Orchestrating Global Systems Science and Information Technologies for Policy Modelling: The SYMPHONY Approach

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Abstract. In our globalized world public policy making and society at large face challenges like climate change and financial crises that are global, shared worldwide and tightly connected with policies across different sectors. Solutions for addressing such highly interconnected challenges in a 'system of systems' world, tend to address only subsystems and so fail to achieve systemic change and anticipate impact and unintended consequences of public action. Pursuing the necessity of informing the policy decision process and proactively sensing possible problems concerning global matters we are proposing a novel computational platform called SYMPHONY that offers a solution for designing and testing policies and regulatory measures. Our aim is to offer policy modellers and policy makers tools that will support them to make decisions which will prevent and mitigate economic and financial crises as well as foster an economically and ecologically sustainable growth path.

Keywords. Policy Modelling, Agent Based Simulation, Social Media Mining, Information Markets.

1 Introduction

Over the last years, a great concern of the global political agenda has been to find ways to overcome the crisis and therefore look for effective policy instruments and even for new theoretical economic frameworks. Responses to this concern still miss

adequate tools for exploring and governing the complex global dynamics of our economic and social system. In this paper we describe a computational framework called SYMPHONY that aims to offer solution for designing and testing policies and regulatory measures with respect to preventing and mitigating economic and financial crises and fostering an economically and ecologically sustainable growth path.

The main component of SYMPHONY is an agent-based macroeconomic artificial economy, accessible through an on-line interface that allows policy makers and policy modellers to set up economic scenarios and run computational experiments. In addition, citizens can use the agent-based artificial economy by playing the role of a particular economic agent through a gamified environment. Citizens' participation into the SYMPHONY platform aims at raising awareness about the economic process and improving the efficacy and the transparency of the decision making process.

SYMPHONY includes social media mining tools able to collect and analyse relevant information and human sentiments from the web, including social networks, blogs and news streams. These tools allow policy makers and experts to explore the evolution of people's beliefs regarding the real world economy. Moreover it incorporates information markets able to collect feedback on specific economic issues through the design of information contracts that aggregate participants' preferences and expectations. The proposed platform increases the transparency of the policy making process, enhances citizens engagement, improves the credibility and effectiveness of policy institutions and provides insights on the interplay between policy making and expectation formation by citizens.

The paper is structured as follows. Section 2 presents the policy making problems which we aim to support with the SYMHPONY platform. Section 3 describes the overall architecture of the platform and provides the details of each of the SYMPHONY components. Section 4 shows how the SYMPHONY platform can be used through a set of use case scenarios. We conclude in Section 5 with our final remarks and our plans for future work.

2 The Problem Space

In our globalized world, public policy making and society at large face challenges like the climate change and financial crises that are global, shared worldwide and tightly connected with policies across different sectors. An issue of major concern is that solutions for addressing such highly interconnected challenges in a 'system of systems' world, tend to address only subsystems and so fail to achieve systemic change and anticipate impact and unintended consequences of public action.

Global Systems Science (GSS) is about providing solutions to global problems of interconnected systems in order to support policy making and decision making [1]. This involves looking at the whole of our planet and its societies as well as providing a transdisciplinary and transformative perspective that connects all kinds of scientific knowledge, and engaging as many people as possible in collective actions. Global Systems Science studies systems like the financial system, the climate system, the global city system, and more, develops evidence, concepts and doubts concerning such systems, helps practitioners dealing with them to reflect on their experiences and

to assess possible consequences of their actions, and combines advanced computing technologies with conversations bridging the gap between science and society. Examples of global systems include the global financial markets, the worldwide factors affecting climate change and the energy industry. A major problem in global systems refers to how they can self-stabilize when shocks occur despite their distributed control. SYMPHONY deals with two challenges faced by societies in the global system, namely financial stability and sustainability transition.

2.2 The Challenge of Financial Stability

In the last thirty years, most of the advanced and developing economies have undertaken a profound transformation of their financial sector; major changes can be identified in the deregulation of financial markets, the liberalization of capital transfers, and in the privatization of the banking system. An important consequence of this process has been the financialization of the economy, namely, the increasing relevance that the financial sector has assumed with respect to the real one. Although the process of deregulation and privatization has not been limited only to the financial sections of the economy, in the case of the financial sector we see the most important and far-reaching changes. This is because of the importance of finance in modern services-oriented economies and the digital communication revolution, benefitted from activities characterized by immaterial assets and centralized exchange.

