Modelling Resiliency Against the Unknown: Theory and Practice

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Stating the Problem

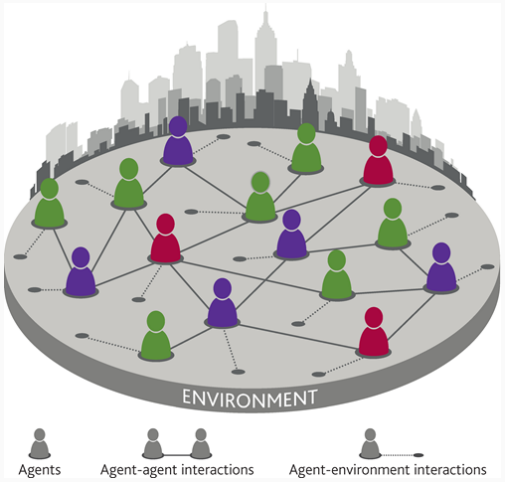
- How to prepare for the next crisis when we do not know what the source is?
- Introduce institutional and social factors into a theoretical economical system.
  (Mathematical simulation model)
- How to determine the trade-off between resilience and efficiency?

Stating the Problem

- Crises are low frequency
- Not entirely random events (e.g. Credit booms tend to precede crises)
- Not necessarily triggered by large shocks
- High cost with unforeseen timing (Deeper recessions than normal)

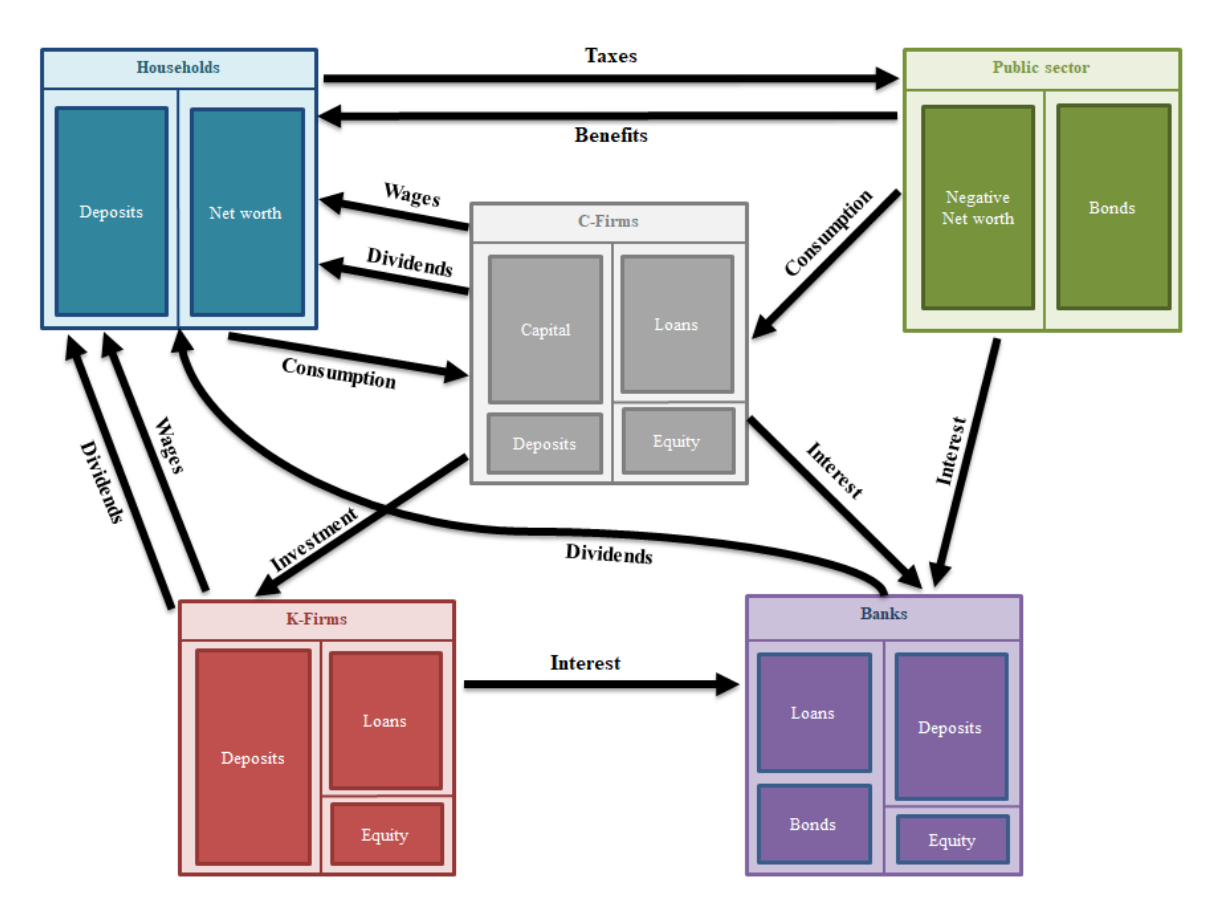
Calls for complex model!

- Preparation for or response to crises requires reallocation of resources.
- How to incorporate social factors into macroeconomic model?
- Crises call for complex systems approach (MABM)
- Two directions: Practical and Epistemological



Applied project

Use a pre-existing macro-ABM to simulate some (stylised) conceivable crisis scenarios & policy responses



Key features:

- Largely Keynesian/demand-driven but potential supply-side constraints
- Heuristic behavioural rules
- Role for credit & banking
- Markets based on search & matching
- Stationary in real dimension; endogenous fluctuations
- Comparatively simple & easy to extend

Crises:

- Pandemic-like
- Natural disaster
- Credit crisis (triggered endogenously)

Policies:

- UBI & macro-prudential (continuous)
- Furlough scheme, income support, credit guarantees, debt relief (one-off)

Consider 2 scenarios:

- Single crisis for detailed examination
- Multiple crises to address question of resilience

Scenario 1: Simulating Effects of Specific Crisis Scenarios

- Exogenous **pandemic** at $t = 0$, succeeded by
- Endogenous **credit crisis** (triggered in 49% of simulations).

