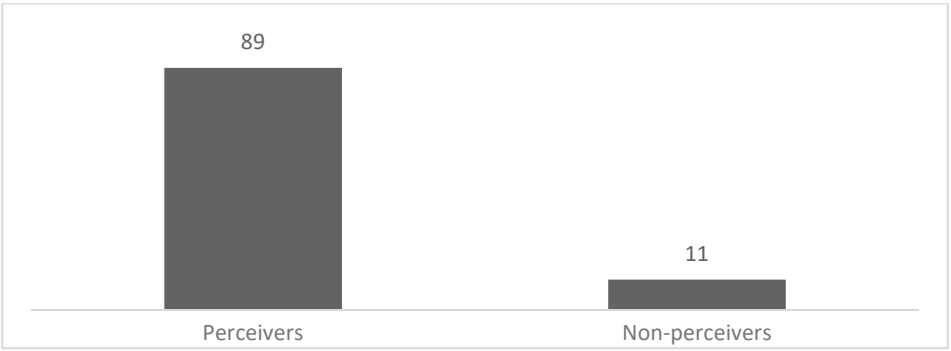
Here $n_{1,}\, n_{2,}\, n_{3.....}\, n_8$ indicate the total number of indicators of their corresponding major component.

4. RESULTS AND DISCUSSION

4.1 Perception of climate change

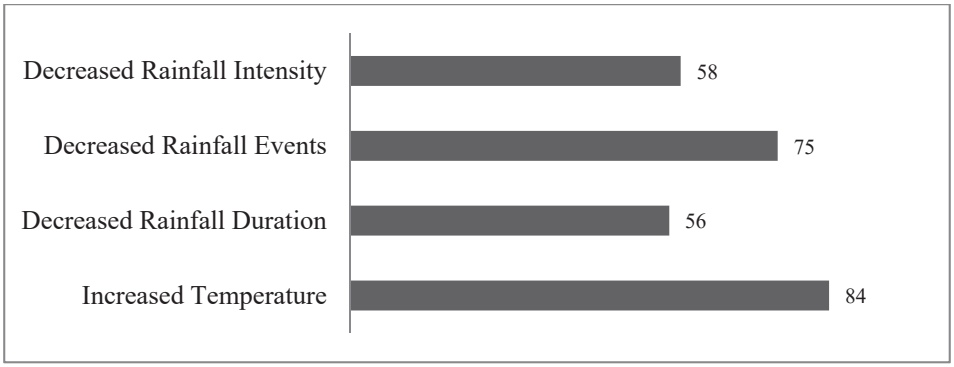
The agricultural households in the arid and semi-arid regions were asked about the long-term changes that have occurred in their environment over the past 10 years. The farmers who reported changes in the climate were considered 'perceivers' and the households who did not notice any changes were considered 'non-perceivers'. Figure 2 shows that 89% of the households were perceivers and 11% were non-perceivers. Analogous to the meteorological data, the major changes recognised by the households were increased temperature, decreased rainfall duration, decreased rainfall events, and decreased rainfall intensity (see Figure 3); these findings are consistent with those of Das (2010) and Dhaka et al (2010). However, a minute percentage of the households also reported an increase in rainfall events and decreased temperature.

Figure 2: Percentage of perceivers and non-perceivers



Source: Primary data

Figure 3: Major perceived changes (in Percentage (%))