The financial market liberalization, the privatization of banking systems and of state-owned manufacturing and services companies, as well as of some forms of social security provisions, such as pensions, have determined the so-called financialization of the economy [2]. The increasing relevance of financial markets, actors and institutions in the operation and in the governance of the economy during the last thirty years can be observed in many ways. Financial trading activities have increased exponentially and have been characterized by the emergence of new actors like hedge funds and private equity firms. The privatization of public companies has augmented the supply of stock shares on one side, while the privatization of retirement financing has created new demand for financial assets on the other side.

Financing in capital markets has been made easier by financial innovation and securitization, which created new financial instruments such as collateralized debt obligations and mortgage backed securities, where households' and companies' loans have been transformed into tradable assets. Financial innovation has allowed an increase of the debt to GDP ratio of the private sector on one side, in particular for households and the financial sector, and has fuelled bubbles in the financial and real estate market on the other side. Both have been self-reinforcing during the boom period, given that inflated financial and real estate assets have been used as collateral for debt, thus fuelling again household's consumption and debt. The contribution to GDP of the finance, insurance and real estate (FIRE) sector has increased from nearly 15% to more than 20% in the last thirty years in US [3].

The rising of household debt-income ratios and corporate debt-equity ratios has made the economy increasingly financially fragile and potentially unstable. In fact, these debt growth dynamics are unsustainable in the long run and the economy may become vulnerable to debt-deflation and prolonged recessions [4]. Internationally,

financial fragility has become already evident in the 1990s with the Mexico (1994), the Asian (1997/1998) and the Russian (1998) crisis, which demonstrated the degree to which a too rapid market liberalization can lead to a currency crisis, in which a sudden reversal of capital flows is followed by financial instability and a consequent sharp decline in economic activity. The crisis of 2007-2009 is a historical and economic event of major relevance which is causing a critical discussion about the cultural and theoretical underpinnings of the deregulation and liberalization process both in the political and in the academic domain.

In this complex environment policy makers require support to monitor citizens and experts expectations on macroeconomic variables which vary depending on the policies they implement as well as tools to simulate and test different economic policy scenarios.

2.3 The Challenge of Sustainability Transition

In order to reach the emission's reduction level necessary for staying below the politically agreed limit of 2°C temperature increase, great efforts at international level are needed. International climate negotiations show that it is becoming more difficult to reach agreements because industrialized countries are reluctant to increase their commitment due to the fact that they fear negative impacts on economic growth. Additionally, developing countries want to catch up in terms of economic development and standards of living and see strong emission targets as a threat to their development. Only if industrialized nations can demonstrate that a different growth model based on a minimal amount of emissions, waste and use of resources is possible, will developing and emerging economies be willing and able to leapfrog the industrial growth model. Instead, industrialized nations have been struggling with the financial crisis and the economic difficulties it triggered. Finding a way out of economic recession has become a top priority. However, it is questionable that there will be an economic recovery under business as usual if the financial crisis is tackled in isolation.

The current discussion around climate policy is centred around finding international agreements on emission reductions. For Europe this means setting a target at EU level which is in line with international agreements. However, even in the absence of an international agreement, the EU targets will not lose their relevance and will be an important guidepost for investors, producers and consumers alike. It is important to note that this discussion is very much focused on the overall economic costs (mainly in terms of GDP) of such a policy and how these costs can be shared among the member states. The economic opportunities are often left aside/understudied.

The most important targets currently in effect are the 2020 targets. These targets were set in 2007 and enacted in 2009 through the "climate and energy package". Today they are widely known as the "20-20-20" targets, which stands for: 20% reduction in EU Green House Gas (GHG) emissions, a 20% share of renewable energy in gross final energy consumption and 20% reduction in total primary energy consumption of the EU (all 2020 levels compared to 1990). Following this, in 2011, the European Commission defined the long term GHG emission reduction target for 2050, which would be in line with the EU's contribution to the global political goal of staying below a 2 °C temperature increase. The target is 80%-95% below 1990 levels. In

2013 the European Commission started a discussion process around the intermediate goals for 2030 by publishing a proposal called the 'Green paper: A 2030 framework for climate and energy policy 2030'[1]. The results reduction targets for 2030: 40% GHG emission reductions, 27% share of renewable energy, no energy efficiency target.

