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Visualising economic crises using accounting models☆

Stephen Kinsella [a, b, *]

[a] Department of Economics, University of Limerick, Ireland
[b] Melbourne School of Government, University of Melbourne, Australia

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ABSTRACT

We build and argue for new visualizations of the Irish economy based on a stock flow consistent model of the national accounts. The 2007/8 Irish crisis came from the financial sector, and these visualisations capture the interconnections between the real and financial sectors of the economy. The visualizations increase the data-density thirty to fifty times more than line graphs typically used by policy makers to guide their decisions. The many connections between the real and financial sides of the economy are made more explicit.

> But what is the full picture? There is no full picture. We make the picture. That is what gives us our power: *people think and act on the basis of that picture!* Do you see? Are you beginning to see?
>
> —Hines (1988: 254), italics in original.

1. Introduction

A visualization is an external artifact supporting decision-making. Visualizations allow the compression of vast amounts of information and the comprehension of emergent properties within datasets (Ware, 2013). We can use visualizations to understand structural changes at the micro and macro levels. In this paper we ask: Could better visualizations have helped policy makers to act sooner to avoid the worst excesses of the global financial crisis? We develop a series of visual representations of an economy based on its national accounts. We use the Irish economy from 2001 to 2017 as a case study because of its openness, recent macroeconomic volatility and its very large financial sector relative to its real economy. The visualizations developed in this paper increase the data-density the policy maker is exposed to between thirty and fifty times that of a line-graph.

This paper argues accounting models, based on the balance sheet as the fundamental object of economic analysis, have the potential to supply many of the missing pieces of the picture policy makers failed to see (Godley and Lavoie, 2005). Several authors (Coyle 2014, 2017; Suzuki, 2003a, 2003b) attribute the prevalence of the very notion of the macro-economy and the resulting economic management of modern society as coming directly from the accounting viewpoint. For Mitra-Kahn (2011) especially, the development of national income accounting did not just give economists tools to measure economic reality: the accounting approach adopted resulted in the construction of economic reality.

More data does not lead linearly to better decisions. Humans typically minimize the effort they expend in getting the necessary gain in information (Ware, 2013, p. 375). The dimensionality of the policy problem complicates visualization, since a large number of indicators and data points are often required to accurately assess potential vulnerabilities. Summarising these indicators appropriately via visualization therefore becomes important in and of itself. Visualizations for policy making are representations of *"reality in order to act on it, control or dominate it, as well as to secure the*

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* Department of Economics, University of Limerick, Ireland.
E-mail address: Stephen.Kinsella@ul.ie.

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compliance of others in that domination" (Bloomfield & Vurdubakis, 1994: 456, quoted in Qu & Cooper, 2011, p. 344). Jordan, Mitterhofer, and Jørgensen (2018: 34) correctly caution against the overconfidence visualizations can give policy makers by which "*complex and potentially not well understood processes come to appear simple, imaginable and 'manageable'*". In such a complex system, one measure will not do. In fact, simple measures often argue *against* one another. Fioramanti (2008), Sarlin and Marghescu (2011) and Billio et al. (2012) have shown indicators of debt, currency, and systemic crises are non-linearly related to one another. Causality is often hard to establish. Different visualizations provide different frames of reference for, and suggest different means of interventions, in, a complex system like an economy. In a macroeconomic context, visualizations are 'carriers of ideas' about the economy's past and future performance (Himick & Brivot, 2018). The purpose of this article is to examine new carriers of more complex ideas derived from a 70-year-old system of data-gathering about the economy, the national accounts.

The decision-theoretical frame we employ assumes policy makers act in a quasi- or boundedly rational way (Simon, 1957, 1985), although constrained by their prior ideological framings (Ban, 2016), and by organizational politics they find themselves in (Cairney, 2016). Following Hudson (2014: 70–77), we argue that in crises, small groups make framing choices based on many different types of evidence.[1] The small group then 'sells' the chosen option to the larger group (Mintz & Wayne, 2016). We now know from accounts of those policy makers directly involved that this is exactly the pattern the Irish crisis response took (see for one example among many Cardiff, 2016).

Ireland's policy makers lacked good visualizations of the looming crisis. Fig. 1a below shows the data Irish policy makers had available to them from official reports in 2005 and 2006 on household liability growth as a percentage of gross domestic product (GDP). The same data are incorporated and generalized in a European context within Fig. 1b using a heatmap, where 'hotter' colors imply larger values. Importantly for our argument in this paper, the data existed in tabular format prior to the crisis. Had they been looking at Fig. 1b, the policy maker would have been able to see the downturn in the financial side of the economy long before the downturn took place in the real side of the economy, using a different 'rhetorical machine' (Busco & Quattrone, 2015). This is because the core driver of the Irish crisis was credit growth.

Pictures of the economy have the power to *cause action* in the real world (Hines, 1988; Quattrone, 2017). They are elements of the rhetoric policy makers use (McCloskey, 1988). The Federal Reserve's 'dot plot', or the forward guidance fan chart of the Bank of England are policy tools in their own rights. They guide the actions of the market (Schwabish, 2014). We understand the firm and the macroeconomy through our visualisations, and accounting and economics share many of the same techniques. Economic reality does not exist independently of accounts of it. The builders of the first national accounts in the UK were aware of this issue. In describing the economy using an accounting framework, they helped construct economic reality. Suzuki (2003a) showed the epistemological underpinnings of the national accounts during their construction in the 1940s. This is not to say Ireland's policy makers *would* have acted differently—the constraints of organizational politics and ideology alone argue a pre-crisis response was unlikely. But they would not have been able to plead ignorance, as they universally did in subsequent reports into the banking and financial crisis. They *could* have acted with this information and identified the key issues.

One of the reports on Ireland's crisis explicitly calls for an examination of the crisis in a way that understands how accounting based views and economic modeling interact. In relation to the diagnosis of a credit bubble by the Irish authorities, Regling and Watson (2010: 40) in their official report on the crisis, write: *"Identification of poor quality loans, and the diagnosis of an undue concentration of credit risks, in the first instance requires accounting, governance and legal skills. However, assessing the pattern of overall financial risk associated with such concentrations also requires economic insights. Resource limitations and formal understandings meant that supervisors were dependent on the central bank for such economic analysis. This interaction did not prove effective."*

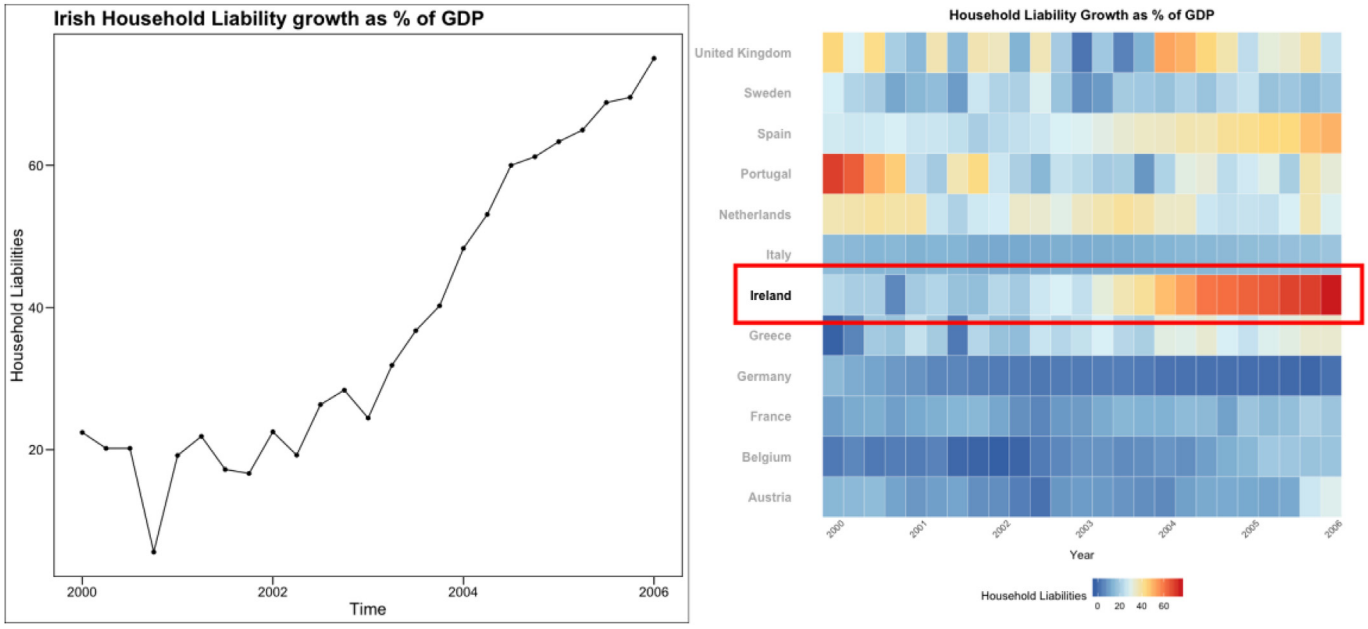

Fig. 1. a. Household liability growth as % of GDP. **b**. Household liability growth as % of GDP for selected European countries.
Source: Eurostat.