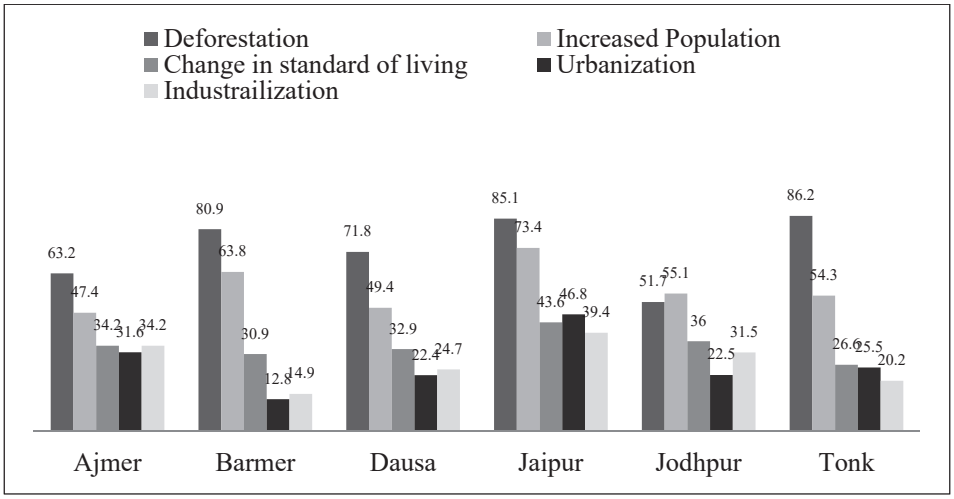


Source: Primary data

The main reasons given for these changes were deforestation, increased population, changing living standards, industrialisation, and urbanisation (see Figure 4). Deforestation was found to be a major cause of the climatic changes by 86.2% of the households in Tonk, 85.1% in Jaipur, 80.9% in Barmer, and 71.8% in Dausa. Cutting down trees to clear land and construct buildings has considerably damaged the ecological balance. Increasing population was accounted a major reason in all districts and the main cause of climate change in Jodhpur, resulting in over-utilisation of resources and fuelling long-term changes in the state. In Jaipur 46.8% of the households said that increased urbanisation has also caused climate change. Construction of social infrastructure and other industries has deteriorated land quality and gradually turned agricultural fields

into barren land. The households also pointed out that changing living standards can play a major role in environmental change. The expanding needs of the population have led to further exploitation of resources and climate change.

Figure 4: Reasons for the long-term changes (in Percentage (%))



Source: Primary data

Table 1 analyses the major factors influencing farmers' perception of climate change. Previous studies have found farm size (Ojo & Baiyegunhi, 2021; Mairura et al., 2021), education level (Guodaar et al., 2021), access to rain-fed agriculture (Tesfahunegn et al., 2016), and access to extension services (Fahad et al., 2020) to be factors influencing households' perception of climate change. Table 1 shows that the gender of the household head significantly influences the perception of rainfall duration. In the study area most of the women work in household chores, making them less observant of the changing rainfall duration than the men. The social responsibility of the household head is negatively related to all the changes because when the primary concern is community issues rather than resolving household problems the result is less observance of climatic changes and more concern with overall agricultural production failures. The household's literacy status positively influences the perception of increased temperatures and decreased rainfall intensity, while the household head's education is negatively related to the perception of increased temperatures and positively related to the perception of decreased rainfall duration.

The years involved in farming positively influence the perception of decreased rainfall duration. Households that have a long experience of farming are highly observant of the changes around them and notice any change in temperature, rainfall, and especially rainfall duration. This is consistent with studies that show experience to be a major determinant of perceptions regarding climate change (Linden, 2015; Horne et al., 2021). Surprisingly, large households did not perceive increased temperatures, because most members have either migrated to cities or are too young to perceive changes. Households that have access to institutions immediately recognize any increase in temperature or decrease in rainfall duration because of their access to resources and effective social interaction. The visit of an extension officer can improve the capacity of households to perceive increased temperatures or decreased rainfall intensity because the officers have access to climate records and can make households aware and inform them about climate change.

