Appendix

1. Model Documentation

The following model documentation **focuses specifically on the insurance policy structed, extended within FRIDA**. It will not provide the whole FRIDA model variables and equations.

This thesis specifically uses FRIDA v2.1 version, including the calibration data set for the complete model [accessible in an open-source model on Zenodo: https://doi.org/10.5281/zenodo.15310859 (Schoenberg et al., 2025)]. The policy model is provided as a separate attachment under the file name: **Model_Theresia_InsuranceThesis.stmx.** As mentioned in Figure 10 in Chapter 3, the insurance policy structures are implemented in the modules and submodules highlighted in green. The following table presents the model settings used in this thesis model.

Stella Architech 4.2.1 Model Setting	
Start Time	1980
Stop Time	2100
DT	1/8
Save Interval	1 Time Units
Time Unit	Year
Integration Method	RK4

The policy decision variables, which also function as policy switches, are specified in the Government Regulations module. These variables control whether each insurance policy is activated, how much of climate-driven defaults is covered, and how the policy is implemented over time.

Variable		Equation	Properties	Units	Documentation
Module: Government Regulation					
Sector: Climate-driven default insurance policy					
Government_Regulations.decision_fraction_of_default_covered_by_central_bank_insurance	Policy Parameter	0.233035		dmnl	A policy parameter sets how much of climate-caused risky defaults absorbed or funded by central bank insurance. It does not directly determine the final amount of defaults covered by central banks insurance. Instead, it represents the decision weight or intended allocation before normalization

Variable		Equation	Properties	Units	Documentation
Government_Regulations.decision_fraction_of_default_covered_by_government_insurance	Policy Parameter	0		dmnl	A policy parameter sets how much of climate-caused risky defaults absorbed or funded by government insurance. It does not directly determine the final amount of defaults covered by government insurance. Instead, it represents the decision weight or intended allocation before normalization
Government_Regulations.decision_fraction_of_default_covered_by_private_insurance	Policy Parameter	0.466965		dmnl	A policy parameter sets how much of climate-caused risky defaults absorbed or funded by private insurance. It does not directly determine the final amount of defaults covered by private insurance. Instead, it represents the decision weight or intended allocation before normalization
Government_Regulations.fraction_of_default_covered_by_central_bank_insurance	Variable	decision_fraction_of_default_covered_by_central_bank_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by central banks insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Government_Regulations.fraction_of_default_covered_by_government_insurance	Variable	decision_fraction_of_default_covered_by_government_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by government insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Government_Regulations.fraction_of_default_covered_by_private_insurance	Variable	decision_fraction_of_default_covered_by_private_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by private insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Government_Regulations.fraction_of_loan_insured	Variable	one_level_fraction		dmnl	This variable represents the total fraction of climate-caused risky defaults that is insured by the policy at a given point in time. It controls the overall size of the insurance intervention, regardless of whether the insured share is funded by private insurance, central bank insurance, government insurance, or a combination of the three. It uses one_level_fraction if it aims to have one one coverage level all the policy simulation period, but it uses two_level_fraction if it aims to have dynamic policy with two coverage level at different certain times.

Variable		Equation	Properties	Units	Documentation
Government_Regulations.insurance_coverage_level	Policy Parameter	70		dmnl	This parameter defines the first target level of insurance coverage, expressed as a percentage of climate-caused risky defaults. It determines the initial coverage level that the policy tries to reach after the insurance start year. For example, if this value is 20, the policy aims to insure 20% of climate-caused risky defaults after the first implementation phase is completed. This value is a policy scenario assumption or optimization input, rather than a calibrated empirical parameter. This variable is capped at 70% of climate-caused risky defaults. This cap is an exploratory policy assumption, not an empirical claim that 70% is the real-world optimal coverage level. The cap is used to test a strong but still partial insurance intervention, while avoiding full 100% coverage that could imply moral hazard (J. E. Stiglitz, 1983; J. Stiglitz & Yun, 2013).
Government_Regulations.insurance_coverage_second_level	Policy Parameter	20		dmnl	This parameter defines the second target level of insurance coverage, expressed as a percentage of climate-caused risky defaults. It is used in the two-stage policy implementation structure. After the first coverage level has been reached, the policy can later move toward this second target level. This allows the model to represent insurance policies that are strengthened, weakened, or adjusted over time. Like the first coverage level, this value is an exploratory policy assumption or optimization input rather than an empirically calibrated value.
Government_Regulations.insurance_coverage_start_year	Policy Parameter	2035.26		Year	This parameter defines the year in which the insurance coverage policy begins to be implemented. Before this year, the insured fraction remains zero and the insurance mechanisms do not affect climate-caused risky defaults. In the thesis, policy implementation is initially introduced after 2030 but the optimization leads to year 2035.26.
Government_Regulations.insurance_coverage_time_to_implement	Policy Parameter	1		Year	A policy parameter sets how long (duration) it takes to ramp from 0 to first-level coverage. Its purpose is to avoid an unrealistic sudden jump in insurance coverage. Instead, insurance coverage is introduced gradually after the selected start year, reflecting the time needed to design, approve, and implement a financial risk-sharing mechanism

Variable		Equation	Properties	Units	Documentation
Government_Regulations.insurance_coverage_time_to_implement_second_level	Policy Parameter	5		Year	A policy parameter sets how long it takes to move from first level to second level. Its purpose is to avoid an unrealistic sudden jump in insurance coverage. Instead, insurance coverage is introduced gradually after the selected start year, reflecting the time needed to design, approve, and implement a financial risk-sharing mechanism
Government_Regulations.insurance_coverage_time_to_start_second_level	Policy Parameter	50		Year	This parameter defines how many years after the first policy start year the second-stage coverage adjustment begins. It allows the model to represent a delayed policy revision, where the insurance mechanism is first introduced at one level and then adjusted later. For example, a value of 50 means that the second-stage coverage change starts 50 years after the first insurance start year. This parameter is useful for testing long-run policy pathways where insurance coverage is gradually scaled or revised over time.
Government_Regulations.one_level_fraction	Variable	RAMP(insurance_coverage_level / insurance_coverage_time_to_implement, insurance_coverage_start_year, insurance_coverage_start_year + insurance_coverage_time_to_implement) / 100		dmnl	The variable is used when the policy is represented as a single implementation phase rather than a two-stage policy. It gradually increases the insured fraction from zero to the one target insurance coverage level over the specified implementation period.
Government_Regulations.total_insurance_coverage	Variable	decision_fraction_of_default_covered_by_private_insurance + decision_fraction_of_default_covered_by_central_bank_insurance + decision_fraction_of_default_covered_by_government_insurance		dmnl	This variable represents the sum of the three institutional decision fractions for private insurance, central bank insurance, and government insurance. It measures the total intended allocation of responsibility across the three funding sources before normalization.
Government_Regulations.two_level_fraction	Variable	SIXPARM(insurance_coverage_level, insurance_coverage_start_year, insurance_coverage_time_to_implement, insurance_coverage_second_level, insurance_coverage_time_to_start_second_level, insurance_coverage_time_to_implement_second_level) /100		dmnl	This variable represents a two-stage insurance coverage path. It allows the insurance policy to first move toward an initial coverage level and later shift toward a second coverage level after a specified delay. This formulation is useful when the policy is assumed to be implemented gradually and then adjusted later as climate-finance risks evolve. The two-stage design captures the idea that financial policies are rarely implemented instantly and may be scaled up, revised, or strengthened over time.