We feel the key to discovering these 'economic insights' is appropriate data visualization. It is now well recognized that policy is determined as much by the decision-making context (and other influences) as by ontologically grounded research evidence (Cairney, 2016, chapter 2). In a large systematic review of the impact of new evidence on health policy-making, Niessen et al. (2012) report the use of economic evidence as being 'small and patchy'. The review was expanded by Oliver, Innvar, Lorenc, Woodman, and Thomas (2014) to 145 more studies, moving beyond health policy studies to incorporate wider economic issues like fiscal policy. Oliver et al. (2014) found few studies even defined what they meant by 'policy', 'evidence' or 'policymaker'. Empirical data about policy processes or implementation of policy were rarely widely available. The policy-making process is not linear. Decisions take shape when individuals or groups must relate their own ideas and modes of thinking to others, and evidence is used in the process of this relating. Visualizations are a key part of evidence-based policy making in the 21st Century. In addition to being accurate (that is, representative of the underlying data), and tailored to its specific audience (in this case, policy makers), a visualization must also be a faithful epistemic representation.

Contessa (2007: 54) argues that a visualization is *"an epistemic representation of a certain target for a certain user if and only if the user is able to perform valid (though not necessarily sound) surrogative inferences from the vehicle to the target. [It] is a completely faithful representation of a target if and only if the [visualization] is an epistemic representation of the target and all of the valid inferences from the [visualization] to the target are sound."* There is a need to design visualizations which are both empirically accurate and epistemically faithful for the purposes of decision-making by policy makers (Murray, 2012).

In surveying the anthropology of decision-making and evidence-use, Boholm, Henning, and Krzyworzeka (2013: 99) identify "decision-making as contextualized processes of interaction between individuals, authorities, and social structures." In one case study of a policy failure in Canada that attempted to understand what happens as a contextualized process of interaction, Sheridan and Shankardass (2015) show the disregard of evidence by policy makers was largely to blame for the failure to provide health cover to refugees, but the process for reaching the decision was highly complex. It is not the case that better evidence leads linearly to better decision-making. However, when crisis-level events are flagged, their effects can be attenuated by policy intervention. Oliver et al. find it difficult in general to describe the role of evidence and other factors influencing policy. Donnelly et al. (2018) urge a deeper connection between research-producers and policy makers based on transparent, inclusive, rigorous and accessible foundations. A response to these findings across multiple fields is the development of the subject-wide evidence synthesis process (Sutherland & Wordley, 2018), where hundreds of journals are read and results categorized in large, comparable databases. These subject-wide processes are less rigorous than systematic, but proportionately less costly to produce. The objective is to assess the research by looking at whether an intervention is beneficial or not and summarize this evidence in a single place which is up to date, freely accessible, and easy to read. The UK government's 'What Works' programme from 2013 to 2018 tried to integrate practice and evidence across a range of domains and found the role of improved evidence and evidence-gathering was crucial[1] (Meier, 2018).

[1] The 'What Works' (2018) centers see their mission as "generating evidence, translating that evidence into relevant and actionable guidance, and helping decision-makers act on that guidance".

Taking a more historical perspective on the national accounts and visualization, Suzuki (2003b) shows macroeconomics developed epistemologically through its visualisations, from the earliest *Tableau Economique* to the modern national income accounts. Stone, Champernowne, and Meade (1942) were concerned with the accuracy and precision of the national accounts, discussing in particular what the national accounts system, then in development, might miss. The national accounts were a project in constructing economic reality by communicating it through an accounting metaphor, as the Hines (1988) quote at the start of this paper alludes to. Tress (1948) and Loosmore (1947) show clearly the 'vision' of the national economy or macroeconomy was influenced directly by the social and statistical construction of the national accounts. Kendrick (1970, 1972) discusses the development of the national accounts as bureaucratic systems, as extensions of the state's synoptic vision of itself, along the same lines are Scott, (1998) describes the development of the state's ability to see itself.

Bray (1952, 1957) shows how the design and interpretation of the national accounts are negotiated objects. Miller (1986), using the French national accounts as his case study, shows clearly the link between national accounting and national power. One exists to augment the other. All of this points to a role for more nuanced visualisations of this complex (and political) object to guide action.

Moving from the historical/political level to the policy/implementation level, many authors have now made the link between accounting and the 2008 global crisis. Both Ryan (2008) and Arnold (2009) write convincingly that accounting scholarship should be used to understand the run up to the global crisis and its aftermath. Houghton (1987) critiques the accounting approach, while de Jager (2014, pp 97–99) elegantly summarises the most recent contributions in this vein and argues that full value accounting in banks was an accelerator, amplifying the financial cycle upswing and deepening the inevitable downturn. Most post-crisis macroeconomic treatments agree with this diagnosis.

Engelen et al. (2012) argue the financial crisis was not a convex combination of accident, conspiracy, and structural failure. The standard remedy for each of these is more technocratic power, either via regulation or other market reforms. Instead Engelen et al. (2012: 375–376) put the blame elsewhere, on detached elites and their misunderstanding of the nature of financial innovation, which naturally increases in concentration, complexity and interconnectedness throughout financial cycles. "*Policy on financial market oversight […] was marked by 'hubristic detachment'– a cavalier lack of interest in the detail of financial market operations and a faith that everything was probably all right. This may have been due to a perception that the 'right kind of people' were in charge of key banking institutions*". Engelen et al. argue the technocratic elite has failed in its task as defenders of the public good. Rather than understanding the crisis as a technical failure, the authors argue finance has been divorced from effective democratic control by accountable politicians.

Coyle (2017: S230) "There is no clear theoretical link between GDP as currently defined and the consumer (and producer) surplus created by innovation, although the empirical link—at least in the long run—is intuitive and clear." GDP does not provide a good tracking statistic to understand the development of economic welfare over time. Harisson (2017: S208) identifies the core issue with the system of national accounts (SNA), as being "a set of recommendations agreed in the somewhat rarefied confines of international agencies rather than in academic institutions and with little role for others to influence the outcome." Reinsdorf, Durant, Hood, and Nakamura (2017) argue GDP is deeply flawed as a crisis measurement, because it obscures or does not capture changes in capital transfers, other changes of volume in assets, and holding gains and losses. The reason for this omission is historic.

The SNA assume income comes primarily from production. The dominant metaphor is manufacturing-based production systems, which were entirely appropriate in the mid-20th Century. Holding gains and losses and default losses obviously do not come from production, and so are not normally included in the SNA. The policy implications were enormous during the 2007/8 crisis. Reinsdorf et al. (2017: S322) aver that using these measures "implied that depository institutions were little affected by the financial crisis, even though in reality these institutions were suffering large losses and were curtailing their lending activity". It is far more helpful to follow Hicks (1946, 178-9) to define income as encompassing all expected sources of change in wealth, and Reinsdorf and his colleagues design exactly such a measure at the aggregate level. The SNA already recommends showing the total of all sources of change in wealth in the balance sheet account, and they expand upon it.

While not visible at the aggregate level, at the sectoral level, these changes are visible in the visualisations we present in section 4 at the asset and liability levels as changes are recorded in the valuation account (SNA 2010: 233, III.3.2). Beyond national accounting issues, the policy import of accounting for stocks and flows is a persistent issue. Gordon Brown, while UK Prime minister, argued for creation of "an early warning system so that international financial flows are properly monitored" (Brown, quoted in Engelen et al., 2012). Clearly a substantial amount of work remains to integrate gross and net flows globally.

The rest of this paper is laid out as follows. Section 2 discusses relevant overlaps between economic modeling, national income accounting, and the sociology of visualization. Section 3 describes an accounting model of the Irish economy. Section 4 concludes.

2. Overlaps between economic modeling, national income accounting, and the sociology of visualization

Several studies have tried to understand how economic ideas are communicated visually. In a classic study, Cleveland and McGill (1984) used economic data to show how people encode decisions and colors. They write (pg. 535) *"The power of a graph is its ability to enable one to take in the quantitative information, organize it, and see patterns and structure not readily revealed by other means of studying the data."* The visual display of quantitative information is not a value-free activity, abstracted from the language it is written within. When connected to the mechanisms of power and influence, visualization as a branch of the rhetoric of economics is a deeply political activity (McCloskey, 1988). Policy makers, however, must decide based on the evidence encoded by these displays, and their decisions can have society-wide consequences. The correct approach, we argue, is to use *all* available information from consistently measured balance and transaction matrices, and display them in a 'dashboard' style, relying on policymaker's natural intelligence to make the necessary inferences as events unfold. This helps us avoid the trap of oversimplifying what is a very complex system.

Tufte (1983, 1997, 2006) argues for the use of maximal informational data density for decision-making, where informational density is defined as the ratio of the number of entries in a data array divided by the area of a data graphic1. Tufte (1983, pages 160–168) defines graphical excellence as something that "gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space". That principle has guided our work here. Models should produce outputs with a combination of graphical clarity, precision, and efficiency to avoid distortions of what the data have to say; aid the reader in their thinking about the information, rather than just the design; encourage the eye to compare data; make large data sets coherent; present a large number of data in a small space as much as possible; reveal data at multiple levels of detail ranging from a broad overview to fine detail; and closely integrate statistical and verbal descriptions of the data. Tufte uses the benchmark of numbers per square inch of text. A sunshine record has a ratio of 160 numbers per square centimeter. A histogram gets around 4 numbers per square centimeter. A line graph of Irish real gross domestic product from 1960 to 2017 for example, has a density of 4 per square centimeter, while an animated weather forecast simulation for the Ireland for one day has a density of 1600 per square centimeter.