Table 1: Factors influencing households' perception (marginal effect)

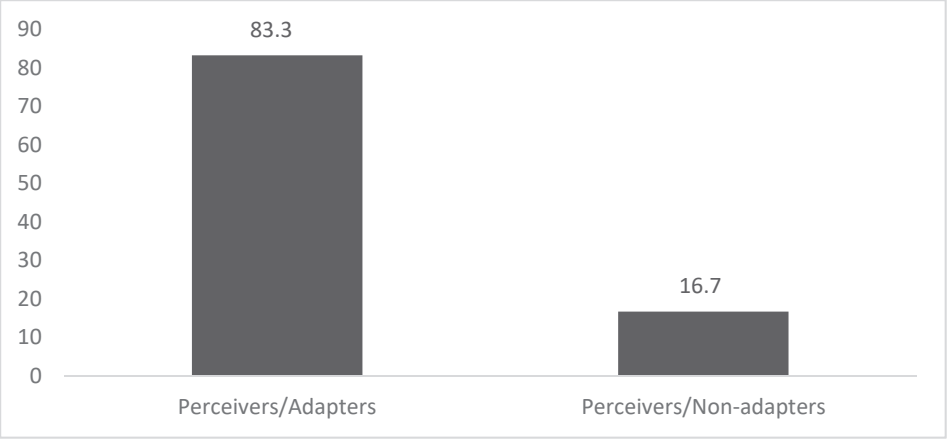
Variable	Increased Temperature	Decreased rainfall duration	Decreased rainfall events	Decreased rainfall intensity
Gender of the HH head	-0.043	0.154*	0.018	0.131
Social responsibility of HH head	-0.092**	-0.129*	-0.141**	-0.301***
Literacy status of the HH head	0.062***	-0.025	0.026	0.035*
Education of the HH head	-0.041***	0.056**	0.007	0.015
Years involved in farming	-0.013	0.053**	0.0193	0.009
Household Size	-0.07***	0.040	0.035	-0.049
Access to Institutions	0.112***	0.18 **	-0.042	0.004
Visit of Extension officer	0.035***	0.011	0.004	0.054***

Note: * indicates significance at 0.1%, ** indicates significance at .05%, *** indicates significance at .01%
Source: Primary data analysis

4.2 Adaptation

The farmers have employed various techniques to adapt to climate change. Figure 5 shows that most of the households have adapted to the changes by employing more than one strategy. 83.3% of the perceivers have adopted strategies to fight climate change and 16.7% have not, even though they are aware of climate stress and losses.

Figure 5: Percentage of adapters and non-adapters

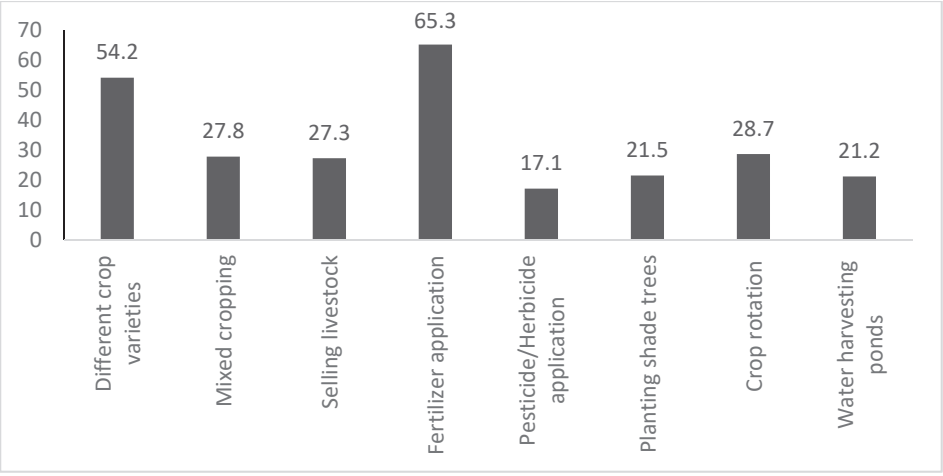


Source: Primary Data

A major adaptation strategy chosen by agricultural households is the application of fertilizers (see Figure 6). Increased economic activity has resulted in land deterioration and reduced crop productivity. 65.3% of the farmers have used fertilizers like urea to improve crop yields and many farmers have started applying bio-fertilizers and vermin composts. 54.2% of households have introduced different crop varieties: crop diversification improves production, especially among farmers with poor access to chemical and technological resources (Lin, 2011). The new varieties are highly water-efficient and require less care, which helps the farmers invest in other assets. 28.7% of the households have adopted crop rotation and 27.8% have opted for mixed cropping, which aids water efficiency, pest control, mutualism and crop co-existence, and use of space and time (Gliessman, 2021).