The following model documentation focuses on the Economy module, in which the insurance policy structure is developed and integrated into FRIDA. In the table below, rows in white refer to policy-related variables and equations developed for this thesis. Rows shaded in grey refer to variables and equations from the FRIDA base model that are directly connected to the policy structures.

Variable		Equation	Properties	Units	Documentation
Module: Economy - Private Insurance					
Private_Insurance.actual_years_of_coverage[Run]	Variable	Insurance_Deposits//private_insurance_payouts		year	It measures how long the current insurance reserve could continue paying claims if payouts remained at their current rate. A higher value means the reserve is more adequate relative to ongoing payouts, while a lower value means the reserve could be depleted more quickly. This variable is then used to influence premium pricing, so reserve adequacy feeds back into the cost of insurance.
Private_Insurance.desired_years_of_coverage[Run]	Policy Parameter	4		years	It represents a target for how many years of payouts that insurers aim to hold in reserve. There is no single or global standard for the 4 years desired coverage. London School of Economics research explores ‘long-term insurance’ solvency terms from 3 to 25 years. The value of 4 years should therefore be described as a modeling assumption in a long-run exploratory model, and it helps keep the insurance fund positive under the tested scenarios, while still allowing the reserve to respond to stress
Private_Insurance.effect_of_years_of_coverage_on_premiums[Run]	Variable	MAX(1e-6, relative_years_of_coverage)^sensitivity_of_premiums_to_years_of_coverage		dmnl	It translates reserve adequacy into a multiplier on the insurance premium rate. When relative coverage is low, the premium effect increases to rebuild the reserve. When relative coverage is high, the premium effect decreases because the reserve is more adequate. Because this variable is a multiplier, it does not itself set the premium, but it changes the baseline premium upward or downward depending on the insurer’s reserve situation.
Private_Insurance.Insurance_Deposits[Run](t)	Stock	Insurance_Deposits[Run](t - dt) + (insurance_premiums[Run] + insurance_earnings[Run] - private_insurance_payouts[Run]) * dt	INIT Private_Insurance.Insurance_Deposits[Run] = 0	b$	It represents the accumulated private insurance reserve. The stock increases through insurance premiums and insurance earnings, and decreases when private insurance payouts are made. It ensures that private insurance is represented as an endogenous reserve mechanism rather than an unlimited external funding source. The initial value is set to zero, which means the private insurance mechanism starts without pre-existing reserves and must build capacity endogenously once the policy becomes active

Variable		Equation	Properties	Units	Documentation
Private_Insurance.insurance_earnings[Run]	Inflow	Insurance_Deposits*Finance.average_private_debt_safe_interest		b$/year	It is the annual return earned on the insurance deposit. It is included because insurers do not only rely on premium inflows. Reserve funds are usually invested in relatively safe assets and generate income. The equation multiplies insurance deposit by private debt safe interest, meaning the larger the reserve base, or the higher the safe interest rate, the more the insurer earns each year. This helps prevent the reserve fund from being depleted too quickly.
Private_Insurance.insurance_premium_rate[Run]	Variable	MIN(MAX(minimum_insurance_premium, normal_insurance_premium*effect_of_years_of_coverage_on_premiums), 1)		dmnl	It is the effective premium rate applied to the investment base to calculate premium inflows. The model needs a pricing mechanism for insurance that can respond endogenously to risk conditions and reserve adequacy. It is shaped by: (1) normal insurance premium, which is baseline cost under normal climate risk, (2) minimum insurance premium, which is a lower bound so insurance never becomes unrealistically cheap, (3) effect of years of coverage on premiums, where longer coverage leads to higher premium due to uncertainty and climate risk can grow over-time.
Private_Insurance.insurance_premiums[Run]	Inflow	insurance_premium_rate*Finance.normal_investment*Government_Regulations.fraction_of_default_covered_by_private_insurance		b$/year	It represents the annual premium inflow into the private insurance reserve. Premiums are calculated from the insurance premium rate, normal investment, and the effective fraction of defaults covered by private insurance. Conceptually, the model treats premiums as the price paid for transferring climate-related default risk away from the banking system.
Private_Insurance.minimum_insurance_premium[Run]	Policy Parameter	0.001		dmnl	It represents the lower bound for the insurance premium rate. It prevents the premium from becoming unrealistically small, even when the insurance reserve is relatively strong. Its value is 0.001, meaning the minimum premium rate is 0.1% of normal investment once the policy is active.
Private_Insurance.normal_insurance_premium[Run]	Policy Parameter	0.005		dmnl	It is the baseline premium rate under normal conditions. Its value is 0.005, meaning the baseline premium is 0.5% of normal investment once the policy is active. This parameter acts as the central pricing anchor from which actual premiums move up or down depending on coverage conditions.
Private_Insurance.private_insurance_payouts[Run]	Outflow	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_private_insurance		b$/year	This variable is the annual payout from private insurance to cover the privately insured share of climate-caused risky defaults. It increases with climate-driven defaults and with the effective private insurance coverage fraction. The payout reduces the default signal entering lending standards, while also depleting the private insurance deposit stock.

Variable		Equation	Properties	Units	Documentation
Private_Insurance.relative_years_of_coverage[Run]	Variable	actual_years_of_coverage/ desired_years_of_coverage		dmnl	It normalizes actual years of coverage against desired years of coverage. A value of 1 means the insurance reserve is exactly at its target coverage level. Values below 1 indicate reserve pressure, while values above 1 indicate a stronger reserve position.
Private_Insurance.sensitivity_of_premiums_to_years_of_coverage[Run]	Policy Parameter	-1		dmnl	It controls how strongly premium pricing reacts to the insurer's relative coverage horizon. It determines the steepness of the premium response relative coverage. The value is set up as -1, meaning that the higher the relative years of coverage, the lower the effect of coverage adequacy on premium rate. The value -1 is an assumption, not an empirical practice. The direction of the relationship is consistent with OECD (2025), which discusses that higher losses and reinsurance pricing pressures can lead insurers to raise premiums or restrict coverage when risks become more severe or uncertain.
Government_Regulation.fraction_of_default_covered_private_insurance	Variable	decision_fraction_of_default_covered_by_private_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by private insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Finance.average_private_debt_safe_interest	Variable	SMTH1(Government.safe_interest, average_time_private_refinances_debt)		1/year	It represents the smoothed safe interest rate faced by private borrowers and lenders. It is based on the government safe interest rate but adjusts gradually over the average time private debt is refinanced. This smoothing reflects that private debt contracts do not instantly adjust to changes in policy or safe interest rates. In the private insurance structure, this rate determines the return earned by the insurance reserve when it is held in safe financial assets.
Finance.normal_investment	Variable	Bank_Investment-exploratory_bank_investment		b$/year	Normal investment is the total bank investment (energy and non-energy investment) excluding Exploratory investment.
Finance.total_climate_caused_risky_defaults	Variable	bad_loans_defaults*fraction_of_defaults_that_are_caused_by_climate		b$/year	It represents the total annual volume of risky-loan defaults in the economy that are specifically attributable to climate damage, and it is the loss base from which policy interventions are calculated.
Module: Economy - Central Banks Policies					
Sector: Central Bank Insurance					
Central_Bank_Policies.Central_Bank_insurance_payout[Run]	Inflow	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_central_bank_insurance		b$/year	This inflow represents the annual central bank payout used to cover the central-bank-insured share of climate-caused risky defaults. The payout increases when climate-caused risky defaults increase and when a larger share of default coverage is allocated to central bank insurance.