Newer visualization techniques are being developed to understand the roots of the crisis. Betz, Oprică, Peltonen, and Sarlin (2014) employ a tree graph method to observe changes in the stability of the banking system. Sarlin and Eklund, (2013a); Sarlin and Peltonen, (2013b), Sarlin (2014, 2016) explores the visualization of financial system and macro-economies, developing self-organized tree maps based on the work of Kohonen (1982, 2001), and other imaging techniques to understand systemic crises, particularly in banking systems. Sigl-Glöckner (2018) develops interbank network visualization tools to help understand systemic threats. The European Central Bank has begun using graphical techniques to try to assist policy makers in 'seeing' crises as they occur. Increasing the informational density of a display aids the viewer in deriving useful insights, as long as the display is not distorted for some reason, and as long as the display does not obscure the content it is designed to display. In the context of the Irish economic crisis, then, if these graphical displays derived from simple accounting models had existed, the clear connections between the financial and real economies could have been more apparent. Rather than focusing on the real side of the economy and expressing the crisis as a liquidity problem for the banks, the very large increases in assets, liabilities, differing funding sources and increasing fragilities of household and financial corporate balance sheets would be more apparent. The problem might well have been expressed as a solvency problem for the sovereign, as it turned out to be. None of the above precludes the likelihood poor decisions in the run up to the 2008 crisis would have occurred. But decisions would have certainly been made with more information, and a lack of information was identified in official reports after the crisis as a key contributing factor (Honohan, 2010; Regling & Watson, 2010). The key principles in constructing visualizations for economic policy makers arising from this experience are:

1. The perception of patterns;
2. The discernment of structure and structural changes within the economic system;
3. The development of appropriate and trusted indicators for taking effective and timely action;
4. The ability to deal with changes in uncertainty.

In order to respond to these issues, we need to be sure the data are correctly measuring the right things, that they are consistent across time and with each other—that is, everything must come from somewhere, and go somewhere—and that these data must integrate the real and financial sides of the economy. Stock flow models were built using the 'money flows' approach of Copeland (1949), the central tenet of which is that every monetary quantity must come from somewhere and go somewhere. The objective is to integrate as many aspects as possible in one 'dashboard' type space. Stock Flow Consistent accounting models, directly stemming from Wynne Godley's work (1999, Godley, Izurieta, and Zezza (2004),Godley and Lavoie, 2005). The aim of the stock flow consistent framework is to provide a comprehensive and fully integrated representation of the real and financial sides of the economy through the adoption of rigorous accounting rules (Nikiforos & Zezza, 2017; Zezza, 2016). This approach employs

specific social accounting matrices to track the variation of financial stocks and flows and to ensure that every financial stock or flow in the economy is recorded as a liability or outflow for someone and an asset or inflow for someone.

Stock flow consistent models are built from the national accounts, which equates the current account with the financial account, and allows the connection of the real economy with the financial in a data-based, and rather theory-free, manner. Transaction-flow matrices and balance sheet matrices are written to ensure the model's elements all 'come' from somewhere and 'go' somewhere else, that is, we can track stocks and flows over time between sectors, and then a series of equations are written, some based on clearly socially constructed but universally accepted 'identities', such as $Y = C + I + G + X$ - M, some balancing, such as consumption supplied Cs equals consumption demanded, Cd, and some behavioral equation relating consumption C to disposable income, YD, and net worth from the previous period NW, such as $C = \alpha_1 YD + \alpha_2 (NW)_{-1}$, where α_1, the marginal propensity to consume out of current income, can be estimated econometrically, as can α_2, the marginal propensity to consume out of past income. At the level of the behavioral equation, different neoclassical, Keynesian, and Post-Keynesian theories can be tested, because the two α parameters of this (typically post-Keynesian) consumption function must typically be estimated using econometrics. For the purposes of this paper, we do not model the economy using behavioral equations. We simply make the data stock flow consistent and display them in novel ways. Alternative empirical approaches have been followed in the past. Zezza (2012) uses a cointegration approach. Duwicquet, Mazier, Petit, and Saadaoui (2015) use a structural vector auto regression approach. In 2011, the Bank of England used an OLS-based flow-of-funds approach to analyze the mechanics of financial instability. Barwell and Burrows (2011) advocated the diffusion of macroeconomic approaches that stress the importance of balance sheet linkages in spotting buildups of financial fragility amongst the sectors of the economy. These models have already been directly applied to the analysis of policy applied to the analysis of policy in the UK by Burgess et al, (2016). Using flow of funds accounts to analyze the US economy at the turn of the century Godley (1999) and later Godley et al. (2004) pointed out how growing household indebtedness was pushing asset inflation and increasing systemic risk under the surface of the great moderation of the early 2000s, anticipating the crisis with significant precision regarding the timing and describing the mechanics of the collapse. Caiani et al (2016) extend the stock flow consistent approach to encompass agent-based models of the macroeconomy.

The stock flow consistent approach is not without its critiques. Taylor (2008) worries about the stability of stock-flow models. Andersson, Lee, Theodosopoulos, Yin, and Haslam (2014) are unconvinced of the need to completely close the matrix of transactions to model the economy. They argue the stock-flow relations between what they term 'material institutional elements' are sufficient. Discrepancies emerge between stock (capitalisations) and liquidity (cash earnings) in certain institutional sectors which transmit to others via the double entry booking process of national accounting. They argue the process inflates, rather than reduces, any financial disturbance.

We turn now to the model of the Irish crisis which itself stems from a deep financial disturbance in the supply of credit to the economy.

3. An accounting model of the Irish crisis

Ireland as a very small and very open economy benefitted from the period of low risk premia and high liquidity that prevailed across the developed world from the beginning of the decade, as well as historically loose monetary policies. Ireland's membership

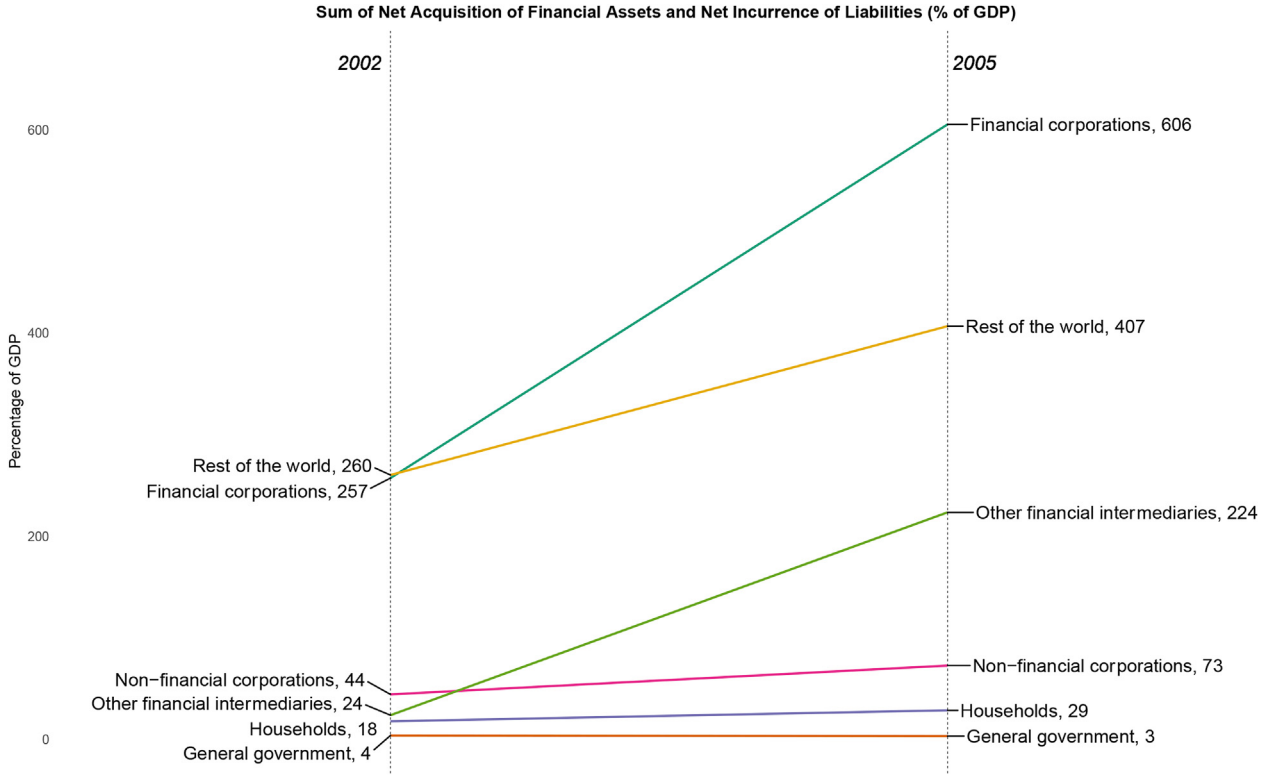

Fig. 2. Slopegraph of net acquisition of assets and liabilities between 2002 and 2005.

of the Eurozone increased the interconnection of capital markets. There was a sea change in the availability of cross-border bank funding without the complication foreign exchange exposure post 2001. Fig. 2 shows a slopegraph of the net acquisition of assets and liabilities by sector from 2000 to 2005. The influence of the Rest of the World is obvious and striking.