27.3% of households have sold livestock for temporary financial relief and to meet other requisites or because they no longer have the resources to look after livestock. 21.5% of the households have planted trees to act as windbreaks to protect the soil and crops. Trees also maintain moisture content in the soil and help crops survive drought. Another major strategy is the construction of ponds for irrigation and other water purposes. 21.2% of farmers have constructed water harvesting systems, bore wells, and ponds for irrigation purposes. 17.1% of households have applied pesticides and herbicides to prevent pest infection, which is also a major problem.

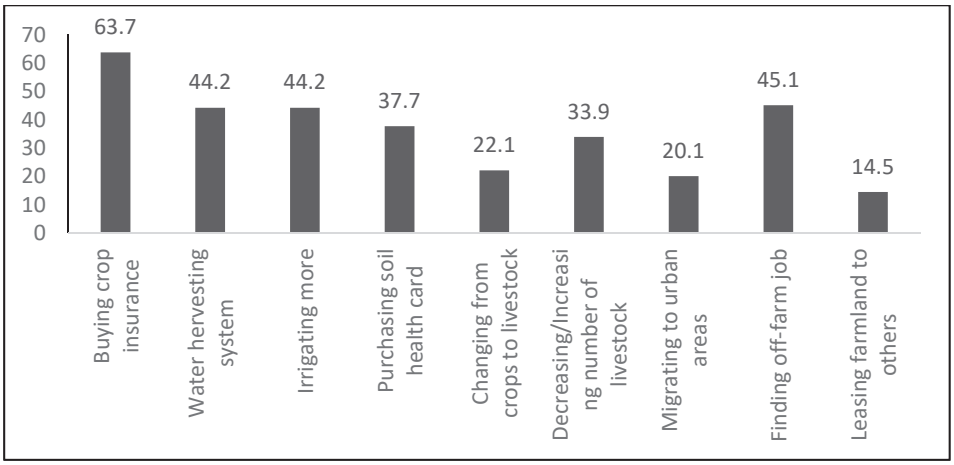
Figure 6: Adaptation strategies (in Percentage (%))



Source: Primary data

Apart from these strategies, Figure 7 shows that the farmers also insure their crops, find off-farm jobs, introduce drip irrigation and sprinkler systems, purchase soil heath cards (A soil health card offers details on the soil's nutritional status and suggestions for the amount of nutrients to be used to increase soil's fertility and health), and lease land to small-scale farmers. Farmers have also migrated to other regions and are willing to move in search of employment if the situation in their area worsens.

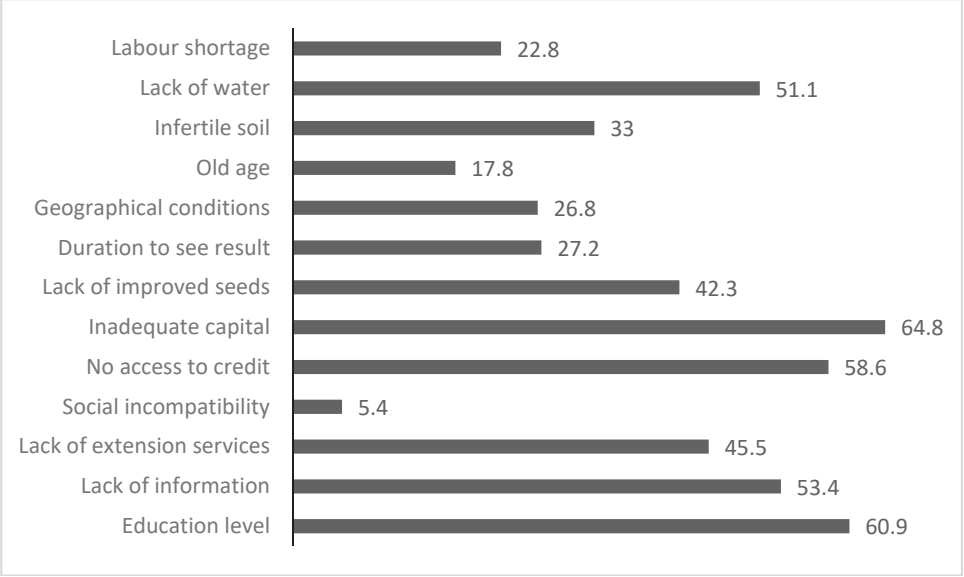
Figure 7: Additional measures (in Percentage (%))