Variable		Equation	Properties	Units	Documentation
Central_Bank_Policies.deposit_earnings[Run]	Stock	Insurance_related_Central_Bank_Deposits*Government.safe_interest		b$/year	This inflow represents the annual return earned on the accumulated stock of insurance-related central bank deposits. The earnings increase when the central bank insurance deposit stock becomes larger or when the safe interest rate rises. Because insurance related CB deposit is treated as an accumulated stock and part of central banks' balance sheet assets, the model allows it to earn the safe interest rate rather than remaining passive.
Central_Bank_Policies.initial_Bank_owned_Central_Bank_Deposit	Policy Parameter	0		b$	It is the initial value of the insurance-related central bank deposit stock at the start of the simulation. This value is 0 b$, meaning the model represents no pre-existing central bank insurance intervention at the start of the simulation.
Central_Bank_Policies.Insurance_related_Central_Bank_Deposits[Run](t)	Inflow	Insurance_related_Central_Bank_Deposits[Run](t - dt) + (Central_Bank_insurance_payout[Run] + deposit_earnings[Run]) * dt	INIT Central_Bank_Policies.Insurance_related_Central_Bank_Deposits[Run] = initial_Bank_owned_Central_Bank_Deposit	b$	This stock represents the cumulative scale of central bank intervention through the insurance policy. This stock should not be interpreted as ordinary savings or an idle deposit account. Instead, it records how much central bank insurance intervention has accumulated over time. It increases through central bank insurance payouts and deposit earnings.
Government_Regulations.fraction_of_default_covered_central_bank_insurance	Variable	decision_fraction_of_default_covered_by_central_bank_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by central banks insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Finance.total_climate_caused_risky_defaults	Variable	bad_loans_defaults*fraction_of_defaults_that_are_caused_by_climate		b$/year	It represents the total annual volume of risky-loan defaults in the economy that are specifically attributable to climate damage, and it is the loss base from which policy interventions are calculated.
Government.safe_interest	Variable	Central_Bank_Safe_Interest		1/year	The safe interest rate is endogenous in the Government module. It is influenced by inflation and unemployment discrepancies through the central bank safe interest structure. rate is endogenous in the Government module. It is influenced by inflation and unemployment discrepancies through the central bank safe interest structure.
Module: Economy - Government					
Sector: Insurance Taxation Policy Structure					
Government.bounded_indicated_government_insurance_taxation_rate[Run]	Variable	MIN(MAX(indicated_government_insurance_taxation_rate, MIN_insurance_taxation_rate), MAX_insurance_taxation_rate)		1/year	It is the policy-recommended tax rate after applying lower and upper limits. This prevents unrealistic tax outcomes, such as negative taxation or excessively high tax rates.

Variable		Equation	Properties	Units	Documentation
Government.change_in_government_insurance_taxation_rate[Run]	Variable	IF Government_Regulations.fraction_of_default_covered_by_government_insurance > 0 THEN ((bounded_indicated_government_insurance_taxation_rate - government_insurance_taxation_rate) / taxation_rate_adjustment_time) ELSE ((0 - government_insurance_taxation_rate) / taxation_rate_adjustment_time)		1/year^2	It represents the rate of change in the actual government insurance taxation rate. When government insurance is active, it moves the actual tax rate toward the bounded indicated tax rate. When the policy is inactive, it gradually moves the tax rate back toward zero.
Government.Diagnostic_Government_Insurance_Reserve[Run](t)	Stock	Diagnostic_Government_Insurance_Reserve[Run](t - dt) + (revenue_from_tax_redemption[Run] - payout[Run]) * dt	INIT Government.Diagnostic_Government_Insurance_Reserve[Run] = 0	b$	This stock represents the cumulative balance between insurance tax revenue and government insurance payouts. This stock rises when taxes exceed payouts and falls when payouts exceed taxes. This is useful because it gives the model a reserve-gap indicator for tax adjustment. It is called "diagnostic" because it does not constrain government spending and it is not the real reserve. It only records what the balance would be if the insurance tax were a dedicated funding stream.
Government.government_insurance_reserve_gap[Run]	Variable	target_reserve_gap-Diagnostic_Government_Insurance_Reserve		b$	It represents the difference between the target reserve position and the current diagnostic government insurance reserve. A positive gap means the diagnostic reserve is below target and the insurance tax rate should rise. A negative gap means the reserve is above target and the tax rate can ease.
Government.government_insurance_taxation_rate[Run](t)	Stock	government_insurance_taxation_rate[Run](t - dt) + (change_in_government_insurance_taxation_rate[Run]) * dt	INIT Government.government_insurance_taxation_rate[Run] = 0	1/year	This stock is the actual implemented insurance tax rate applied to owner savings. It is modeled as a stock because tax policy does not adjust instantly to the desired rate. Instead, it changes gradually over the taxation-rate adjustment time.
Government.indicated_government_insurance_taxation_rate[Run]	Variable	(government_insurance_payout+reserve_correction_flow)/ MAX(Circular_Flow.owner_savings, 0.000001)		1/year	It represents the desired insurance tax rate implied by current payout needs and the diagnostic reserve gap. It shows what tax rate would be needed to finance current government insurance obligations and gradually correct the reserve position. If the reserve gap is positive, the indicated rate rises, but if the reserve position is stronger than needed, the indicated rate falls.
Government.MAX_insurance_taxation_rate[Run]	Policy Parameter	0.02		1/year	It is the upper bound parameter with value of 0.02, or 2% of owner savings per year. Global tax cooperation frameworks, such as the 2024 G20 proposal for a coordinated tax on the ultra-wealthy, identify 2% of net wealth as a feasible annual standard to address regressive taxation and mobilize resources for social stability (Zucman, 2024). Additionally, wealth tax is 5% and we are using half of it.

Variable		Equation	Properties	Units	Documentation
Government.MIN_insurance_taxation_rate[Run]	Policy Parameter	0.001		1/year	It is a lower-bound parameter with value of 0.001, or 0.1% of owner savings per year. This ensures that the tax rate does not collapse to an unrealistically small when the policy is active. This is an exploratory lower-bound assumption.
Government.payout[Run]	Outflow	government_insurance_payout		b$/year	It is the outflow from the diagnostic reserve stock, and it is equal to government insurance payout, and captures the expenditure side of the government insurance mechanism.. If payout is larger than revenue for a long time, the diagnostic reserve will trend downward, indicating under-taxation relative to insurance burden.
Government.reserve_correction_flow[Run]	Variable	government_insurance_reserve_gap/reserve_correction_time		b$/year	It is the correction setting used when reserve gap are larger or when a quicker response is needed. It represents he annual amount of funding correction needed to close the government insurance reserve gap gradually. This variable translates the reserve gap into a tax-adjustment signal.
Government.reserve_correction_time[Run]	Policy Parameter	5		Year	It is a parameter representing the adjustment time used to close the diagnostic reserve gap. A shorter value makes the government respond faster to reserve shortfalls, while a longer value makes tax adjustment more gradual. IMF guidance argues that medium-term fiscal frameworks generally manage revenue, expenditure, and debt over a 3 to 5-year period (IMF, 2024). Similarly, OECD describes medium-term budgeting as multi-year budgeting, usually over 3-5 years (OECD, 2025). Therefore, 5 years is used as an adjustment period.
Government.revenue_from_tax_redemption[Run]	Outflow	insurance_tax_redemption		b$/year	This variable represents the annual inflow into the diagnostic government insurance reserve from insurance tax revenue. It is equal to insurance tax redemption and shows how much dedicated insurance-tax funding is collected each year.
Government.target_reserve_gap	Policy Parameter	0		b$	It is the desired benchmark for the government insurance reserve gap. In this model, the target is set to zero, meaning the government aims for insurance tax revenue to broadly cover insurance payouts over time without building a large positive reserve.
Government.taxation_rate_adjustment_time[Run]	Policy Parameter	2		years	It represents the time required for the actual government insurance taxation rate to adjust toward the bounded indicated tax rate. It captures administrative, institutional, and political delays in implementing tax changes. The taxation rate adjustment time is set to 2 years, meaning the actual tax rate gradually moves towards the desired bounded tax rate over approximately 2 years.