Ireland experienced the buildup and collapse of asset values in the residential and commercial property markets. Three reports into the crisis explored the mechanisms behind the emergence of the asset bubbles (Honohan, 2010; Nyberg, 2011; Regling & Watson, 2010). Each report agreed the primary cause was excessive credit lent to households and businesses from the financial corporate sector, as shown in both Fig. 1a and b. The level of risk management within individual banks, as well as core credit risk controls, were not sufficient Kinsella, 2012, 2014; O'Sullivan & Kinsella, 2013; O'Riain, 2014). The growth rate of the ratio of private sector credit to GDP increased by 450% from 2002 to 2007 before reducing significantly in 2008 as the crisis took hold. The expansion of credit fed into an unstable dynamic of increasing asset prices, increasing expectations amongst households of ever-increasing property values, which fed into wage increase demands and fed further demand for property. With effective regulatory supervision, credit supply could have been more effectively contained.

Combined with the decade-long experience of very strong domestic expansion from 1994 to 2004, these inflows exposed Ireland to large inward downside risks, channeled through the domestic banking system. For a very small open economy with a highly developed export sector dependent on multinational companies, particularly in pharmaceuticals, countries outside the euro area with excessively expansionary fiscal policies helped push the level of Irish nominal GDP ever higher. The international context certainly contributed to the expansion of the credit boom, the strong increase in household debt, the generation of the property bubble and the general overheating of the economy, including altering the labour market and affecting Ireland's long run competitiveness as measured by unit labour costs.

Irish fiscal policy was, and remains pro-cyclical (Fitzgerald, 2009; Lane, 2011; Weymes and Bermingham, 2012) and as the years of the boom went on, increasingly dependent on windfall taxes from property transaction taxes rather than on carbon, water, or site-value-type taxes. Computed from 1990 to 2016, and especially from 2000 to 2017, Ireland has one of the highest standard deviations in taxation revenue per person in the OECD. This volatility comes from the changing nature of the sources of expenditure, rather than the expansion of the targets of that expenditure. Fig. 4 shows the changing sources of taxation in the Irish economy. The two most volatile series over the period from 1984 to 2017 were Property-related taxes, chiefly stamp duties, and Corporate-related taxes, chiefly the standard corporate rate. These taxes are highly pro-cyclical. This policy has historically challenged its ability to weather sustained economic crises (Lee and Lee, 1989). Coordinated wage setting policies increased wages over the period, and income tax policy accommodated these increases by reducing

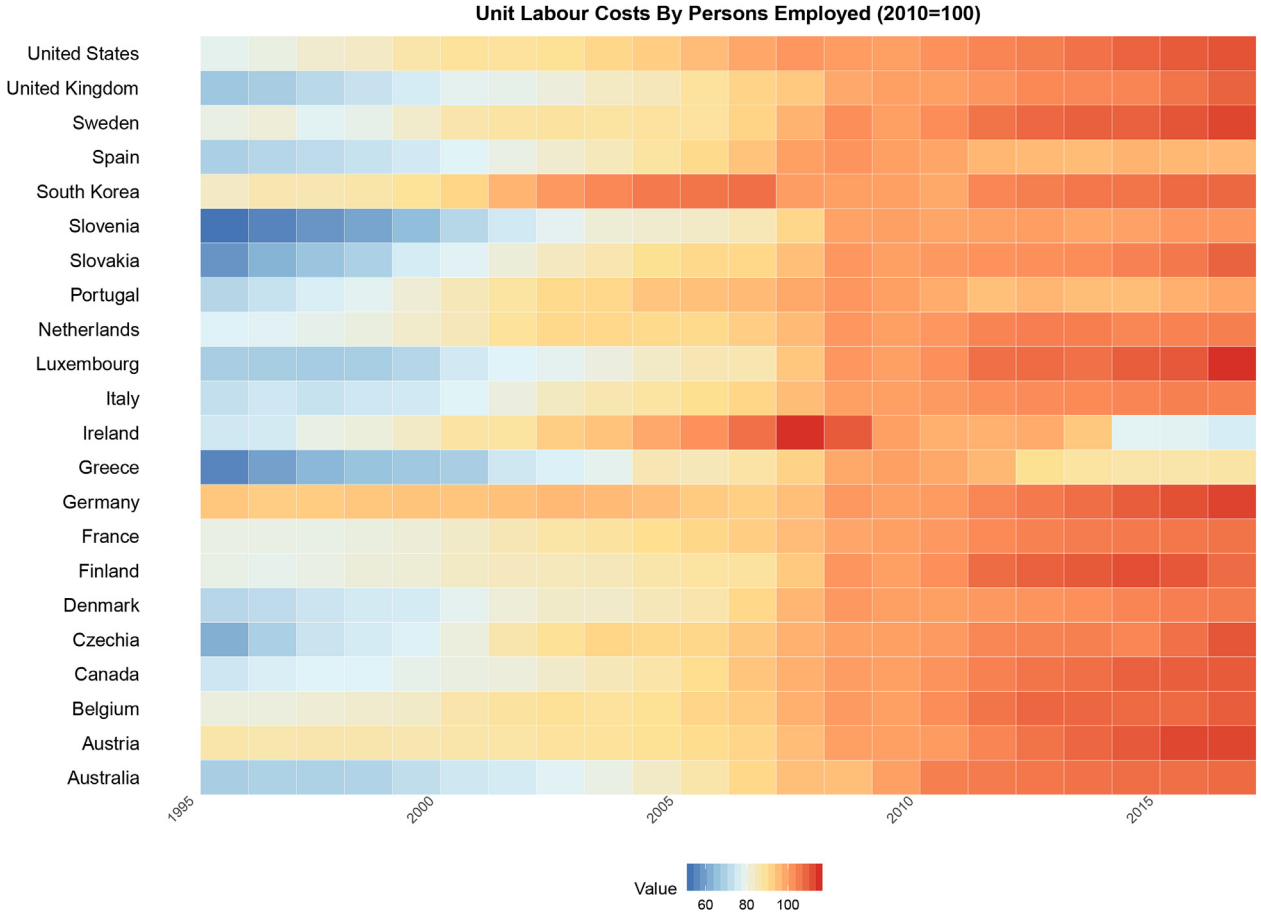

Fig. 3. Heatmap of unit labour costs.
Source: Eurostat.

income tax rates. This substitution from income taxes to stamp-duty and capital gains taxes did not go unnoticed. Both the EU Commission and the OECD highlighted the weaknesses coming from a narrowing of the tax base, but as Ireland's Stability and Growth Pact targets and commitments were never in breach, they had little official recourse and as detailed in O'Riain (2014) and Byrne (2012), the Irish authorities were not interested in discussing any potential weaknesses. Once the crisis hit, only Ireland's extremely low debt to GDP ratio (24% net debt to GDP in 2006) helped in buffering the large fiscal shock as the authorities tightened fiscally as output fell and unemployment rose from 4% to 15.1% in 23 months.

Note that in each mechanism outlined above, there was a clear connection between the 'real' and 'financial' aspects of the economy. The best representation we have of these interconnections is the balance sheet. Proceeding from this insight, it makes sense to look at an accounting representation of the Irish economy before, during, and after the crisis.

We model the economy following the national account structure as a five-sector system with interacting balance sheets. Households (HH), Non-Financial Corporates (NFC), Financial Corporates (FC), Government (G) and the Rest of the World (ROW). Each row and column are designed to ensure stock flow consistency. That is, every element in the balance sheet and transaction matrices comes from somewhere, and goes somewhere (Copeland, 1949). Full details of the model are given in the appendix. Having aggregated national accounts data so as to make them stock-flow consistent, the data now exist in a format where, if simply tabulated, and displayed as they evolve over time, they can serve as a guide for policy formation.

Visual displays provide the highest bandwidth channel from the computer to the human (Ware, 2013, p. 2). According to Flood, Lemieux, Varga, and Wong (2016: 191) Visualisations act as a form of "*externalised memory [...] which can enlarge an analyst's problem-solving capabilities by enabling the processing of more data without overload*".

Fig. 5a and b shows alluvial graphs. Alluvial graphs are typically used to visualise changes in group composition between states or over time. They typically include statistical information to reveal any significant changes. Alluvial diagrams highlight important structural changes that can be further emphasized by colour, and make identification of major transitions easy.