Source: Primary data

The barriers to adopting adaptation strategies include education level, lack of information, lack of extension services, social incompatibility, no access to credit, inadequate capital, lack of improved seeds, duration to see results, geographical conditions, old age, infertile soil, lack of water, and labour shortages (see Figure 8). 64.8% of the households found lack of capital for agricultural investment to be a major barrier. 60.9% believe that their poor education level has made them unaware of new technologies and other practical knowledge required for improving their farming. 58.6% have found lack of credit to be another reason for poor adaptation to climate change. Lack of information (53.4%) followed by inadequate water for drinking and irrigation (51.1%) are other barriers to adaptation. The farmers have no system or technology to forecast the weather and are not informed about climate change. Many households do not have enough water for irrigation, and although some households have constructed farm ponds, many others do not have the finances to do so.

Figure 8: Barriers to adaptation (in Percentage (%))



Source: Primary data

The factors influencing agricultural households' adaptation to climate change can be categorised as personal attributes, psychological factors, and socio-economic factors (Guo et al 2021). Studies have found the main determinants of adaptation to climate change to be gender (Qazlbash, 2021), farm size (Moroda et al., 2021), household size (Getahun et al., 2021), livestock holding (Khan et al., 2021; Alauddin & Sarker, 2021), and income (Sertse 2021). Table 2 shows that education is a major determinant of using different crop varieties, mixed cropping, fertilizers, and tree planting. Farming experience is a major determinant of using fertilizers, mixed cropping, and tree planting: it positively influences the use of fertilizers, as the longer the farmer is involved in farming the more, he improves his land by adding fertilizers, but it negatively influences mixed cropping and tree plantation as experienced farmers limit themselves to the old methods while inexperienced farmers abandon conservative farming methods for new techniques.

External support is a major determinant and influences decisions regarding the use of different crop varieties, mixed cropping, pesticides, tree planting, and the construction of farm ponds. External support in terms of financial backing and

provision of agricultural machinery helps farmers adapt to the changes. Agricultural training provides them with crop varieties that are not easily available and encourages them to plant more trees. The size of the farmers' land is another determinant that influences farmers' decisions regarding adaptation strategies. Large farmers are able to construct farm ponds and use mixed cropping methods while small farmers have to depend on local wells and taps for irrigation. When the household income is adequate, farmers adopt new techniques like mixed cropping and reduce the cost of the conventional techniques of applying pesticides and fertilizers.

Access to agricultural institutions is a major factor that determines adaptation strategies (Deressa et al., 2009; Shahid et al., 2021). Households that are near to agricultural institutions and other extension services use mixed cropping and construct farm ponds because they have access to financial resources and quality seeds. Distance from the farmland is another important determinant that negatively influences adaptation strategies such as using different crop varieties, mixed cropping, and selling livestock, because when the farmland is far away it costs the farmers time and money and they are reluctant to introduce new strategies that require time and effort.