Variable		Equation	Properties	Units	Documentation
Module: Economy - Government					
Government.government_insurance_payout[Run]	Inflow	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_government_insurance		b$/year	This variable is the annual government payout used to cover the government-insured share of climate-caused risky defaults. It reduces the perceived default burden in the banking system but also creates fiscal implications because government insurance is financed through taxation and debt dynamics.
Government.insurance_tax_redemption[Run]	Outflow	Circular_Flow.insurance_taxation		b$/year	It represents the insurance tax revenue collected from the Circular Flow module. This variable is the fiscal funding stream for government insurance. It reduces government debt and also enters the diagnostic insurance reserve as revenue.
Government_Regulations.fraction_of_default_covered_by_government_insurance	Variable	decision_fraction_of_default_covered_by_government_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by government insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Circular_Flow.insurance_taxation	Variable	IF Government_Regulations.fraction_of_default_covered_by_government_insurance > 0 THEN Government.government_insurance_taxation_rate * owner_savings ELSE 0		b$/year	It represents the annual insurance tax collected from owner savings in the Circular Flow module. This outflow reduces owner savings and becomes insurance tax redemption in the Government module. This means the tax is levied as a percentage of owner wealth after the policy starts and is zero before then.
Finance.total_climate_caused_risky_defaults	Variable	bad_loans_defaults*fraction_of_defaults_that_are_caused_by_climate		b$/year	It represents the total annual volume of risky-loan defaults in the economy that are specifically attributable to climate damage, and it is the loss base from which policy interventions are calculated.
Government.Government_Debt[Run](t)	Stock	Government_Debt[Run](t - dt) + (government_taking_up_debt[Run] + government_insurance_payout[Run] + bailouts[Run] - insurance_tax_redemption[Run]) * dt	INIT Government.Government_Debt[Run] = initial_government_debt	B$	It is the stock, representing the accumulated stock of public debt. In insurance policy structure, government debt increases when government insurance payouts are made and decreases when insurance tax redemption is collected. This captures the fiscal trade-off of government-funded insurance.
Government.bailouts[Run]	Inflow	bank_bailouts		b$/year	It represents government spending used to support banks when bank solvency support is required. This variable is part of the broader government debt structure and adds to government debt when bank bailouts occur.
Government.government_taking_up_debt[Run]	Inflow	public_expenditure - total_public_tax_income		b$/year	It represents the annual increase in government debt from ordinary fiscal imbalance, calculated from public expenditure minus total public tax income. It is part of the existing government debt structure.

Variable		Equation	Properties	Units	Documentation
Module: Economy - Circular Flow					
Sector: Government Insurance Taxation to Owner Saving					
Circular_Flow.insurance_taxation	Inflow	IF Government_Regulations.fraction_of_default_covered_by_government_insurance > 0 THEN Government.government_insurance_taxation_rate * owner_savings ELSE 0		b$/year	It represents the annual insurance tax collected from owner savings in the Circular Flow module. This outflow reduces owner savings and becomes insurance tax redemption in the Government module. This means the tax is levied as a percentage of owner wealth after the policy starts and is zero before then.
Government.government_insurance_taxation_rate	Variable	government_insurance_taxation_rate[Run](t - dt) + (change_in_government_insurance_taxation_rate[Run]) * dt	INIT Government.government_insurance_taxation_rate[Run] = 0	1/year	This stock is the actual implemented insurance tax rate applied to owner savings. It is modeled as a stock because tax policy does not adjust instantly to the desired rate. Instead, it changes gradually over the taxation-rate adjustment time.
Government_Regulation.fraction_of_default_covered_by_government_insurance	Variable	decision_fraction_of_default_covered_by_government_insurance//total_insurance_coverage*fraction_of_loan_insured		dmnl	This variable represents the effective fraction of climate-caused risky defaults that is actually covered by government insurance after applying the policy coverage level and the normalization of institutional decision fractions.
Circular_Flow.owner_savings	Stock	owner_savings[Run](t - dt) + (non_bank_profits[Run] + owner_savings_interest[Run] + bank_profits[Run] + rent[Run] - owner_consumption[Run] - profit_tax[Run] - rent_tax[Run] - wealth_tax[Run] - insurance_taxation[Run]) * dt	INIT Circular_Flow.owner_savings[Run] = initial_owner_savings	b$	It represents the stock of accumulated savings held by owner households. In the government insurance structure, owner savings are used as the tax base for the insurance taxation mechanism.
Module: Economy - Finance					
Sector: Impact of Insurance Policy to the perceived risky assets defaults					
Finance.perceived_defaults_of_risky_assets_for_lending_standards	Variable	SMTH1(total_risky_asset_defaults - (Private_Insurance.private_insurance_payouts +Central_Bank_Policies.Central_Bank_insurance_payout + Government.government_insurance_payout), reporting_delay)		b$/year	This variable represents the amount of risky-asset defaults that banks perceive when deciding whether to tighten or loosen lending standards. Its equation takes actual risky defaults, subtracts insurance coverage, and then smooths the result through a reporting delay (using SMTH1). This smoothing reflects that banks and markets do not respond instantly to default information. Even if individual banks observe their own loan failures, the broader financial system needs time to recognize, report, interpret, and act on aggregate default conditions.