In order to define policies that will allow Europe to reach the defined emissions' reduction targets, policy makers need support to analyse and assess climate change mitigation policies and verify their potential to trigger a sustainability transition.

3 The SYMPHONY Solution

SYMPHONY is an integrated set of innovative tools for supporting policy making as shown in Figure 1. The main engine is an agent-based macroeconomic artificial economy (or agent based model) that is accessible through a web interface. It is possible to connect to the agent-based economy in order to run simulations or to participate by taking the role of one specific economic agent. Expert users, including policy makers, are able to set up different economic scenarios and to run simulations using the web interface. A complete set of visual and quantitative tools for the analysis of the real time outcomes of the simulations are available to the user. Citizens are also able to participate in the agent-based artificial economy through a game-like interface by playing the role of a particular economic agent. They take decisions, according to their role, and observe the consequences of their decisions. A player in the role of a commercial bank can, for instance, may modify the rules for granting credit to firms or households and observe the effects of her/his decision on the internal variables of the bank (bank's balance sheet for example) and on the overall economy. Citizens' participation in the artificial economy aims at raising awareness on the economic processes and at improving the efficacy and the transparency of the policy decision making process.

Besides the agent-based model, the SYMPHONY solution includes social media mining tools and techniques able to collect and analyse relevant information and human sentiments from the web, including social networks, blogs, news stream, etc. Policy makers and experts use these tools in order to explore the evolution of people's beliefs about the real world economy. In particular, the tools are used to set up real time measures of citizen's expectations on economic indicators. The platform incorporates a second tool for information gathering. Users can create information markets in order to collect feedback on specific economic issues. It is possible to design information contracts that are traded in the markets, disclosing valuable information about participants' preferences and expectations. By combining these information extracting tools, policy makers and experts acquire a deeper vision of sentiments, trust and expectations which are prevailing among the economic agents.

The SYMPHONY solution, increases the transparency of the policy making process, enhances citizens' engagement, and improves the credibility and effectiveness of policy institutions.

[1] http://ec.europa.eu/clima/policies/2030/index_en.htm

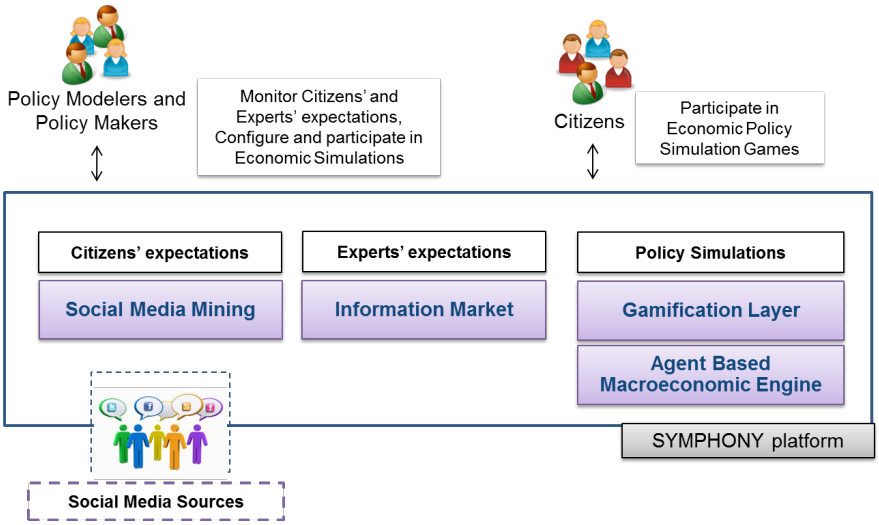

Fig. 1: Conceptual Architecture of the SYMPHONY platform

3.1 Agent Based Modelling

Agent based models (ABMs) are computerized simulations of a number of decision makers (agents) and institutions, which interact through prescribed rules [5]. The agents may represent various entities and institutions including consumers, policy-makers, banks and governments and act according to rules specifying their behaviour while considering their current situation and the state of the artificial world where they live. ABMs do not rely on the assumption that the economy will move towards a predetermined equilibrium state and can handle a wider range of nonlinear behaviour than conventional equilibrium models. With the use of ABMs policy-makers can simulate different policy scenarios and quantitatively explore their consequences.