Table 2: Factors determining households' adaptation strategies (marginal effect)

Variables	Usage of variety of crops	Mixed cropping	Livestock selling	Fertilizers	Pesticides	Trees plantation	Crop rotation	Farm ponds
Educational status of HH head	0.04***	0.04***	-0.18	0.04**	-0.03	0.03**	0.07	0.07
Number of years farming	0.02	-0.03**	0.03	0.07***	0.04*	-0.04**	-0.02	-0.03
External support	0.19***	0.18***	-0.22***	-0.05	0.18***	0.09**	0.02	0.14***
Agricultural Training	-0.02	0.01	-0.07	-0.03	-0.04	0.11***	-0.17	0.04
Land size	-0.03**	0.02*	-0.01**	-0.001	-0.02*	-0.01	-0.02*	0.03**
Agricultural income	-0.05	0.05	0.08	0.05	-0.12***	-0.04	0.07*	-0.03
Agricultural Institutions	-0.13	0.15***	-0.03	-0.06	-0.04	0.06	0.04	0.03**
Farmland distance	-0.06***	-0.53***	-0.05***	-0.04	-0.04	0.03	1.06***	0.06
Storage	-0.06	-0.61	0.90**	-0.11**	0.06	0.03	0.05	-0.01

Note: * indicates significance at 0.1%, ** indicates significance at .05%, *** indicates significance at .01%

Source: Primary Data

4.3 Livelihood vulnerability index

The livelihood vulnerability index has 8 major components: economic wellbeing and stability, gender discrimination, dependency burden, interconnectivity, susceptibility to environmental change, housing quality, awareness level, and institutional and infrastructure environment. These components are divided into sub-components. Weights are assigned to each sub-component and their value is calculated. Table 3 shows the variables and the weights assigned to them.

Table 3: Variables under study

Sub-Indices (min–max)	Indicators (min–max)	Values/Weights	Explanation
Economic wellbeing and stability	Total Household Assets (1–4)	1 for <5 2 for 5–10 3 for 10–15 4 for >15	Types of assets the households own
	Land rights (0–2)	0 if no land 1 if shared/leased 2 if land is owned	Whether the household possess any land rights
	Income diversification (0–1)	0 for no income diversification 1 for income diversification	Whether the households are engaged in any off–farm activities.
	Healthy household members (0–3)	0 if none 1 if only 1 2 if 2–4 3 if >5	Number of household member healthy enough to work.
	Female participation (0–3)	0 if no participation 1 if 2–3 days working 2 if 3–5 days working 3 if 7 days working	Whether the women in the households are working or not.

Gender Discrimination	Women's land rights (0–1)	0 if no 1 if yes	Whether woman in the household has any land rights
	Decision-making power (0–1)	0 if no 1 if yes	Whether woman in the household has any decision–making power
	Women's health (0–1)	0 if no 1 if yes	Whether women are allowed to visit the doctor
	Women's skills (0–1)	0 if no 1 if yes	If the woman in the household possesses any skills
	Women's responsibility as caregivers (0–2)	0 if women do not fetch water 1 if women fetch water 2 if both men and women fetch water	The household member who fetches water for the household
	Strategies during crop failure (0–1)	0 if no strategy 1 if there is a strategy	If any strategies are being used by the woman in the household
Dependency Ratio	Household members with terminal illness (0–2)	0 if none 1 if 1 2 if >2	Number of household members with terminal illness
	Non-working household members (0–2)	0 if none 1 if <3 2 if >4	Number of household members not working

Level of inter connectivity	Geographical scope of social capital contacts and social categories a household relies on (0–1)	0 if no contacts 1 if there are contacts	Whether the household has any social connectivity
	Groups to which household belongs (0–1)	0 if no groups 1 if there are groups	Whether the household belongs to any social group or organization
Susceptibility to environmental change	Contribution of farming to household livelihood (0–3)	0 if not significant 1 if <30% 2 if 30–70% 3 if > 70%	The percentage of contribution of agriculture to annual income
	Cooking energy source (0–1)	0 if wood/kerosene/dung 1 if gas	Cooking energy source used by the household
	Source of drinking water (0–1)	0 if free source 1 if paid source	Source of drinking water
Housing quality	Quality of house (0–2)	1 if kutcha 2 if mixed 3 if pucca	The quality of the house
Awareness level	Ability to describe environmental change (0–1)	0 if no awareness 1 if there is awareness	If the household is aware of climate changes
Institutional and infrastructure environment	Access to institutions and organizations (0–1)	0 if no access 1 if there is access	Whether the household has access to social institutions and extension services