Variable		Equation	Properties	Units	Documentation
Private_Insurance.insurance_payouts	Variable	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_private_insurance		b$/year	This variable is the annual payout from private insurance to cover the privately insured share of climate-caused risky defaults. It increases with climate-driven defaults and with the effective private insurance coverage fraction. The payout reduces the default signal entering lending standards, while also depleting the private insurance deposit stock.
Central Bank Policies.Central Bank insurance payouts	Variable	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_central_bank_insurance		b$/year	This inflow represents the annual central bank payout used to cover the central-bank-insured share of climate-caused risky defaults. The payout increases when climate-caused risky defaults increase and when a larger share of default coverage is allocated to central bank insurance.
Government.government_insurance_payout	Variable	Finance.total_climate_caused_risky_defaults * Government_Regulations.fraction_of_default_covered_by_government_insurance		b$/year	This variable is the annual government payout used to cover the government-insured share of climate-caused risky defaults. It reduces the perceived default burden in the banking system but also creates fiscal implications because government insurance is financed through taxation and debt dynamics.
Module: Economy - Finance					
Finance.total_risky_asset_defaults	Variable	bad_loans_defaults + risky_asset_interest_defaults		b$/year	It represents the total annual defaults from risky bank assets. It combines defaults from maturing bad loans and defaults caused by increases in risky interest rates. This variable is used as the raw risky-default signal before insurance payouts and reporting delays are applied. In the insurance policy structure, it is the starting point for calculating perceived defaults used in lending standards and risk-premium adjustment.
Finance.measured_default_rate_of_risky_assets_for_lending_standards	Variable	(perceived_defaults_of_risky_assets_for_lending_standards/risky_bank_assets)		1/year	It represents the perceived risky-default rate used by banks when adjusting lending standards. It converts perceived risky defaults from a flow in b$/year into a default rate relative to risky bank assets. In other words, instead of reacting to defaults in absolute b$/year, banks react to a normalized measure of how severe risky defaults are relative to the relevant risky-asset base.
Finance.perceived_defaults_of_risky_assets_for_interest_rate	Variable	SMTH1(total_risky_asset_defaults-(Private_Insurance.private_insurance_payouts + Central_Bank_Policies.Central_Bank_insurance_payout + Government.government_insurance_payout) *fraction_of_insurance_payouts_not_influencing_risk_premium, reporting_delay)		b$/year	This variable measures the perceived risky-default flow used to adjust the risk premium on risky loans. Insurance payouts reduce this signal only partially, through fraction_of_insurance_payouts_not_influencing_risk_premium. This reflects the assumption that insurance dampens credit-risk perception but does not make risky lending risk-free.

Variable		Equation	Properties	Units	Documentation
Finance.fraction_of_insurance_payouts_not_influencing_risk_premium	Variable	Government_Regulations.fraction_of_loan_insured		dmnl	This variable defines how much of the insurance payout is excluded from the default signal used for risk-premium adjustment. It is equal to fraction of loan insured, meaning that higher insurance coverage makes insurance more relevant for reducing perceived credit risk. The variable ensures that insurance dampens risk pricing but does not completely eliminate the risk premium.
Finance.Bank_Assets	Variable	Safe_Loans +Bad_Loans +Good_Loans +Exploratory_Loans +safe_loans_for_financing_innovation +Government.Government_Debt +Central_Bank_Policies.Insurance_related_Central_Bank_Deposits +Central_Bank_Policies.Investment_related_Central_Bank_Deposits		b$	It represents the total assets held by the banking system. It includes safe loans, good loans, bad loans, exploratory loans, innovation-related safe loans, government debt, and central-bank-related deposit assets.
Finance.Bank_Liabilities	Variable	Circular_Flow.Worker_Savings+Circular_Flow.owner_savings+Circular_Flow.Firms_Checking_Accounts + Private_Insurance.Insurance_Deposits		b$	It represents the total liabilities of the banking system. It includes worker savings, owner savings, firms' checking accounts, and private insurance deposits.
Finance.assets_to_liability_ratio	Variable	Bank_Assets/Bank_Liabilities		dmnl	It represents the ratio between bank assets and bank liabilities. It is used as an indicator of bank solvency and balance-sheet strength, influencing whether banks feel pressure to contract or expand investment.
Module: Economy - GDP					
Sector: Objective Function Maximize Discounted Real GDP Utility Score					
GDP.Cumulative_Discount_Exponent[Run](t)	Stock	Cumulative_Discount_Exponent[Run](t - dt) + (discount_rate_accumulation[Run]) * dt	INIT GDP.Cumulative_Discount_Exponent[Run] = 0	dmnl	It represents the accumulated amount of discounting since the objective evaluation start year. This stock converts the annual discount rate into a cumulative discounting process over time. Initial value is 0 because there is no discounted accumulated yet. Because safe interest rate is dynamic, it changes over time in the model. This stock answers: "How much total discounting has built up since 2030/ welfare start year?"
GDP.discount_factor[Run]	Variable	EXP(-Cumulative_Discount_Exponent)		dmnl	It represents the weight applied to future Real GDP utility. The value starts at 1 when discounting begins and declines over time as the cumulative discount exponent increases. A lower discount factor means that future utility contributes less to the objective score. This gives the shrinking weight over time: at 2030, factor = 1. Later, factor gets smaller so later welfare counts less.

Variable		Equation	Properties	Units	Documentation
GDP.discount_rate_accumulation[Run]	Inflow	IF TIME >= objective_evaluation_start_year THEN ramp_discount_rate ELSE 0		dmnl/year	It represents the annual inflow into the cumulative discount exponent. It is active only after the objective evaluation start year and accumulates the discount rate over time. Before 2030, no welfare discounting and from 2030 onward, discount using the ramp discount rate.
GDP.discounted_Real_GDP_utility_change[Run]	Inflow	IF TIME >= objective_evaluation_start_year THEN (instantaneous_Real_GDP_utility*discount_factor) / time_unit_correction ELSE 0		dmnl/year	It represents the annual contribution of Real GDP utility to the objective score after applying the discount factor. This is the flow that accumulates into the Discounted Real GDP Utility Score.
GDP.Discounted_Real_GDP_Utility_Score[Run](t)	Stock	Discounted_Real_GDP_Utility_Score[Run](t - dt) + (discounted_Real_GDP_utility_change[Run]) * dt	INIT GDP.Discounted_Real_GDP_Utility_Score[Run] = 0	dmnl	It represents the accumulated discounted Real GDP utility from the objective evaluation start year to the end of the simulation. The final value of this stock is used as the objective function for comparing and optimizing policy runs.
GDP.fixed_discount_rate	Objective Fuction Parameter	0.025		dmnl/year	It represents the initial discount rate used to value future Real GDP utility. It gives lower weight to benefits occurring further in the future and acts as the starting point for the declining discount-rate path. It is set at 2.5% per year. As reference, the UK Green Book describes the discount rate as the Social Time Preference Rate, reflecting the concept that people generally prefer benefits sooner rather than later (HM Treasury, 2026). The Green Book also uses a declining discount-rate schedule for long-term appraisal, falling from 3.5% in years 1–30, to 3.0% in years 31–75, and 2.5% from year 76 onward.
GDP.instantaneous_Real_GDP_utility[Run]	Variable	LN(MAX(Real_GDP_in_2021c$, 1e-06))		dmnl	It represents the utility value of real GDP in a given year. It uses a logarithmic function so that higher GDP still increases utility, but each additional unit of GDP contributes less when GDP is already high.
GDP.objective_evaluation_start_year	Objective Fuction Parameter	2030		Year	It represents the year when the policy objective starts being evaluated. Before this year, the objective function does not accumulate discounted Real GDP utility. In this thesis, it is set to 2030 to begin evaluation after the policy implementation period starts.
GDP.ramp_converter	Objective Fuction Parameter	0.000155		1/year^2	It represents the rate at which the discount rate declines over time after the objective evaluation start year. A higher value makes the discount rate fall faster, while a lower value creates a more gradual decline. This value is not interpreted as a direct empirical estimate, but as a modeling coefficient used to implement a gradual declining discount-rate path over the policy evaluation period. Starting from a fixed discount rate of 2.5% in 2030, this converter reduces the discount rate by 0.0155 percentage points per year, reaching approximately 1.4% by 2100.