Fig. 5a and b which depict the non-financial transaction flows in the economy for each sector in 2003 and 2009 as alluvial graphs. Through these charts, policymakers can identify the changing sizes in sectors and items within the economy. For instance, the growth

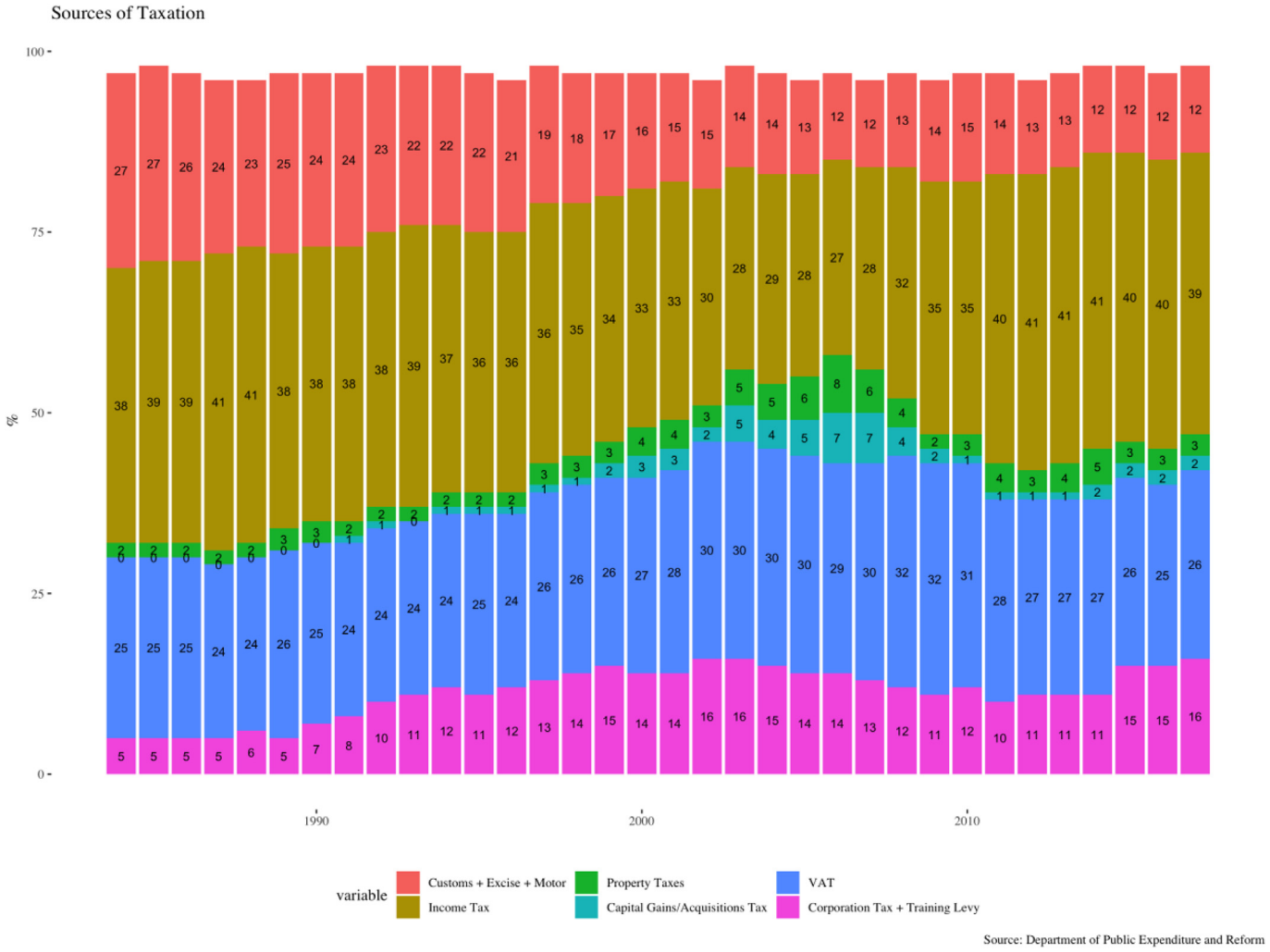

Fig. 4. Sources of taxation.
Source: Department of Public Expenditure and Reform.

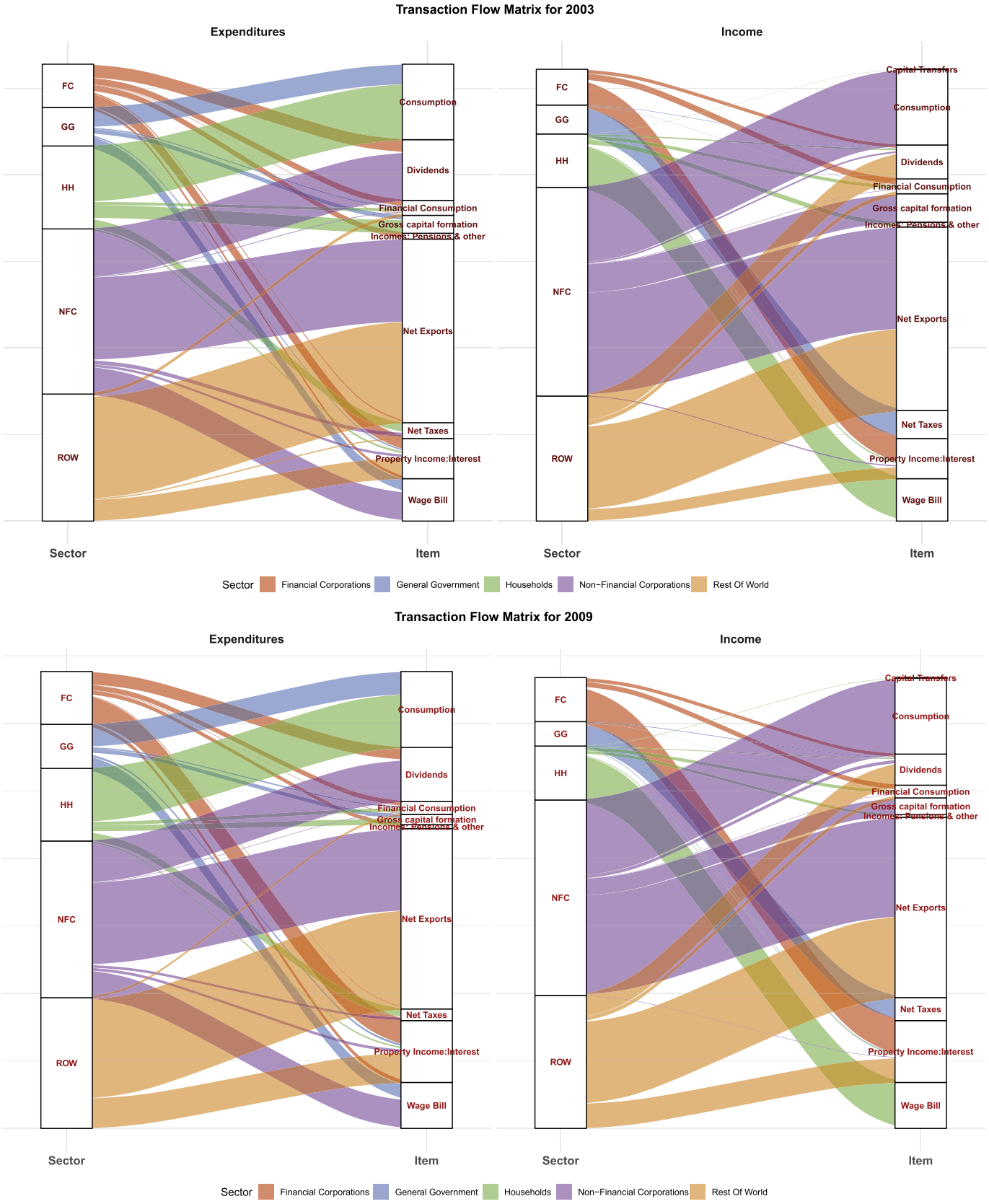

Fig. 5. **a** and **b**. The absolute values of non-financial transaction flows in Ireland in 2003 and 2009 for each sector accounts.