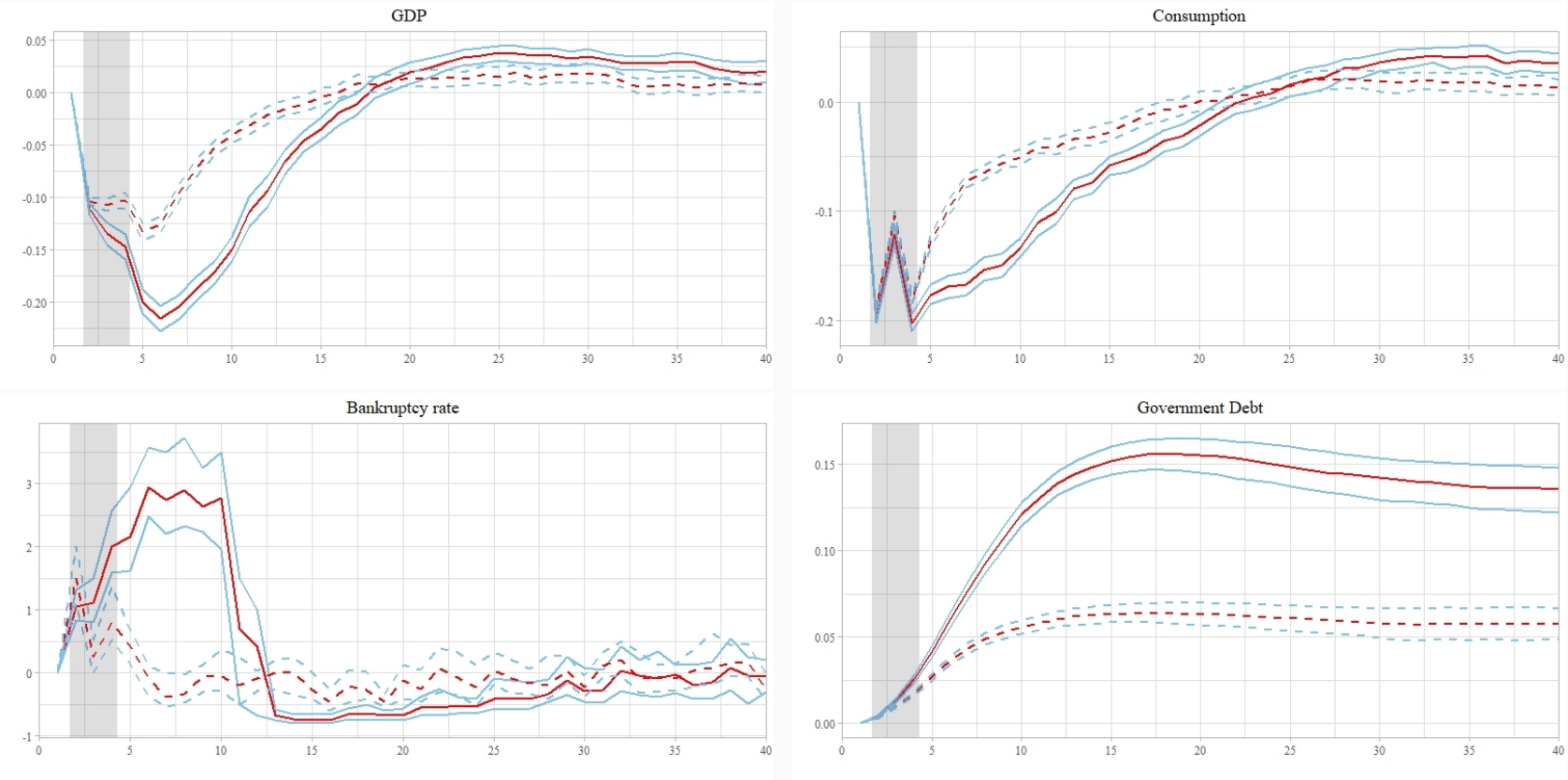


Figure 1: Crisis effect on the state of the economy with (solid) and without (dashed) endogenous credit crisis.

Scenario 1: Effect of Income Support

- Simulation frequency of credit crisis decreases: 49% $\rightarrow$ 19%
- Smaller recession and faster recovery

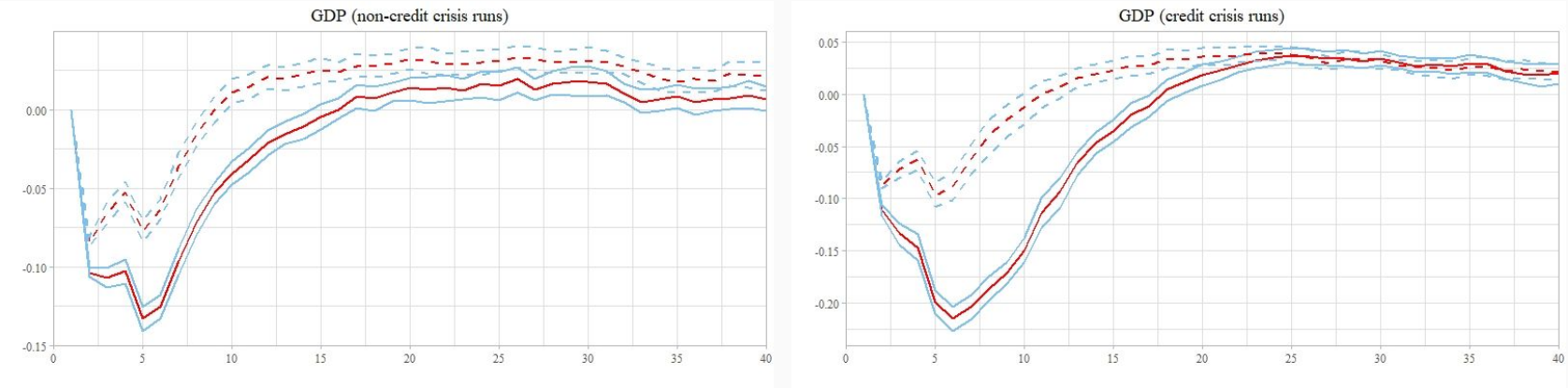


Figure 2: Effect on GDP without (left) and with (right) previous credit crisis with (dashed) and without (solid) income support