Variable		Equation	Properties	Units	Documentation
GDP.ramp_discount_rate	Variable	fixed_discount_rate - RAMP(ramp_converter, objective_evaluation_start_year)		dmnl/year	It represents the time-varying discount rate used in the objective function. It starts from the fixed discount rate and gradually declines over time according to the ramp converter after the objective evaluation start year.
GDP.time_unit_correction	Objective Fuction Parameter	1		Year	It represents the unit-conversion factor used to keep the discounted Real GDP utility accumulation dimensionally consistent over time. It ensures that the annual utility flow can be accumulated properly in the stock.
GDP.Real GDP in 2021c$	Variable	Nominal_GDP/Inflation.inflation_adjustment_b$_per_bc$		bc$/year	It represents real GDP measured in constant 2021 dollars. This variable removes inflation effects and provides the real economic-output value used as the basis for calculating Real GDP utility.

2. Insurance-Related Parameter Assumptions

Policy Parameters	Tag	Unit	Value	Min	Max	References/ Notes
Private Insurance-Related Parameters						
desired years of coverage	Assumption	years	4	1	6	It is consistent with regulatory discussion that insurers maintain multi-year capital buffers under repeated shocks (IAIS, 2024) . Additionally, London School of Economics research explores 'long-term insurance' solvency terms from 3 to 25 years (London School of Economics (LSE). (2011). WP62: What role for 'long-term' insurance in adaptation? An analysis of the prospects for and pricing of multi-year insurance).
sensitivity of premiums to years of coverage	Assumption	dmnl	-1	-2	-0.2	The value -1 is an assumption, not an empirical practice. The direction of the relationship is consistent with OECD (2025), which discusses that higher losses and reinsurance pricing pressures can lead insurers to raise premiums or restrict coverage when risks become more severe or uncertain.
normal insurance premium	Assumption	dmnl	0.005	0.002	0.02	Credit-guarantee schemes provide relevant empirical references: a World Bank review reports (Levitsky & Prasad, 1989) guarantee fees of 0.5% per annum on the outstanding loan amount, while the Hong Kong SME Financing Guarantee Scheme (HKMC, 2010) used a minimum annual guaranteed fee of 0.5% p.a. with guaranteed coverage of 50–70% of bank financing.
minimum insurance premium	Assumption	dmnl	0.001	0.001	0.002	Credit-risk-sharing examples, such as the INOSTART programme in Lithuania, reported by the European Association of Guarantee Institutions, used a 0.1% annual guarantee fee for innovative projects (AECM, 2022) . Although is not a climate-default insurance scheme, it provides a reference of a low guaranteed fee used in a credit-risk-sharing instrument.
decision fraction of default covered by private insurance	Policy	dmnl	0.47	0	1	

Policy Parameters	Tag	Unit	Value	Min	Max	References/ Notes
Central Bank Insurance-Related Parameters						
decision fraction of default covered by central bank insurance	Policy	dmnl	0.23	0	1	
Government Insurance-Related Parameters						
target reserve gap	No Sensi	b$	0	0	0	This means the government aims for insurance tax revenue to broadly cover insurance payouts over time, but it is not trying to build a large positive reserve
reserve correction time	Assumption	year	5	2	10	IMF guidance argues that medium-term fiscal frameworks generally manage revenue, expenditure, and debt over a 3 to 5-year period (IMF, 2024). Similarly, OECD describes medium-term budgeting as multi-year budgeting, usually over 3-5 years (OECD, 2025).
MIN insurance taxation rate	Assumption	1/year	0.001	0.001	0.005	Norway's net wealth tax rate was reported at 0.85%, while Spain's progressive wealth-tax rates ranged from 0.2% to 2.5%. Therefore, 0.1% is below common observed wealth-tax rates and can be interpreted as a modest minimum contribution from the owner-savings tax base (Drometer et al., 2018)
MAX insurance taxation rate	Assumption	1/year	0.02	0.01	0.05	Global tax cooperation frameworks, such as the 2024 G20 proposal for a coordinated tax on the ultra-wealthy, identify 2% of net wealth as a feasible annual standard to address regressive taxation and mobilize resources for social stability (Zucman, 2024)
taxation rate adjustment time	Assumption	years	2	1	5	OECD reform guidance notes that reform timelines should account for administrative approvals, financing, procurement procedures, and legal changes, and that unrealistic timeframes should be avoided. The same guidance states that reform programs are typically managed over a 3-5 year horizon, while shorter reforms below three years can still be implemented when the same structured steps are followed. (OECD, 2024)
decision fraction of default covered by government insurance	Policy	dmnl	0.0	0	1	
Policy Regulation						
insurance coverage level	Policy	dmnl	70	1	70	This value should not be interpreted as an empirical claim of 70% coverage in real-world, Instead, it is as an upper-bound exploratory assumption to test the maximum stabilizing effect of insurance. Additionally, full coverage (100%) will lead to a classic moral-hazard problem in insurance: when an actor is fully protected from losses, it may take less care to avoid or reduce risk (J. E. Stiglitz, 1983; J. Stiglitz & Yun, 2013)
insurance coverage second level	Policy for dynamic scenario	dmnl	20	1	70	
insurance coverage start year	Policy	year	2035.26	2030	2100	
insurance coverage time to implement	Policy	year	1	1	20	
insurance coverage time to implement second level	Policy for dynamic scenario	year	5	1	20	
insurance coverage time to start second level	Policy for dynamic scenario	year	50	1	70	

3. Policy Optimization Result

The following table presents the Stella optimization results for the combined-funding insurance policy.

Starting optimization "Optimization Insurance to Discounted Real GDP Utility Score" at 2026-Apr-13 13:21:54

Method	tolerance	init_step	maxiter
Powell	0.00001	1	0

Payoff:	**Payoff Discounted Real GDP Utility Score**
Action	maximize
Kind	Outcome Optimization
Element	GDP.Discounted Real GDP Utility Score[1]
Weight	1
Time Range	Final value

Parameter:	Government Regulations.decision fraction of default covered by private insurance	Government Regulations.decision fraction of default covered by central bank insurance	Government Regulations.decision fraction of default covered by government insurance	Government Regulations.insurance coverage first level	Government Regulations.insurance coverage start year first level	Government Regulations.insurance coverage time to implement first level
min_value	0	0	0	0	2030	1
max_value	1	1	1	70	2100	20
scaling	100	100	100	1	1	1

	Government Regulations.decision fraction of default covered by private insurance	Government Regulations.decision fraction of default covered by central bank insurance	Government Regulations.decision fraction of default covered by government insurance	Government Regulations.insurance coverage first level	Government Regulations.insurance coverage start year first level	Government Regulations.insurance coverage time to implement first level	**Payoff Discounted Real GDP Utility Score**
Starting at	0.25	0.25	0.25	**20**	2,030	5	**454.81**
After 1328 runs	0.528800338	0.263893672	0	70	2,035.26	1	**461.03**
	Government Regulations.fraction of default covered by private insurance	Government Regulations.fraction of default covered by central bank insurance	Government Regulations.fraction of default covered by government insurance				
Normalized fraction	**0.466965**	**0.233035**	**0**				

Finishing optimization at 2026-Apr-13 13:28:48

This thesis also explored an optimization setup with a dynamic policy structure, where insurance coverage could vary over time. However, after several explorations, the optimization results suggested that the optimal policy maintains the same coverage level from the policy start year until the end of the simulation period. The following Stella's results shows one of optimization run with a dynamic policy structure.