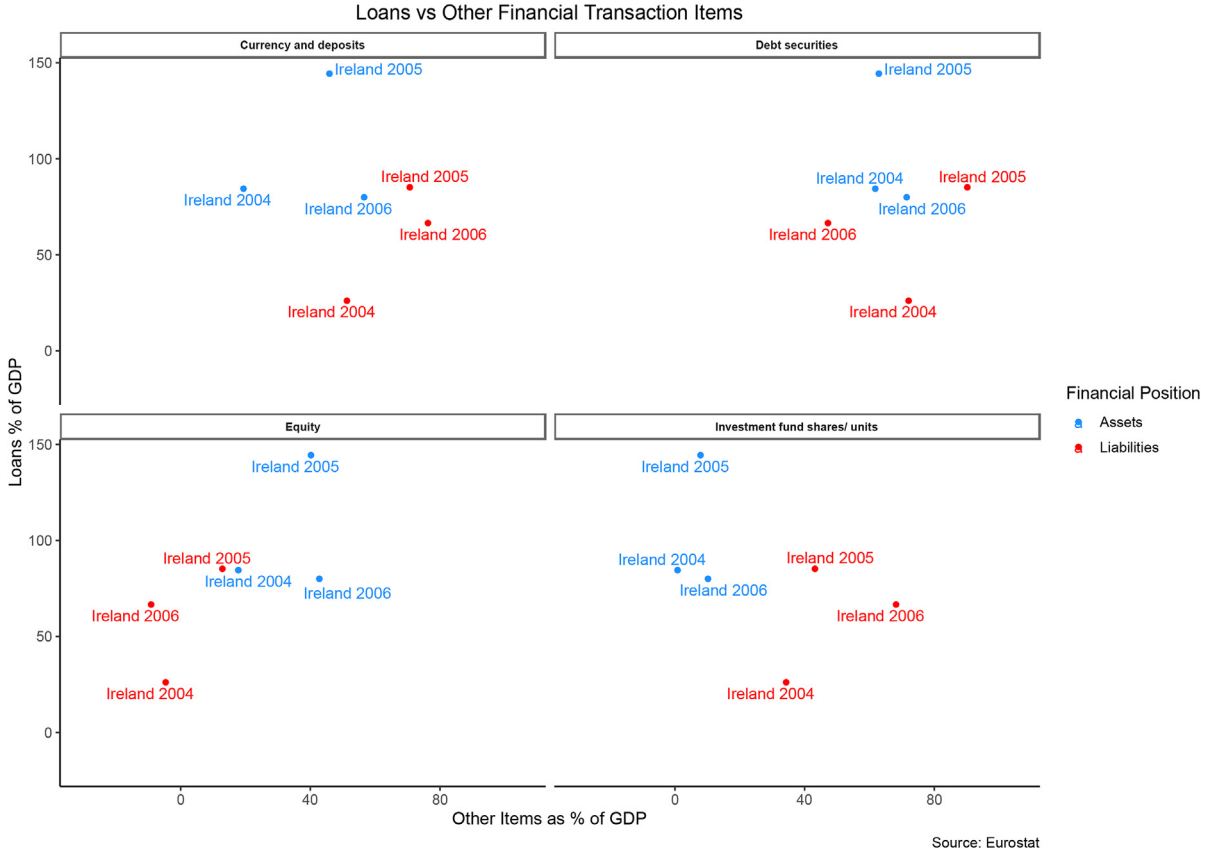

Fig. 6. **a** and **a**. Scatter plots depicting stock and flow transactions of 26 countries plus the average of the EU28 and the EA19. Ireland is highlighted. *Note:* Luxembourg, Malta and Cyprus are omitted.

in property income from interest is seen in 2009 when compared to 2003. The financial corporation sector also increased in size in this period. While gross capital formation reduced in size in this period. The disparity between expenditure and income of households is also clear, indicating the continued growth in household debt. To fully inform the policy-maker in a real-time setting an animated version could be used displaying the changes over time.

Changes in the composition of transaction-flow data for a small open economy are highly important. However, absent data on the flows of capital into, and out from, the economy, we miss a crucial part of the story. Fig. 6a and b shows scatter plots depicting 26 countries plus the average of the EU28 and the EA19. Luxembourg, Malta and Cyprus are then omitted to further highlight Ireland's position. The charts are data dense and contain close to 3000 observations.

Fig. 6a shows a balance sheet scatter plot. For balance sheets scatter plot. This scatter plot outlines the relationship between total loans and other selected financial items, with each point representing a European country in a specific year. For clarity, Ireland is highlighted.

In each chart Ireland had significantly larger financial holdings compared to the rest of Europe. The large size of the financial sector and the clear financialisation of other sectors of the economy is also observable from Fig. 6a. These large holdings relative to EU were not outlined in the years leading up to the crisis and heavily exposed Ireland to international shocks.

Fig. 6b is similar to Fig. 6a, but shows flows rather than stock positions. From this figure, the rapid growth in Irish investment, debt and loans is visible. The rapidly increasing importance of the Irish financial sector is also evident from the chart, as both assets and liabilities increased in size. If charts like these were used by the government rather than simple line charts, the unsustainable nature of Ireland's growth would have been evident to both policy-makers and the public.

It is unlikely this treatment of the data is enough. Policy makers and their advisors are uniquely overwhelmed with large quantities of material to read and digest. As Tufte (2003) writes "*comparisons must be enforced within the scope of the eye span, a fundamental point occasionally forgotten in practice*". The next step in informing policy makers using the full extent of these data comes in displaying them to their greatest effect and with their greatest level of density.

Heat maps are two-dimensional representations of data in which values are represented by colors. The strength of the correlations between 'inflows' and 'outflows' by sector and by size over time allows us to represent the Irish economy in a completely new way utilizing the balance sheet data made stock flow consistent above. Figs. 7 and 8 present correlation-based heat maps of the individual elements of the balance sheet of the Irish state. We aggregate from the 'pre-crisis' years of 1999–2007 and then from the 'crisis and post-crisis' years from 2008 to 2017, but quarterly

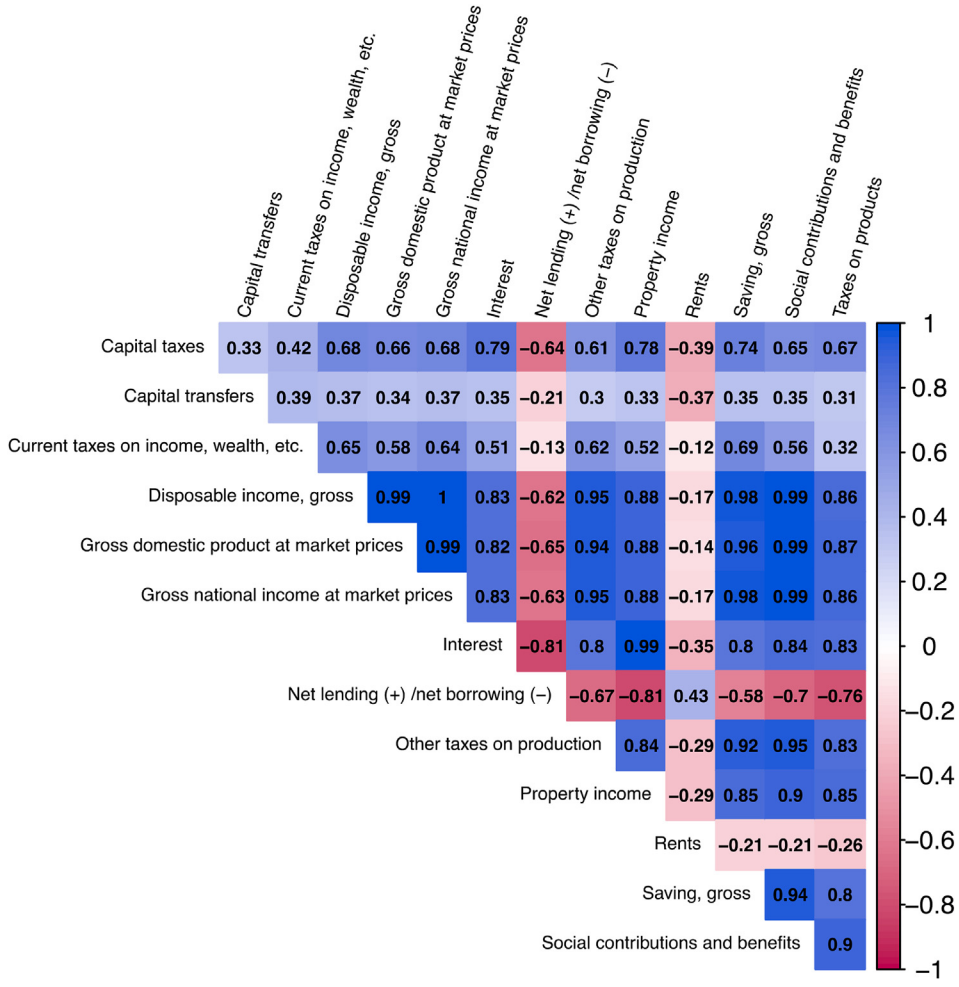

Fig. 7. Correlation matrix: 1999–2007.

correlation maps are just as easy to produce. These are very high-resolution correlation maps, encoding a data density of roughly 1000 per square centimeter on a single graphic, a more than 50-fold increase in resolution over a line graph. There are roughly 90,000 observations per chart.

The complexity of the model is subsumed within relatively simple visualizations. This is to contain, as much as explain, the underlying complexity. Humans process simple visual objects serially. For highly concentrated tasks, this processing occurs at a rate of between 40 and 50 milliseonds. Humans remain 'fixated' on a given object for between 100 and 300 ms. The average human can therefore process between two and six simple objects or shapes selectively at a time (Bundesen & Habeskost, 2008). This is Kahneman et al.'s (1992) object file concept. To quote Ware (2013: 393), "*visual imagery uses the same neural machinery as normal seeing*". Figs. 7 and 8 display correlograms, which outline the relationship between major items of the national accounts before and after the financial crisis. Each of these figures is intended to be viewed as an animation, with the correlation coefficient changing over time in response to new data, as well as structural shocks. The idea display would show a series of correlations—short term, with items correlated year to year, medium term, with items correlated over a three-year moving average, and over an eight to ten year period, as shown in the figures below.

Fig. 7 shows the strong co-movement in these items. Net lending/borrowing being the strongest negative value suggests that the economy as a whole was becoming heavily indebted over this period. Fig. 9 holds weaker coefficients as the national account items decreased or stagnated in value in the years following the crisis. Note the changing nature of important elements of the national accounts, such as the correlation of interest with property incomes, which weakened from an average correlation of 0.99 over the first eight years of our data set to 0.71 in the second ten years.