The SYMPHONY ABM is based on the EURACE macro agent-based model [6]. The ABM represents a fully integrated macro-economy consisting of the real sector, the credit sector, the financial sector, the public sector, the foreign sector, the real estate sector and the environment in order to introduce sustainability aspects. The real sector represents the production of consumption and capital goods with labour, the capital goods and energy as factors of production and relative markets, and the technological innovation whereas the credit sector represents the financing production plans of firms. The financial sector consists of the exchange of claims on the equity capital of producers as well as of governments' liabilities, whereas the public sector models the policy making, i.e., the fiscal policy made by Governments and the monetary policy set by the Central Bank. Finally the foreign sector introduces the possibility of exchanges between different countries and thus the application of different economic policies.

The interface to the ABM is gamified in the sense that even non-experts (including citizens) can use it through an intuitive (see Figure 2 for an indicative view). Users

assume a role (e.g. the central bank) and modify related parameters (e.g. the interest rates set by the central bank) that affect the evolution of the simulated economy.

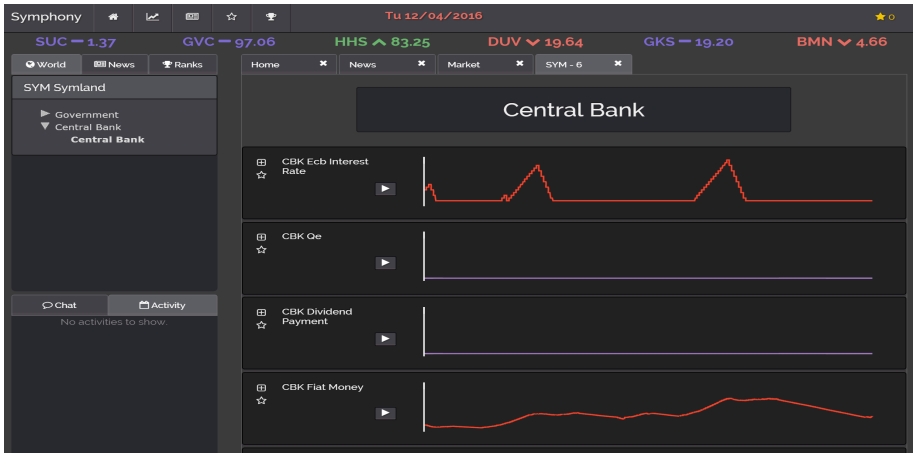

Fig. 2: The SYMPHONY game interface for the role "Central Bank". Users can set variables such as the interest rates and the amount of fiat money, affecting the evolution of the simulated economy.

3.2 Nowcasting expectations with Social Media Mining.

Nowcasting in economics is a process of measuring the state of the economy in a real time [7]. For instance, Giannone et al., [8] show how the process of nowcasting can be formalized with a model describing the direction of change in GDP before official figures for GDP are published. Recently, new approaches merging social media mining with nowcasting have been developed. Social media is a source of information, opinions, ideas or any kind of other expression of individuals or organizations which arose with the development of the web and enable instant and open global communication. There is a long list of social media applications that includes Twitter, YouTube, Instagram, Facebook, Snapchat. These applications are intensively worldwide, for instance more than 350,000 tweets are send every minute [9]. Approaches for nowcasting with social media utilize vast data streams to assess standard economic measures in shorter periods of time. Several approaches are based on sentiment mining of social media streams and assume that sentiment values obtained from social media streams can be correlated with financial data streams ([10], [11]).

In SYMPHONY we perform social media mining in interconnection with mining electronic news media. We perform analysis across-languages and consider different aspects of the data including text, sentiment, geographical spread and diffusion dynamics. We do this to obtain a rich set of features which are used for correlations and in the final phase for predicting current actual values of macroeconomic indicators, including the sensibility of citizens to environmental problems and their willingness to change job.

3.3 Information Markets

Pursuing the necessity of informing the policy decision process and proactively sensing possible problems concerning global matters, in SYPMHONY we use the `market´ as an institution which efficiently aggregates diverse information using the price mechanism and the Web as the medium where 'Information Markets' (IMs) can be created and run.

IMs are considered an example of collective intelligence because of their capability to aggregate and nowcast information that arrives with a lag by making use of specifically designed contracts that yield payments based on the outcome of uncertain future events [12]. Contract prices provide a reasonable estimate of what the traders in aggregate believe to be the probability of the aforementioned events, and as such, markets are able to generate forecasts. IMs are characterized by their accuracy, easy deployment, and ability to dynamically incorporate new information available to traders by continuously adjusting an event's price and hence its probability conditioned to the new market information.