Starting optimization "Optimization Insurance to Discounted Real GDP Utility Score" at 2026-Apr-13 12:45:26

Method	maxiter	init_step	tolerance
Powell	0	1	0.00001

Payoff:	**Payoff Discounted Real GDP Utility Score**
Action	maximize
Kind	Outcome Optimization
Element	GDP.Discounted Real GDP Utility Score[1]
Weight	1
Time Range	Final value

Parameter:	Government Regulations.decision fraction of default covered by private insurance	Government Regulations.decision fraction of default covered by central bank insurance	Government Regulations.decision fraction of default covered by government insurance	Government Regulations.insurance coverage first level	Government Regulations.insurance coverage start year first level	Government Regulations.insurance coverage time to implement first level	Government Regulations.insurance coverage second level	Government Regulations.insurance coverage time to start second level	Government Regulations.insurance coverage time to implement second level
min_value	0	0	0	0	2030	1	0	1	1
max_value	1	1	1	70	2100	20	70	70	20
scaling	100	100	100	1	1	1	1	1	1

	Government Regulations.decision fraction of default covered by private insurance	Government Regulations.decision fraction of default covered by central bank insurance	Government Regulations.decision fraction of default covered by government insurance	Government Regulations.insurance coverage first level	Government Regulations.insurance coverage start year first level	Government Regulations.insurance coverage time to implement first level	Government Regulations.insurance coverage second level	Government Regulations.insurance coverage time to start second level	Government Regulations.insurance coverage time to implement second level	**Payoff Discounted Real GDP Utility Score**
Starting at	0.25	0.25	0.25	**20**	2,030	5	**20**	**50**	5	**454.807**
After 2210 runs	0.313867234	0.04254423	0	70	2,035.27	1	19.46821037	65.49685728	1.527158259	**461.057**

100,000-runs Uncertainty Test

Figures 33 and 34 compare the full-scale uncertainty results for the baseline scenario without policy (P0) and the optimized insurance policy scenario (P5) to assess whether P5 remains effective taking into account the full uncertainty of the model. In both P0 and P5 the parameters were varied identically to ensure direct comparability.

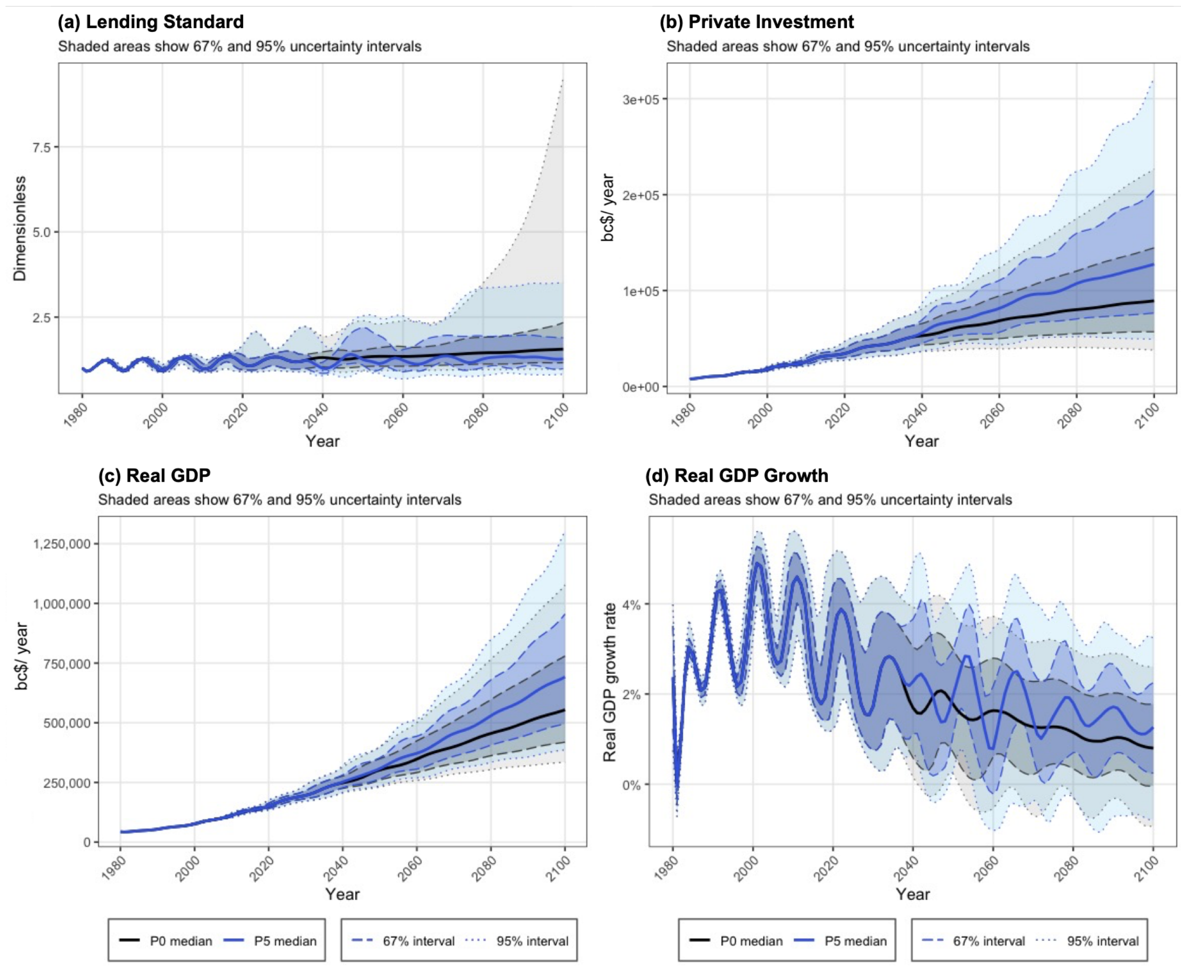


Figure 1: Full-scale uncertainty ensemble comparing the baseline scenario without policy (P0) and the optimized insurance policy scenario (P5). The plots show: (a) Lending Standard (unit: dmnl), (b) Private Investment and (c) Real GDP which are using a constant 2021$ (unit: 2021$ billion/year), and (d) Real GDP Growth (unit: 1/year). Shaded blue area and line refer to P5 while gray area and black line refer to P0.

Figure 33a shows lending standards. In the baseline scenario, the uncertainty interval is very wide over time, meaning that under some parameter combinations, the climate-finance feedback can generate very high lending standards in the long run. In contrast, when P5 is implemented, both median and upper uncertainty range are lower, with uncertainty interval is also more compressed. It means that the policy reduces the risk of extreme lending-tightening outcomes, and a more compressed interval means that lending standards are less sensitive to uncertain parameter combinations when the optimized policy is active.

Figure 33b shows private investment. Under P5, the median and uncertainty intervals shift upward compared with P0. This means that the optimized policy improves investment across the ensemble, not only in one deterministic run. Furthermore, it also indicates that even less favorable parameter combinations still produce stronger investment outcomes under P5 than under the baseline.

Figures 33c and 33d show real GDP and real GDP growth. In Figure 33c, P5 shifts the real GDP median and interval upper-lower bound higher, meaning that the optimized policy increases GDP output across the ensemble. However, the uncertainty interval remains wide, especially later in the simulation. This indicates that long-run GDP remains sensitive to broader model uncertainty even when the optimized policy is active. Figure 33d shows that the median real GDP growth rate under P5 is higher than under P0, especially in later simulation. This means that the optimized policy reduces the extent to which climate-financial instability weakens long-run growth. However, the P5 (blue) uncertainty interval is seen wider than the P0 interval. This means that P5 does not eliminate growth uncertainty. By reducing lending standard tightening and supporting higher investment, P5 also makes growth more responsive to future uncertain assumptions about investment, defaults, productivity, inflation, and other macroeconomic variables.