Fig. 9 maps the progress of the economy in a heatmap through time. Two boxes show the buildup of short-term loans on the liability side, analogous to the data shown in Fig. 1a and b. The next box shows long term loan buildup on the asset side, analogous to the mismatch which developed in the property market. Combining both 'across time' and 'across flow type' visualizations, we now have a tool kit for policy makers to 'see' the evolution of the Irish economy, or any ESA-2010 compliant economy, in a more detailed and interconnected manner. In a very real sense, we can now 'see' the austerity policies implemented from 2011 to 2013. Policy makers interested in tracking and mapping the correlation structures of individual elements of the economy can 'zoom' in by looking at non-financial transactions, financial transactions, and balance sheet values. We can also show a comparison for just the financial corporate sector, or the household sector, using the same data.

Fig. 10 depicts the net saving rate for European households in a

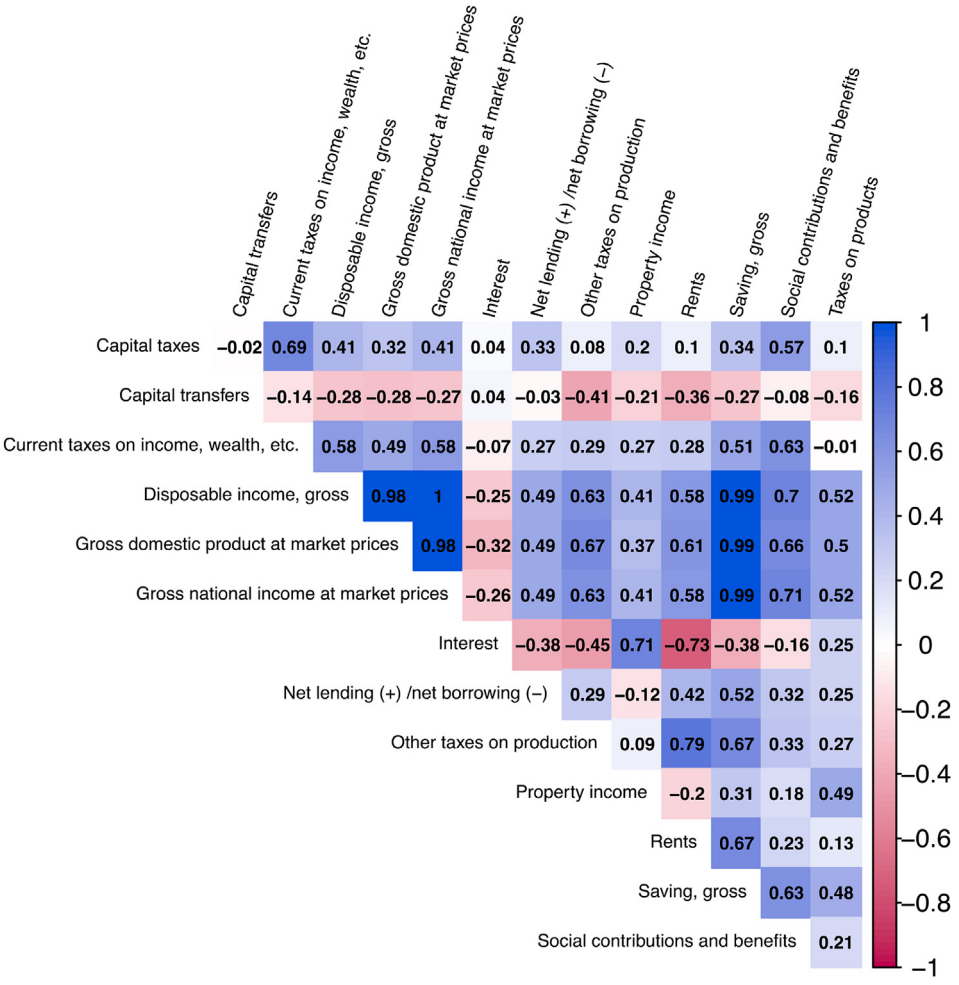

Fig. 8. Correlation matrix, 2008–2018.

grid mirroring their geographical location. This is total saving minus net financial asset position. When a data element falls below the dotted line, it indicates growing household debt, whereas a positive value indicates increasing saving and investment. Perhaps the greatest contrast is seen between Ireland and Germany leading up to the crisis. Irish households held the largest debts in Europe relative to GDP, Germans holding the highest savings and investments in Europe relative to GDP. It is vital to understand Ireland as a regional economy within Europe, and this figure does just that.

There are different dimensions to the crisis, and different visualizations illuminate them. The unsustainable build-up of credit, sourced mainly from the rest of the world, can be seen in Figs. 1b and 2. The effect of procyclical fiscal policies and unsustainable labour market dynamics can be seen in Figs. 3 and 4. The flow-based nature of many elements of the crisis can be seen in Fig. 5a and b. Fig. 6a and b shows the 'capital story'. Figs. 7 and 8 show us the changing nature of the economy before and after the crisis in correlational terms. Figs. 9 and 10 show us the time and geographical/regional dimensions of the policy problem.

We argue for a suite of visualisations to avoid what Jordan et al. (2018: 34) correctly caution against: the overconfidence visualizations can give policy makers by which "*complex and potentially not well understood processes come to appear simple, imaginable and 'manageable'*".

4. Conclusion

Crises occur when a macroeconomic shock like the collapse of a bank-credit fueled asset bubble exposes weaknesses in sectoral balance sheets. The shock can be transmitted across the country very rapidly if it occurs within the banking system. The more fragile the banking system is in terms of its ability to use risk-absorbing capital to offset losses, the more likely a banking crisis is to happen. These crises do not come from space. They buildup within the balance sheets of key sectors of the economy. There are severe distributional consequences associated with macroeconomic shocks like these. Ireland experienced most of them. There is a pressing need for specific evidence-based measures to guard against such shocks. Given the complexity of the policy problem, the objective of this paper was to argue for, and then to develop, a series of accounting-based representations of an economy based on its national accounts. These visualizations are designed to act as a 'dashboard' of data-based displays for policy makers to use into the future.

The crisis has exposed a need for models to incorporate the real and financial sides of the economy, modeling feedback effects, systemic risk and asserting the primacy of banks and other financial corporates into our thinking about what policies might stabilize the economy over time. The use of a stock-flow consistent accounting type model of the economy rather than standard economic models is sensible in this context. In addition to improved

Fig. 9. Time-based correlation heatmap for the entire Irish economy.
Source: Eurostat.

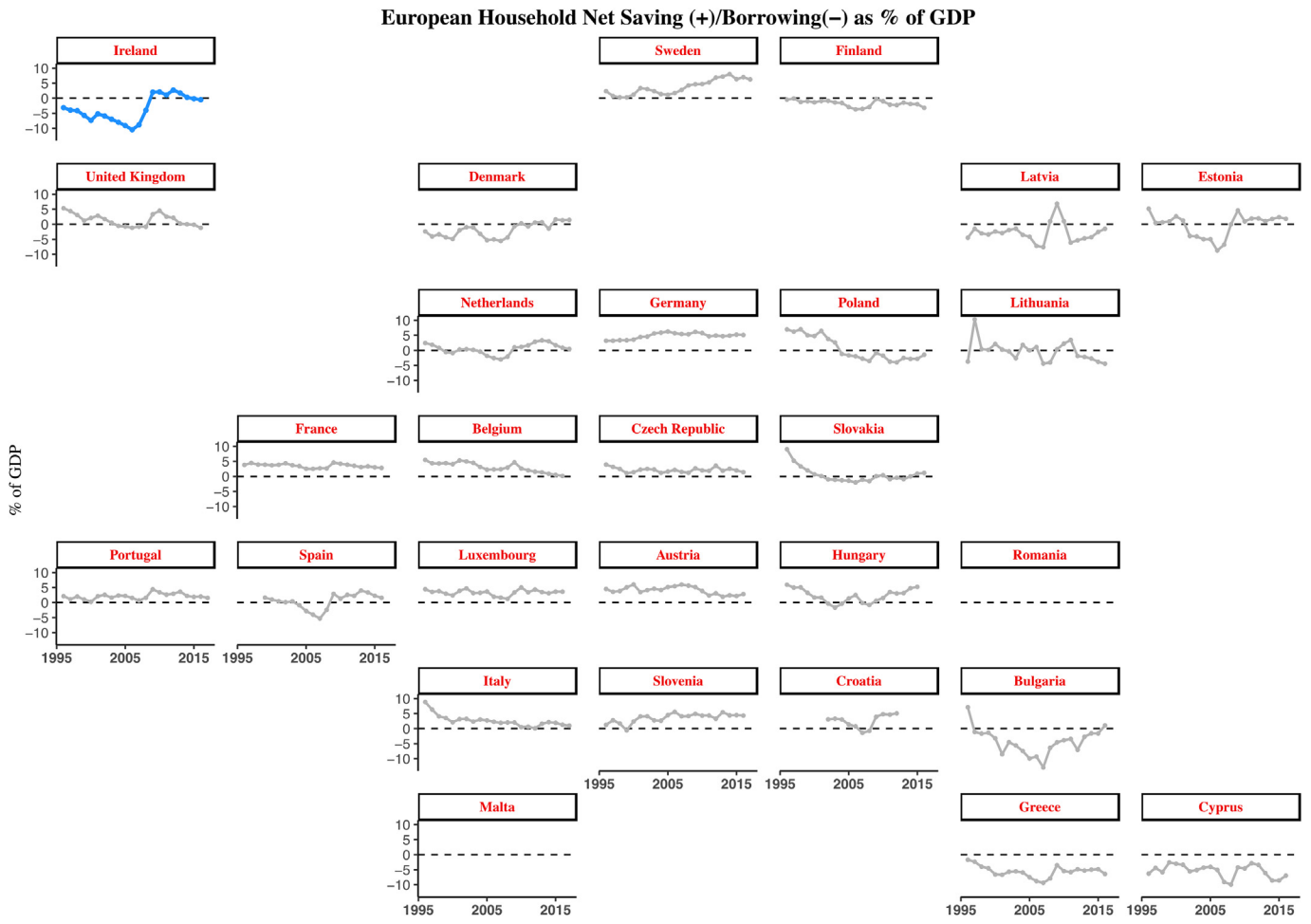

Fig. 10. European household net saving/borrowing.
Source: Eurostat.