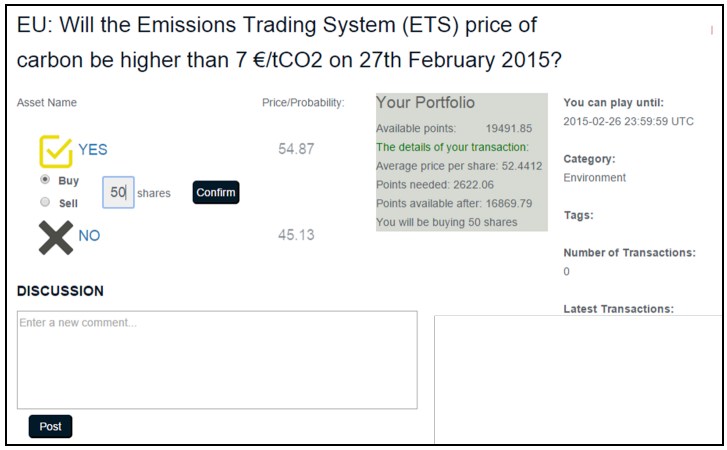

Fig. 3: View of the PolicyOracle trading interface. Users can buy or sell shares of contracts that represent different answers to questions related to trends of policy indices. Moreover they can provide comments and opinions in a discussion forum.

In SYMPHONY we propose a new web-application called PolicyOracle for making predictions with the benefit of the "wisdom of crowd" effect. PolicyOracle is an IM for collecting, aggregating and interpreting stakeholders' and citizens' opinions, expectations and preferences in order to improve public decision-making. PolicyOracle's primary focus is on sustainability transition issues by exploring economic and financial policies. Our platform supports decisions on policy matters contingent on the status of key policy variables e.g., "Price of carbon needed to reach 30% GHG emissions reduction by 2030". Relevant policy decisions could be private or public whereas markets provide information related to a variety of public policy matters such as costs, benefits, net benefits of policy options or the likelihood of certain events depending on the choices of policy makers. The current version of the platform,

among others, includes functionalities that allow trading of virtual contracts using an implementation of an automated market maker and discussions on the policy indices that are presented as contracts to participants (see Figure 3).

4 Indicative Use Case Scenarios

In this section we provide two indicative scenarios which show how the SYPHONY solution can be used in order to support policy decisions.

4.1 The Voice of the Crowd: Sensing the Views of the TechnoSociety

Policy makers and policy modellers can use the SYMPHONY social media mining and information markets services to monitor expectations on key policy variables in near real time. These expectations reflect the beliefs of citizens and stakeholders about the real world economy.

Consider that Mr Smith is an executive at the European Central Bank. In order to make financial policy related decisions he has to observe expectations on issues of the real world economy. In our example he wants to have access to near real time expectations on unemployment rates. Mr. Smith opens his web-browser and enters the SYMPHONY platform url. SYMPHONY is offered as a software-as-a-service and can be accessed by all stakeholders who wish to use the toolset. Administrators for the SYMPHONY platform have been appointed by the Central Bank and have already setup the proper access rights. Consider also Kristian, a sales assistant in Hamburg that he finds it hard to find a job. He tweets "I will never find a job … #unemployed". The SYMPHONY social media mining platform processes information shared in social media by Kristian and other people from all around Europe in order to infer citizens' expectations on job finding. The platform analyses the text and sentiment of the social media information and derives related beliefs and expectations. By selecting different keywords, Mr. Smith can view the trends related to other key variables of the economy with respect to time (how the beliefs of social media users vary in time), including employment rates, inflation rates, interest rates and expected growth rates. By selecting different social media mining features (sentiment, frequency etc.) the policy maker can visualize social media data in different perspectives.

Mr Smith wants to get the expectations of expert stakeholders on the key variables of the economy he is interested in. He creates a new information market and places some questions on which he would like to have the opinion of other stakeholders including the European GDP in the next quarter, the unemployment rates and the debt level of European countries. Once the information market is ready, he invites participants inlcuding co-workers and executives from other organizations. Participants login and buy or sell information contracts according to their expectations. The contract prices gradually represent the current expectations of participants on the questions set in the market. Mr Smith regularly visits the information market and acquires an overview of the expectations of the participants.