Figure 34, then, shows the uncertainty in a broader range of macroeconomic indicators: government debt, debt-to-GDP ratio, inflation, unemployment, and labour share of GDP.

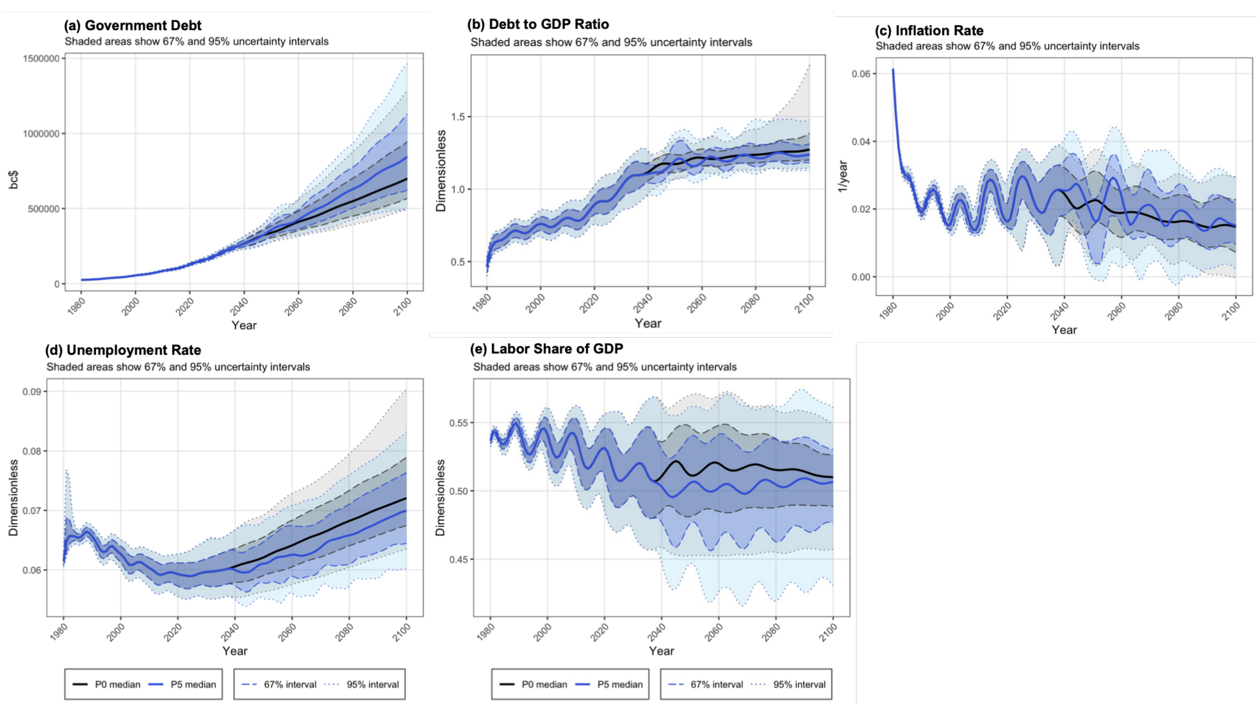
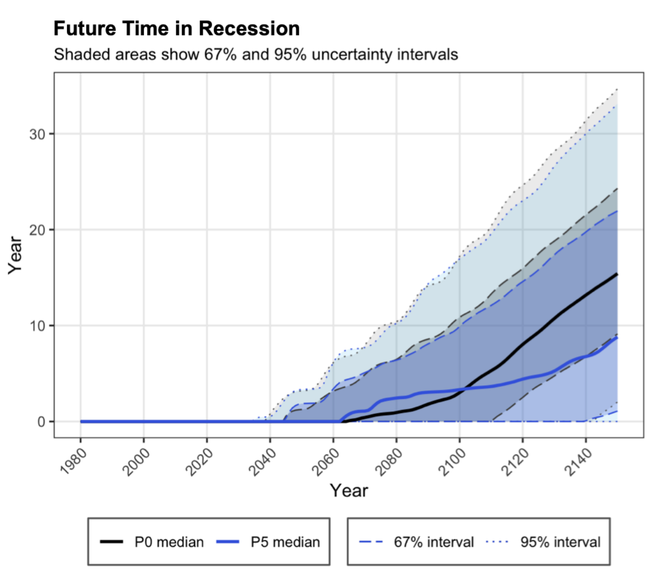


Figure 2: Full-scale uncertainty ensemble comparing the baseline scenario without policy (P0) and the optimized insurance policy scenario (P5). The plots show: (a) Government debt (using a constant 2021$, unit: 2021$ billion/year), (b) Debt-to-GDP ratio, (c) Inflation Rate (Unit: 1/year), (d) Unemployment rate (unit: 1/year), and (e) Labor Share of GDP growth (unit: dimensionless). Shaded blue area and line refer to P5 while gray area and black line refer to P0.

Figure 34a shows that long-run government debt is higher in P5 across the uncertainty ensemble. This result indicates a macroeconomic trade-off of the optimized policy. When P5 increases investment and the economy scale, the policy interacts with fiscal flows, debt accumulation, public expenditure, and interest payments, which contribute to higher public debt. Figure 34b shows that despite higher absolute debt under P5, debt-to-GDP ratio does not increase strongly relative to P0. This means that P5's debt burden relative to GDP remains broadly comparable within the uncertainty ensemble.

Figure 34c shows that the median inflation path is broadly similar to P0, and the uncertainty ranges overlap. This result suggests that while P5 eases lending tightening and improves investment, inflation remains sensitive to model uncertainty because stronger investment interacts with employment, productivity, interest rates, and default adjustment delays, which can affect inflation dynamics.

Figure 34d shows that across the ensemble, P5 reduces the risk of unemployment in the future under uncertain parameter combinations. It is shown by a lower median line, and interval range is sifted down under P5 compared with under P0. As explained before, with higher investment, it supports more desired hiring and labour demand. Meanwhile, Figure 34e shows that under P5, labour share of GDP is lower in the median, but the uncertainty interval is wider. This means that the distributional effect of the optimized policy is more sensitive to parameter uncertainty. With more investment, P5 raises GDP through stronger firms' cash inflow, investment, profits, rent, bank profits, and owner-income channels. Wages also benefit indirectly through higher employment, but they adjust through employment and but they do not necessarily rise as fast as total GDP and owner income. As a result, aggregate output increases more strongly than aggregate wages in many runs, lowering the labour share.



Additionally, Figure 35 shows the uncertainty range for future time in recession . In scenario P5, the median line is lower than in P0 although the uncertainty range is still wide. This indicates that the optimized policy reduces the risk of futures with prolonged recession periods because P5 weakens the persistent financial instability that contributes to repeated or extended recessionary periods and improves the GDP.

Figure 3: Full-scale uncertainty ensemble comparing the baseline scenario without policy (P0) and the optimized insurance policy scenario (P5). The plots show Future Time in Recession. Shaded blue area and line refer to P5 while gray area and black line refer to P0.

Taken together, the full-scale ensemble supports the interpretation that P5 weakens the climate-finance default loop within the tested uncertainty space. P5 continues to move the system in the expected direction: it lowers lending-standard pressure, supports higher private investment, increases real GDP, and reduces the risk of high unemployment and recession times compared with the baseline scenario.