Scenario 1: Effect of Credit Guarantees

- Simulation frequency of credit crisis decreases: 49% $\rightarrow$ 17%
- Smaller recession and faster recovery

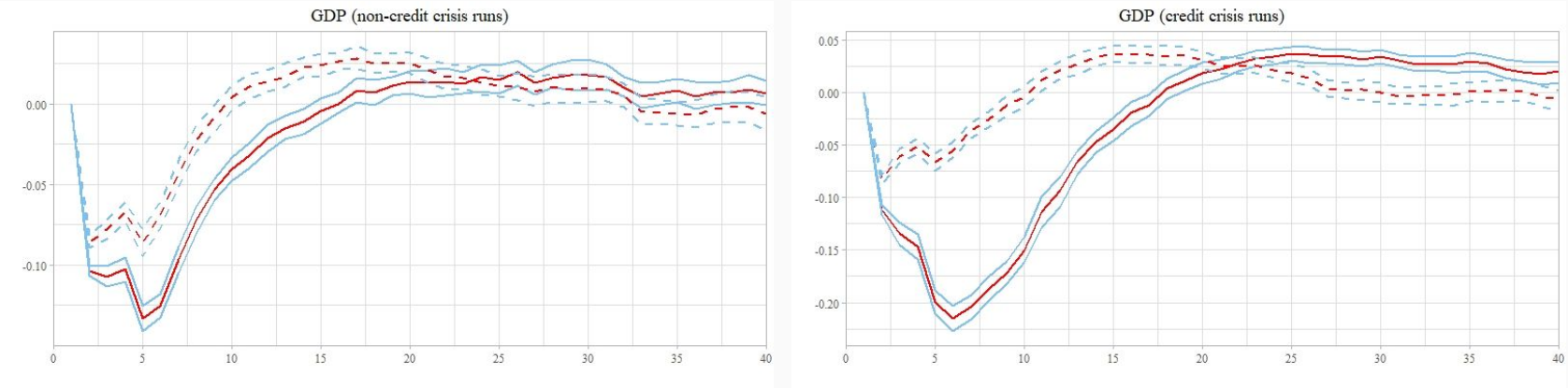


Figure 3: Effect on GDP without (left) and with (right) previous credit crisis with (dashed) and without (solid) credit guarantees

Scenario 1: Effect of Credit Guarantees

- Bankruptcy rate significantly improves
- This drives a reduced incidence of credit crises

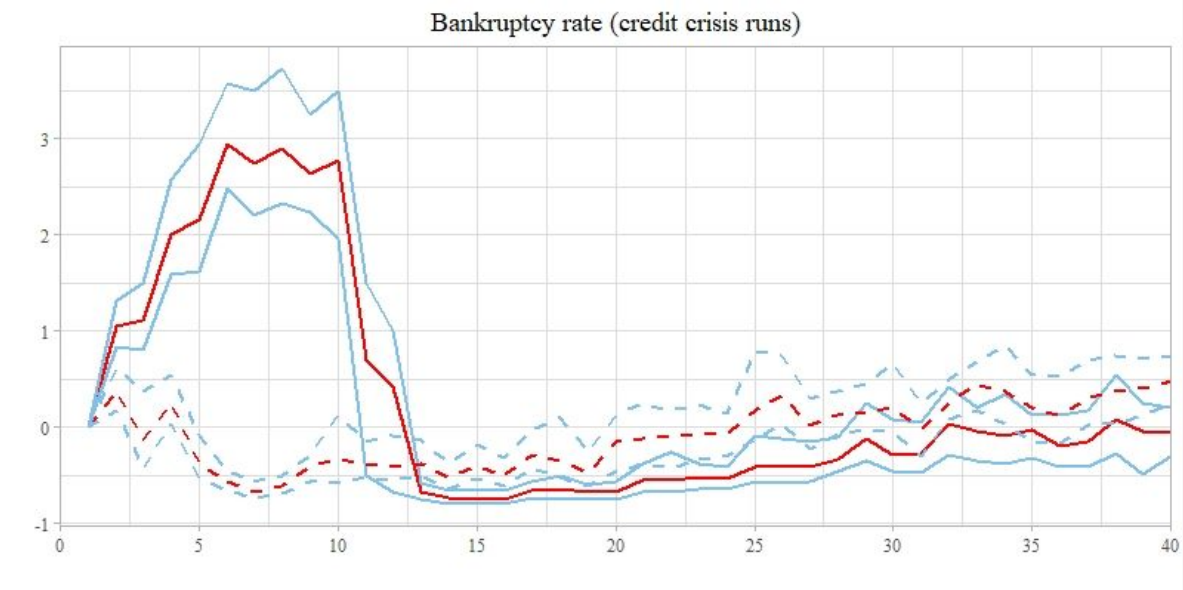


Figure 4: Effect on bankruptcy rate with previous credit crisis with (dashed) and without (solid) credit guarantees