Source: Vincent (2007), modified by Mwamba (2013)

The vulnerability index analyses households' vulnerability with values of 0 to 1. There are five different levels of vulnerability: households that fall into the range of 0–0.2 are the least vulnerable, followed by less vulnerable (0.2–0.4), moderately vulnerable (0.4–0.6), highly vulnerable (0.6–0.8), and extremely vulnerable (0.8–1). Table 4 shows that most of the households are moderately vulnerable to climate change. No households fall into the least vulnerable or extremely

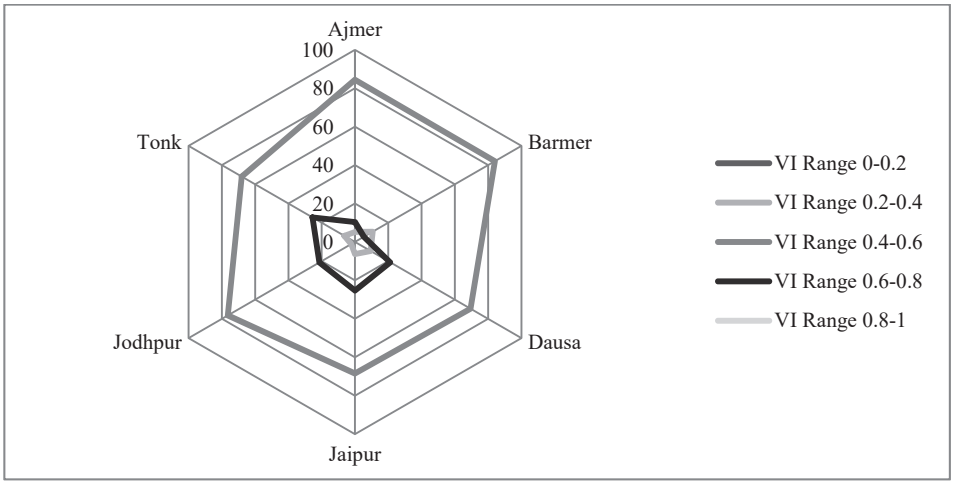
vulnerable categories. The radar graph in Figure 9 compares the vulnerability of households in different districts. There is zero variation in the ranges 0–0.2 and 0.8–1, indicating that no households fall into these categories.

Table 4: District-wise vulnerability index values

District	VI Range 0–0.2	VI Range 0.2–0.4	VI Range 0.4–0.6	VI Range 0.6–0.8	VI Range 0.8–0.1
	Percent	Percent	Percent	Percent	Percent
Ajmer	–	5.19	84.41	10.39	–
Barmer	–	10.64	84.04	5.32	–
Dausa	–	9.41	69.41	21.18	–
Jaipur	–	6.31	68.42	25.26	–
Jodhpur	–	2.24	76.40	21.35	–
Tonk	–	6.34	68.09	25.53	–