With SYMPHONY Mr Smith can observe the expectations of citizens and experts and make informed decisions without having to wait for statistical reports that arrive with a lag.

4.2 Let's Play Together: Citizens and Policymakers Collaboratively Explore Policies with the SYMPHONY Gamification environment

The SYPHONY gamification environment provides dynamic data-driven games that lets policy makers and citizens, interested in economics and monetary policies, come together to interact with SYMPHONY's agent-based artificial economic world. Players' decisions impact the in-game virtual economy, and each player is made to feel the repercussions of financial decisions made by everyone taking part.

Within the game there are five roles players can take charge of: household, firm (CGP - Consumer goods producers), commercial bank, central bank, government, Retail sellers (malls) and Investment goods producers (IGP). Each role requires the player to work to a set of objectives: for household players it consists of being able to survive on a budget, firms to produce a successful business, the central bank to keep interest rates down and the government to ensure the correct policies are enacted. Decisions made by government and central bank players can have dramatic effects on households and firms, vice-versa if households and firms aren't making enough output they can affect central bank and government players. Each role has certain effects on each other, allowing players to feel connected to each other within the game environment. A chat room function is available to allow players to communicate with each other and provide a space where players can share game strategies, help each other out and share economic tips about playing the game. The SYMPHONY gamification provides a different experience every time the game is played based on the underlying ABM simulation. A general game scenario runs over a course of a week. Policy makers/stakeholders are able to set the scenario conditions and invite users to join. Potential players can sign up to a game scenario by visiting the game website and are informed when the scenario begins through email. Consider the following set of players.

Mr Linn is an executive at the European Central Bank, responsible for monetary policy issues. He has been recently informed about the SYMPHONY game and decides to participate. He creates an account and selects the role of central bank from the available options. He can now control a set of variables and make actions associated with the role of central bank, including settings of the monetary policy (e.g. interest rates in %), capital requirements for banks (the maximum ratio between total weighted assets of a bank and its equity capital) and make decisions to perform unconventional policies (as quantitative easing by buying government bonds), thus affecting the course of the game.

Marta, a dentist in Ljubljana. She saw the SYMPHONY game being mentioned in a post in Facebook and has decided to participate. She creates an account and selects the role of household from the available options. The options she can set and are associated with the household role include: how much to consume, how much to save,

how much to invest in the financial market, which assets (firms' stocks and government bonds) to buy and which to sell. Another player

Mark is a member of the parliament in Germany. He has been informed of the SYMPHONY game from an email newsletter and decides to join. From the available roles he selects the one of a Prime Minister which allows him to take fiscal policy decisions. Indicative examples include: setting tax rates on corporate profits, household labour and capital income, setting public expenditure, e.g.: unemployment benefits, household's transfers, and public wages and issuing government bonds to finance public deficit.

Giancarlo owns a small business in Italy. A local newspaper had an article on the SYMPHONY game which sounded interesting. He accessed the provided url and decided to join. He selects the role of firm manager. Among the available actions of his role in the game are: how much to produce, how many people to hire and how much to invest.

The games starts and users are notified with an email that they should make their actions. Mr Linn sets the interest rates at 2%, Marta decides to buy more goods and invest in stocks part of the income she receives within the game, Mark allocates more money to public expenditure for unemployment, Giancarlo decides to hire more employees in his firm and request a loan that is evaluated positively from Pedro's bank. The economy in the game evolves and players understand how their decisions affect the system.

5 Conclusions

The SYMPHONY solution aims to be a holistic platform for modelling policies. Policy modellers and policy makers using the SYMPHONY macro-economic engine will have the ability to test concepts, directions, thoughts and drafts as soon as possible and at the minimum cost, with the use of artificial economies whereas citizens and stakeholders will participate through the a gamification layer and understand the inner workings of the economic system. Policy makers will be able to run "in vitro" trial runs of a policy concept and obtain not only reactions and overall sentiment, but actual input and feedback both in terms of anticipated impact, scrutiny and even new ideas and expressed suggested alternatives. Using the SYMHPONY social media mining and information market services, policy modellers and policy makers will be able to monitor expectations on key economic variables in near real time for more informed decisions.

The SYMPHONY platform will be evaluated by supporting real life global problems in cooperation with organizations such as the Global Climate Forum (GCF), Germanwatch (GW) and the Bank of England.

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