Scenario 2: Multi-crisis scenario

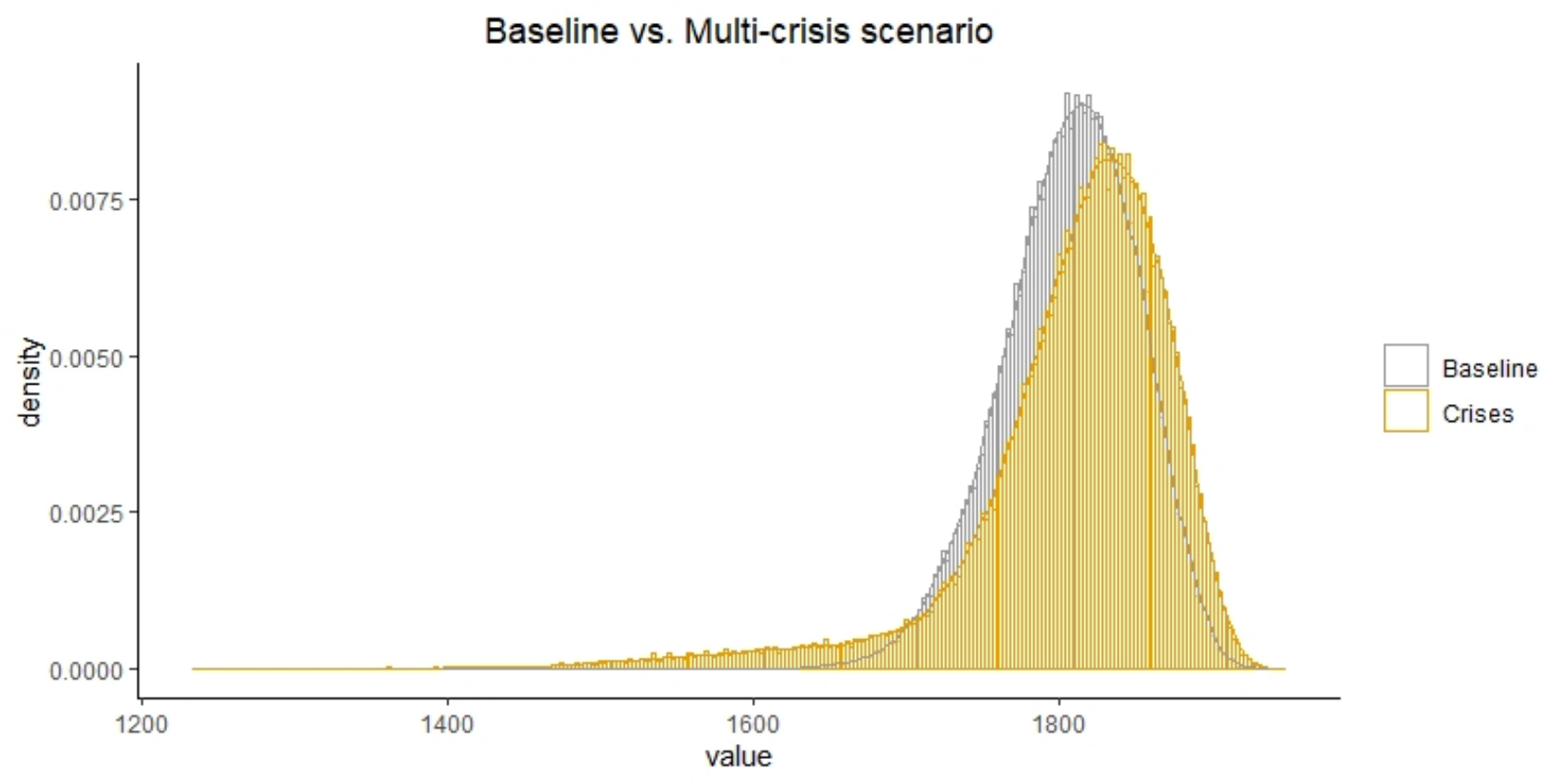


Figure 5: Baseline with no crises vs. combined crises scenario

- Distribution of post-transient GDP
- A heavy tail of low GDP value
- The sizeable change in the skewness and kurtosis