Source: Primary Data

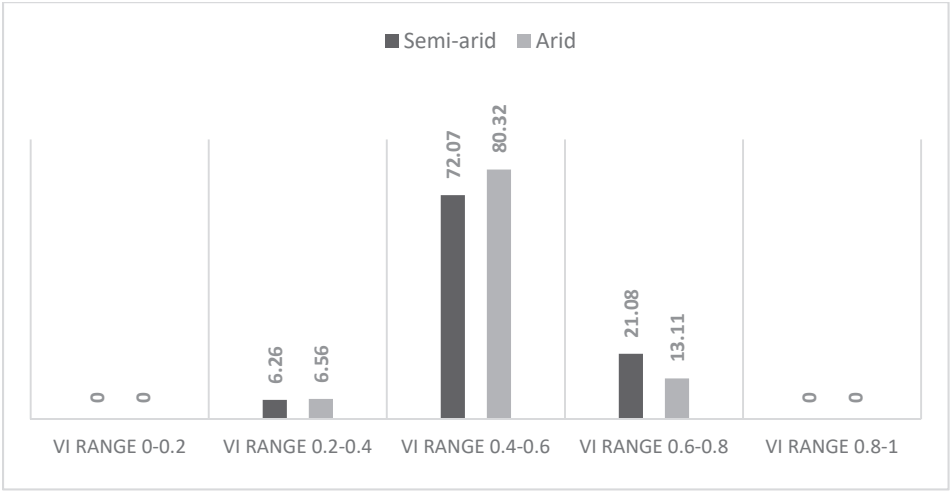
Figure 9: Radar graph of vulnerability



Source: Primary Data

Figure 10 shows the vulnerability to climate change of households in the arid and semi-arid regions. 80.32% of the arid households and 72.07% of semi-arid households are moderately vulnerable. The percentage of less vulnerable households is the same at approximately 6% of the total vulnerable population. Access to credit, availability of agricultural machinery, improved awareness and education, quality seed varieties, extensive government support, and cheap loans account for the lower vulnerability in these areas. However, the percentage of households falling into the highly vulnerable category is higher in the semi-arid region (21.08%) than in the arid region (13.11%). This implies that households in the arid regions are adapting to climate change by employing several strategies, making them less vulnerable.

Figure 10: Region-wise vulnerability



Source: Primary Data

5. CONCLUSION

Increasing temperatures, erratic rainfall patterns, and rising sea levels due to climate change are now an existential threat. Agriculture is a climate-sensitive sector, involving much uncertainty and many risk factors that negatively affect agricultural households. This study analyses agricultural households' perception of climate change and the major adaptation strategies undertaken to mitigate climate change in the arid and semi-arid regions of Rajasthan, and identifies the

factors acting as barriers to adaptation. The majority of the households perceive the existence of climate change and have noticed long-term changes such as increased temperature, decreased rainfall intensity, and decreased rainfall events. Their perception is entirely analogous to the meteorological data for Rajasthan. The respondents identify deforestation, changing living standards, increased population, urbanisation, and industrialisation as major factors causing climate change. The major factors that have a significant influence on the farmers' perception are gender, social responsibility, the household head's literacy status and education, years of farming experience, household size, access to institutions, and visits by an extension officer.

The major adaptation strategies of the agricultural households include crop diversification, applying fertilizer, constructing farm ponds, mixed crop farming, crop rotation, planting trees, and selling off livestock. The major determinants of adaptation strategy are found to be educational status of the household head, farming experience, external support, training, land size, agricultural income, access to agricultural institutions, farmland distance, access to crop insurance, social capital, and storage. A vulnerability index measuring adaptive capacity shows that most of the households are moderately vulnerable to climate change.

Based on the above analysis, policy addressing the issues facing rural households needs to be improved to include providing information on climate change, agricultural training, and an efficient weather forecasting system, so that farmers can adapt. Households should receive specific training on the management of climatic stress. Financial support in terms of cheap and easy access to credit should be facilitated, and farmers should receive information about smart agricultural practices. Farmers should be made aware of the benefit of crop insurance schemes such as the Fasal Bima Yojana or Kisan Credit Card. Community-based organisations that include women, and agricultural extension services should function to extend support to farmers during climatic stress.

The current study has attempted to understand the micro-level perception, vulnerability, and adaptation strategies of agricultural households. A limitation of the study is that it only considers the arid and semi-arid belts; future research could consider the vulnerabilities, perception, adaptation, and barriers to adaptation in other agroecosystems. The study's vulnerability index only

measures adaptive capacity: future studies might compute vulnerability based on all its respective components; i.e., exposure, sensitivity, and adaptive capacity.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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