An example of continuous policies

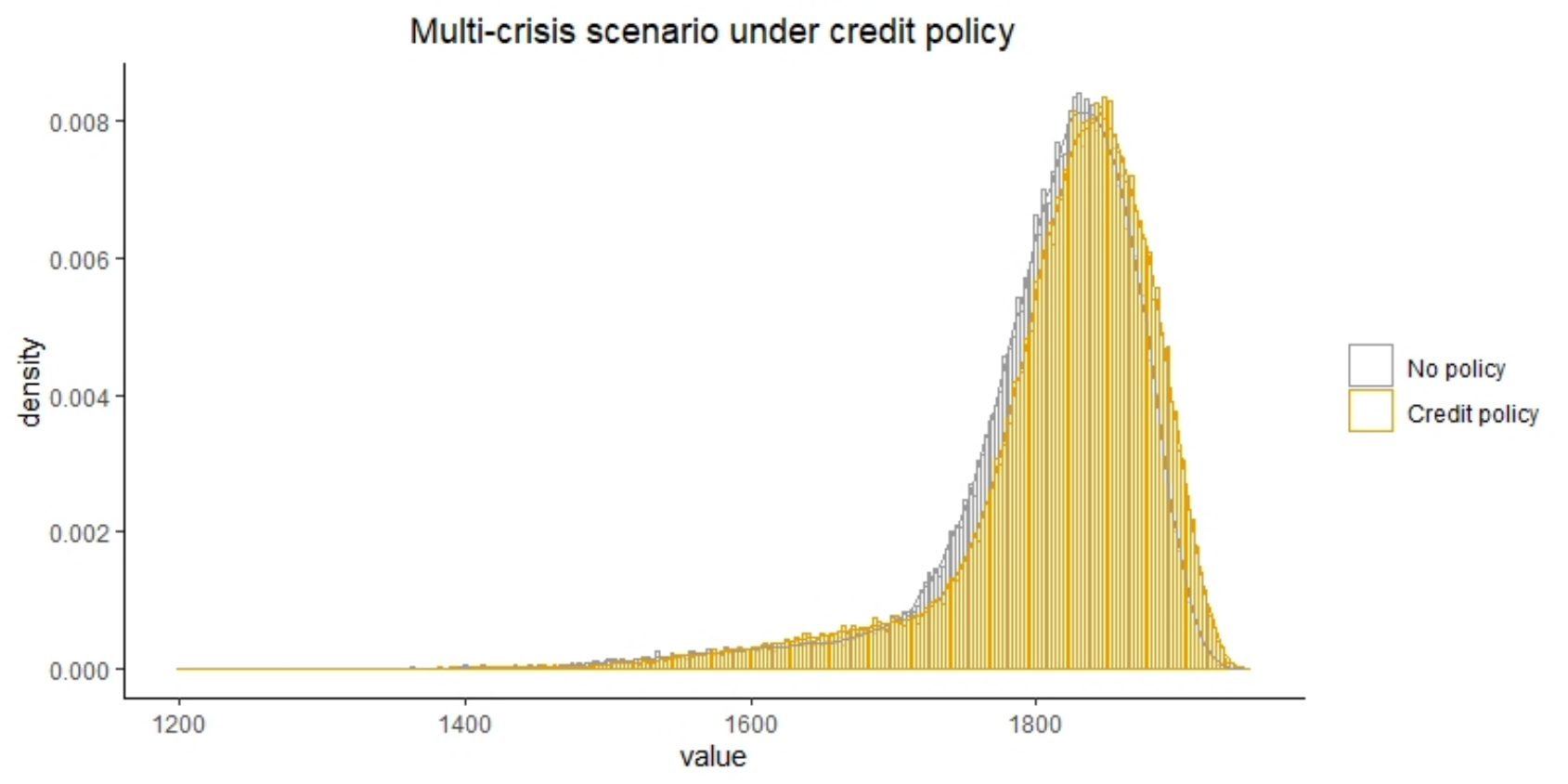


Figure 6: Combined crises scenario with and without credit policy

- Credit policy: Counter-cyclical leverage restrictions on banks.
- The skewness and kurtosis reduce slightly.
- Volatility is unchanged.

An example of one-off policies

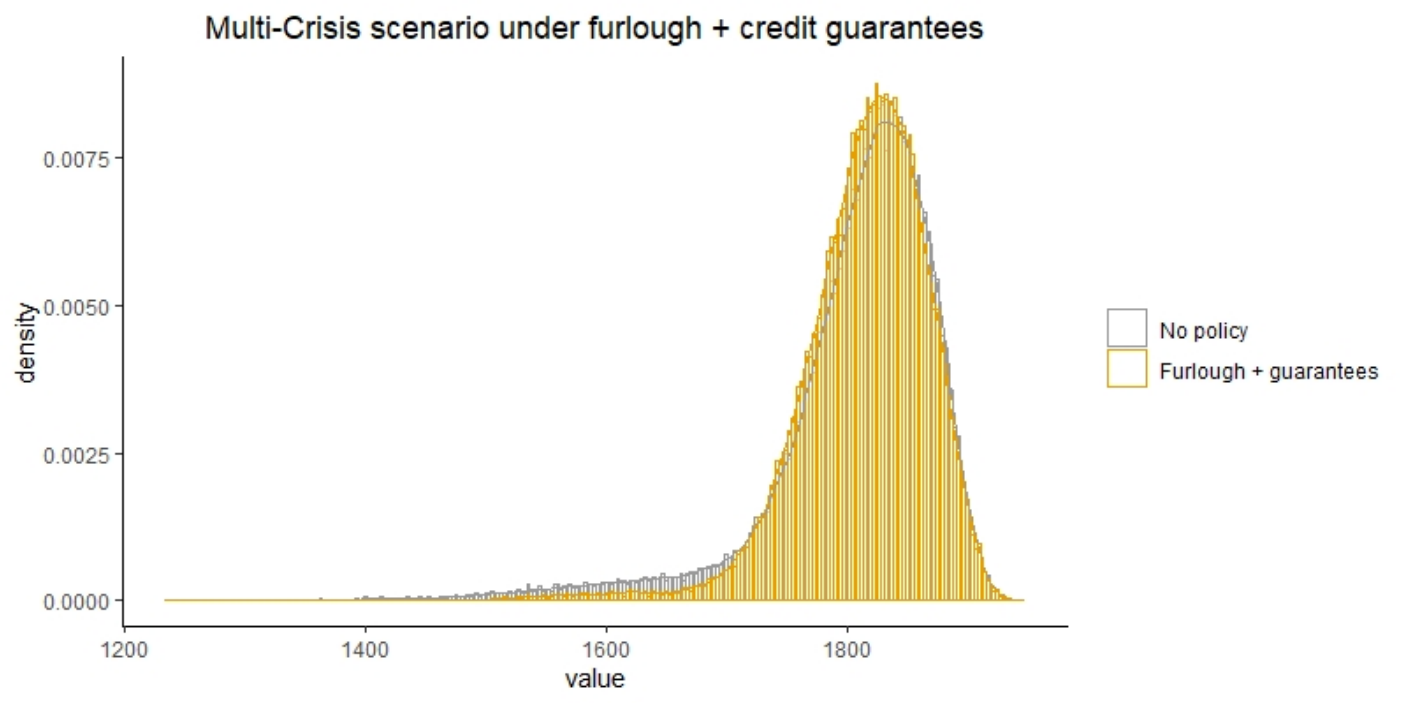


Figure 7: Combined crises scenario under furlough scheme & credit guarantees

- Combinations of two policies to support business: Job retention and Credit guarantees
- They reduce the weight of the lower tail of the distribution effectively.

Effects on government debt and inflation

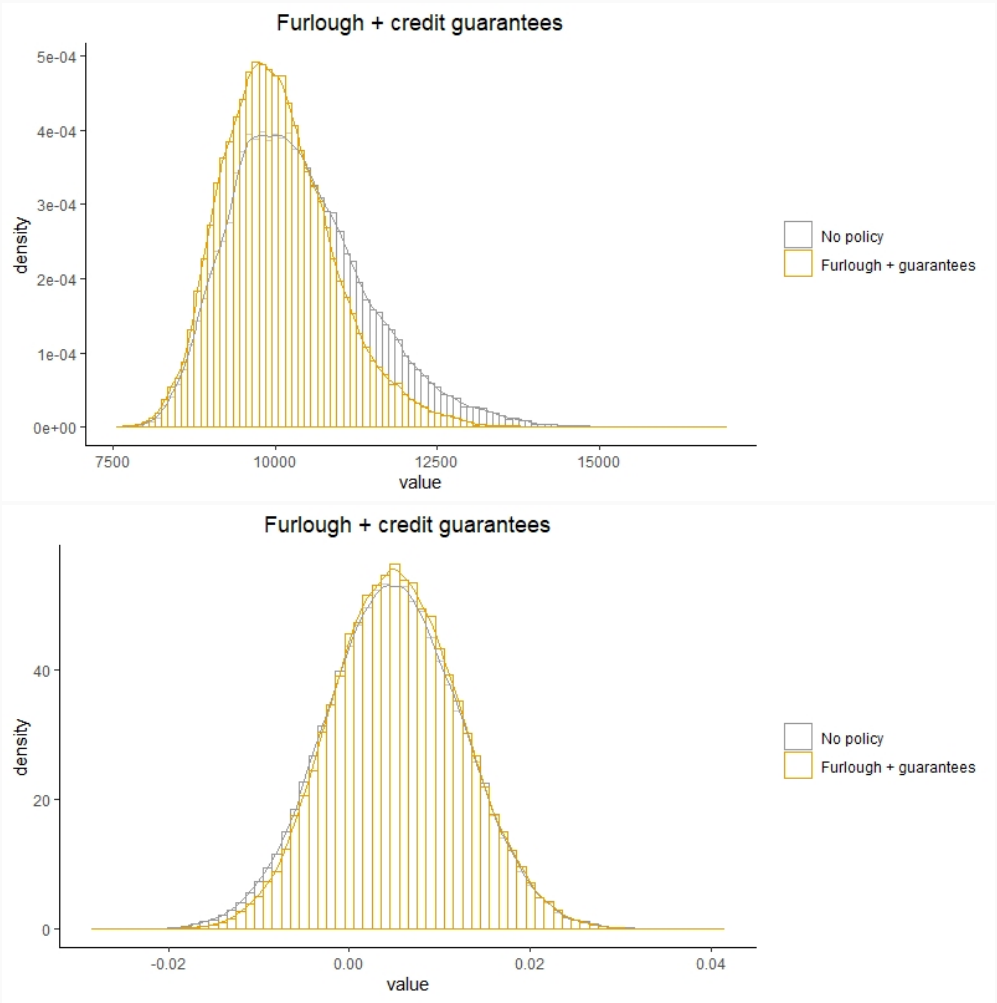


Figure 8: Effect of furlough and credit guarantees on real gov. debt & inflation rates

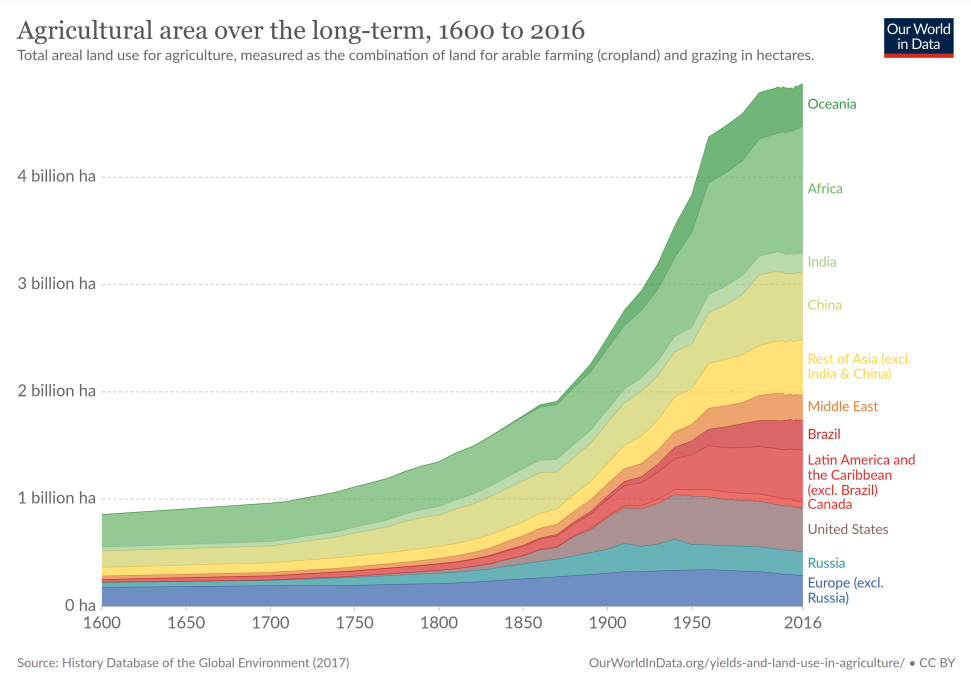
Methodological and modelling limitations

Recall: Methodology

- Applied exogenous shocks to macroeconomic model
- Analysed system response under policy regimes

Limitations

- Economic - ecological coupling a source of crises
- Absence of social / behavioural dynamics



Economy $\rightarrow$ environment

- Land use change
- Climate change

Environment $\rightarrow$ economy

- Land-use changes create human-livestock-wildlife interfaces
  $\Rightarrow$ increased risk of zoonotic diseases
- Climate change increases risk of natural disasters

Ecological crises are **not** exogenous to economic system

Missing phenomena

- Agent forecasting and moral hazard / incentive effects
- Political feasibility of policy interventions
- Adherence to policies during crisis

Game-theoretic social / behavioural dynamics

- Multiplex social and economic modelling
- Behavioural states influence(d by) economic layer
- Readily compatible with macroeconomic ABMs

Transcending Models

The Unknown, Crisis, and the Question of Resilience

- Modelling choices defines what is unknown
- Future is uncertain but actively under construction
- Resilience is more than a cost or opposition to efficiency

Static Models in Dynamic Social Worlds

- Any model is limited in understanding social dynamism
- Limited view of policymaking *impacts* and *possibilities*

Rethinking Method & Theory

Reconstituting the Unknown

- Eschewing prediction for creation; optimality for humility
- Embracing active construction of the economic world

Reconstituting the Resilient

- Recognizing resilience as enactment, not as trait
- Reclaiming willingness and responsibility to intervene
- Reinvigorating the policy imaginary

Reconstituting the Social

- Uncovering social interactions
- Understanding the relationship between our theory and enacted realities

Policy Making

Strengths

- Enables the implementation of preemptive measures
- Comparison of different policies
- Alternative tool to tackle complex problems (climate crisis)

Limitations

- Disconnect between modellers and policy-makers
- Underlying conditions can be subject to political agendas
- Political short termism
- Difficulty of modelling hypothetical policies (C19)

Solutions

- Must be clear about assumptions to foster buy-in from decision makers
- Focus on specific problem, avoid all-purpose model
- Decision theory application in policy making

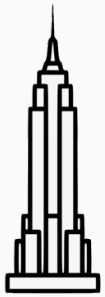
Theory: Efficiency vs Resilience

Efficiency: Design for the average-case. Performs well for what we expect to see.

Resiliency: Design for the *worst* of all cases. Risk aversion taken to the extreme.

How can we prepare for the next crisis?

- Focus on the worst possible outcomes
- Prepare for greater severity



DeepABMs to the rescue?

Agent based models can help us understand and combat unknown crises, but doing so effectively *requires more realistic models.*

Enter two powerful techniques from Facebook & Co

- Computing interactions on social network graphs *in parallel* and *on GPUs*. (From 5 hours runtime to 30 seconds.)
- (Yet more powerful) *Tuning parameters automatically* with gradient descent & reinforcement learning techniques. (From months of tuning to hours.)

DeepCATS: Towards hyper-specialized ABMs

- Modular, extensible, easily-tuned framework to encompass the innovations of our theoretic group.
- Forget generic models; the interesting stuff comes from the nuanced & unique.
- DeepABMs might provide a way to easily model the particular.

Conclusion

In sum:

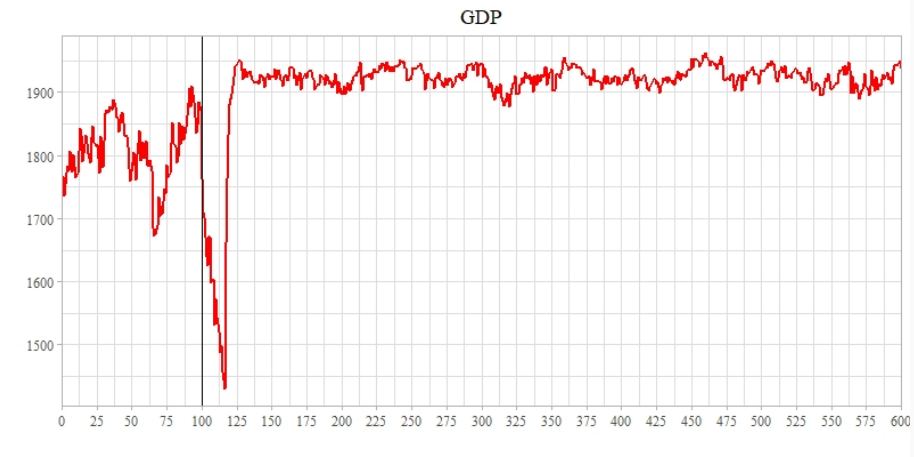
- Devised modeling framework for predicting the effects of unpredictable crises, and implemented initial experiments.
- Identified ways to further extend the framework: endogenizing environmental effects and social factors.
- Theorized uses and limitations of ABMs in preparing for crises.

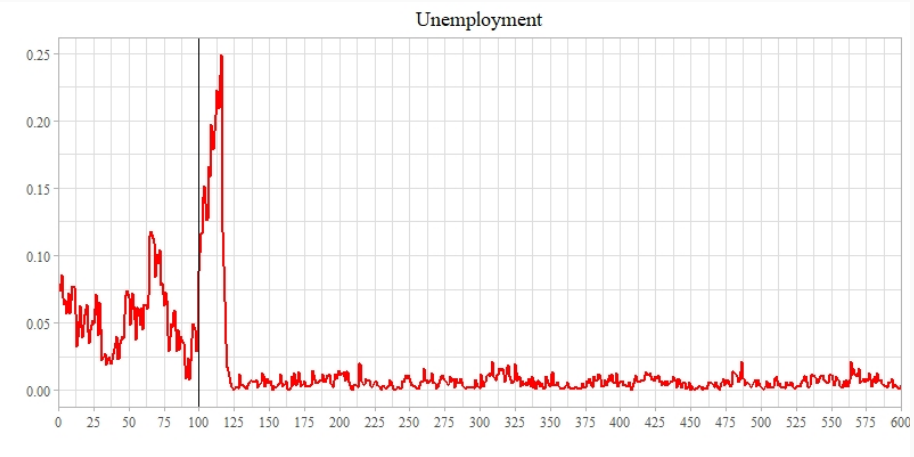
Future Steps:

- Further pursuing and formalizing epistemological ideas on efficiency/resilience trade-offs and the limits of modelling.
- Improving existing ABM frameworks: making agents more forward looking.
- Completing implementation of DeepCATS.

Appendix

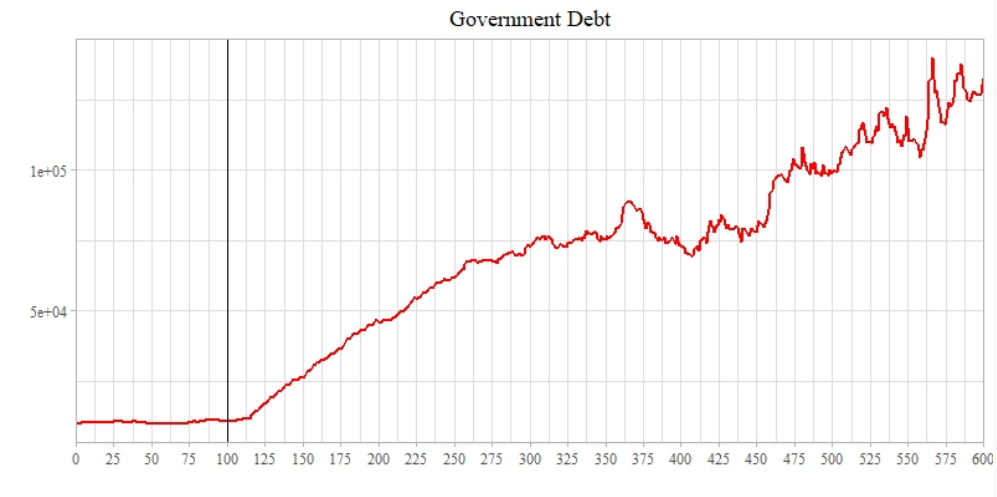
Costs of policy interventions

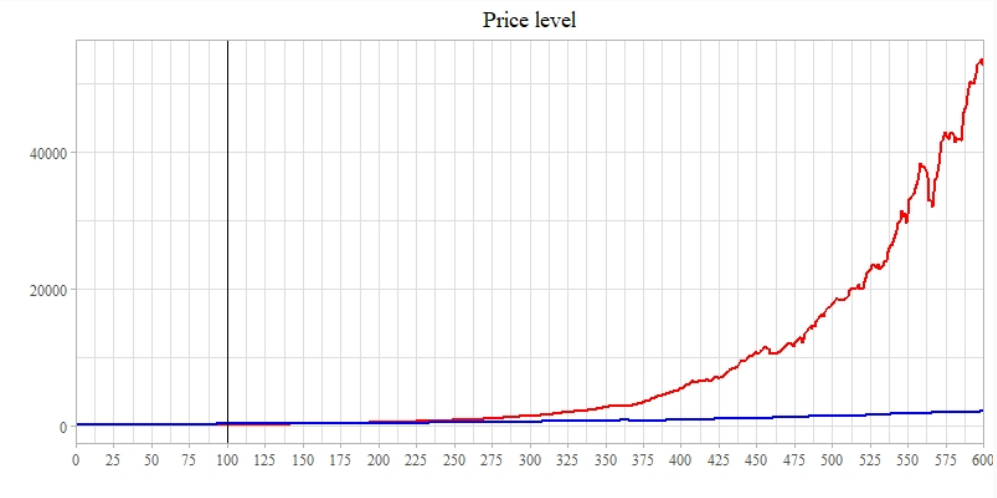




- Combination of two policies: Income support and debt relief.
- It does not converge toward the previous levels of GDP and unemployment. Why?

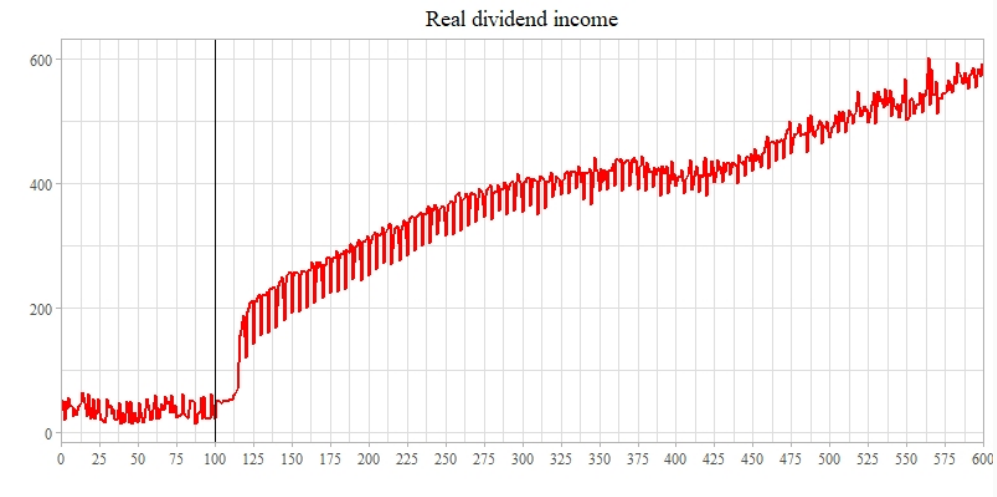
Costs of policy interventions





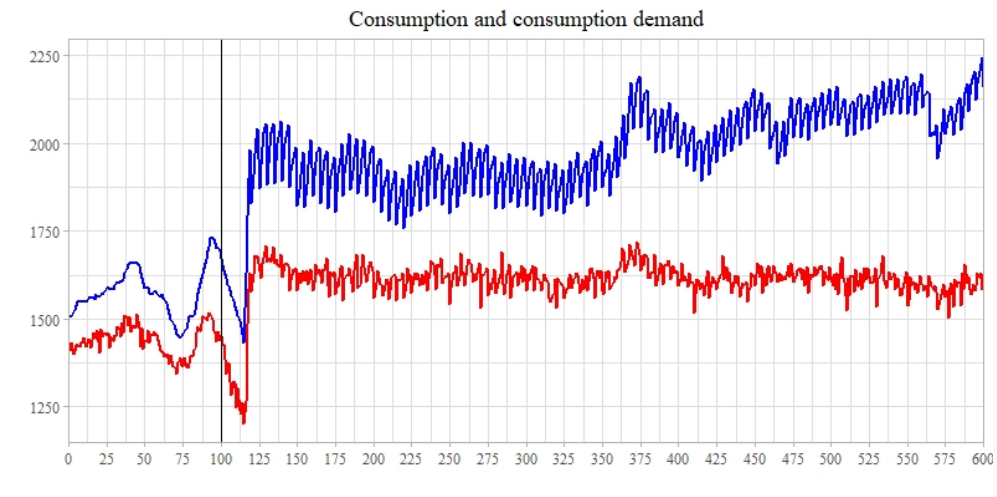
- Government debt increases both in nominal and real terms.
- The price level rises much faster than in the baseline

Costs of policy interventions



- Purchasing power is redistributed from workers to firm owners.

Costs of policy interventions



- The loss in real demand from workers is more than compensated by the increased real demand from firm owners
- Thus, overall demand for consumption increases.
- Firm owners' real demand continuously increases with real interest income.
- As a result, the gap between consumption demand and actual consumption is larger.