visualizations, the 2008 financial crisis also exposed the need for economic models that can incorporate the real and financial sides of the economy. Wieland, Cwik, Müller, Schmidt, and Wolters (2012) compared 50 mainstream macroeconomic models. All failed to predict the crisis. All continued to underestimate the scale of the crisis for an average of 8 quarters after the onset of the crisis. Models based on national accounting data were the most successful at 'seeing' the build-up of the crisis (Bezemer, 2010). The models of Wynne Godley (1999) were particularly successful at pointing out both the causal mechanisms and the likely extent of any downturn. Given that models based at least partially on accounting were the most successful at 'seeing' the buildup of the crisis, it follows that models based on accounting will be at least beneficial in helping policy makers avoid the worst kinds of omission.

In a macroeconomic context, external artifacts such as visualizations are 'carriers of ideas' about the economy's past and future performance (Himick & Brivot, 2018). The purpose of this article is to examine new carriers of more complex ideas derived from a 70-year-old system of data-gathering about the economy, the national accounts.

We therefore built an accounting-based model of the Irish economy and developed a suite of open-source visualizations based on the stock flow consistent data produced from the model. These visualizations markedly increase the data-density the policy maker is exposed to. They do not subtract overly from the complexity of the data or the decision-making task, but rather add layers of evidence to support decision-making by small teams. The economy is too complex to be described by one measure, or even one set of measures.

In practice this toolkit will have to expand along the lines outlined by Sarlin (2014). Future work will involve building real-time interfaces of many countries and country groupings simultaneously, as well as network models of international interactions in both the real and financial spaces. A key weakness of the current approach is the isolated nature of some of the national accounting data, as well as the financialisation which can distort small open economy national accounts (Froud et al., 2006). A comparative and up to date set of visualizations would be key in discovering these measurement errors, and helping answer important policy problems, such as the role of tax havens in the 21st Century.

Appendix

Custom R scripts 'rip' data from the national accounts from the ECB's databases, and merge them into the balance and transactions matrices displayed below. Details of this merging process are given within the scripts for reproducibility. These scripts are freely

available and documented and can be used for any country with comparable national accounts.

The economy is composed of households (H), non financial firms (NFC), financial firms (F), the government (GG), and the rest of the world (ROW). Data are quarterly from Q1, 1999 to Q2, 2017. The bottom part of the table covering the standard income and expenditure flows and the top half covering financing flows. The two halves of the table are linked together by each sector's 'net lending balance'. Tables A1 and A2 show the detailed interactions between each sector's balance sheets in gross terms.

To read tables A1 and A2, begin by noting the exact location in the system of national accounts for the data we use. Thus in table A1, the symbolic matrix, the transaction flow matrix F3: Bonds shows the reader precisely where to find these data for any country in their national account structure. We note the stock of assets and liabilities for each sector as well as the income and expenditure location. So for example the first element in the Bonds row: +A.BND.H represents the euro denominated nominal value of the stock of bonds held as an asset (A) by household sector (H) in the national accounts in a given quarter. Bonds BND are held as assets and liabilities by every other sector. In the transaction flow matrix, the flow of bonds around the system are tracked within the row, so for example + A.FL.BND.F is the inflow (or uses) of bonds into the financial corporate section F, booked on the asset side of the balance sheet, and -L.FL.BND.F is the outflow (or resources) of bonds emitted by the financial corporate sector, booked on the liability side. Down the columns we can sum the aggregate values of assets and liabilities by sector, giving us L.FL.NETFTR.H as the net financial wealth of the household sector, which is essentially the capital account.

Moving to the real economy for another example, Net Taxes are emitted by households, -EXP.T.H, financial corporates, -EXP.T.F, non-financial corporates, -EXP.T.N, and the rest of the world, -EXP.T.R, and are absorbed by the government as income, +INC.T.G. It is also the case that net lending and borrowing in the real economy, EXP.NL.H and net lending and borrowing on the financial side, L.FL.NETFTR.H, balance, period by period. The same is true for other columns. The same logic and notational convention applies across this matrix. It shows the integration of the real (B.9) and financial sides (B9.F) of the Irish economy, essentially where the current and capital accounts balance. This is what is missing in most macroeconomic models today. Each balance sheet and transaction matrix is consistent within both quarters and across time. Table A1 shows an example for the financial part of the transaction second quarter of 2012 with the algebraic (balance sheet) relationships of Table A1 given numeric form. Returning to Tufte's data density concept, this table has 70 numbers in a 7 cm square, with a data-density of 10. A line graph of the 48 points of household incomes contains a data density of roughly 4 per square centimeter, as mentioned in the introduction. Having aggregated national accounts data so as to make them stock-flow consistent, the data now exist in a format where, if simply tabulated, and displayed as they evolve over time, they can serve as a guide for policy formation.

Table A1
Real and Financial Integration via transaction matrix description of the economy: Financial side.

Financial Flows

Sector	Households		Financial Corporations		Non-Financial Corporations		Government		Rest of World	
	incomes_hh	expenditures_hh	incomes_fc	expenditures_fc	incomes_nfc	expenditures_nfc	incomes_gg	expenditures_gg	incomes_row	expenditures_row
Cash	+CASH.H		+CASH.F	-CASH.F	+CASH.N		+CASH.G	-CASH.G	+CASH.R	-CASH.R
Deposits	+DEP.H		+DEP.F	-L.FL.DEP.F	+A.FL.DEP.N		+A.FL.DEP.G	-L.FL.DEP.G	+A.FL.DEP.R	-L.FL.DEP.R
Bonds	+A.FL.BND.H		+A.FL.BND.F	-L.FL.BND.F	+A.FL.BND.N	-L.FL.BND.N	+A.FL.BND.G	-L.FL.BND.G	+A.FL.BND.R	-L.FL.BND.R
Loans		-L.FL.LN.H	+A.FL.LN.F	-L.FL.LN.F	+A.FL.LN.N	-L.FL.LN.N	+A.FL.LN.G	-L.FL.LN.G	+A.FL.LN.R	-L.FL.LN.R
Equities				-L.FL.EQ.F		-L.FL.EQ.N			+A.FL.LN.R	
Insurance & reserves	+A.FL.ITR.H			-L.FL.ITR.F					+A.FL.ITR.R	
Other Accounts	+A.FL.OTH.H	-L.FL.OTH.H	+A.FL.OTH.C	-L.FL.OTH.F	+A.FL.OTH.N	-L.FL.OTH.N	+A.FL.OTH.G	-L.FL.OTH.G	+A.FL.OTH.R	-L.FL.OTH.R
Net Financial transactions		L.FL.NETFTR.H		L.FL.NETFTR.H		L.FL.NETFTR.N		L.FL.NETFTR.G		L.FL.NETFTR.R

Table A2
Real and Financial Integration via transaction matrix description of the economy: Real side.

Real Economy Flows										
Sector	Households		Non-Financial Corporations		Financial Corporations		Government		Rest of World	
	incomes_hh	expenditures_hh	incomes_fc	expenditures_fc	incomes_nfc	expenditures_nfc	incomes_hh	expenditures_hh	incomes_fc	expenditures_fc
GDP	+INC.GDP.H		+INC.GDP.F		+INC.GDP.N	-EXP.GDP.N	+INC.GDP.G			
Wage Bill	+INC.WB.H			-EXP.WB.F		-EXP.WB.N		-EXP.WB.G		
Net Taxes		-EXP.T.H		-EXP.T.F		-EXP.T.N	+INC.T.G			-EXP.T.R
Property Income-Interest		-EXP.INT.H	+INC.INT.F			-EXP.INT.N		-EXP.INT.G		-EXP.INT.R
Incomes: Pensions & other	+INC.PENS.H			-EXP.PENS.F					+INC.PENS.R	
Dividends				-EXP.DIVD.F		-EXP.DIVD.N			+INC.DIVD.R	
Insurance premia		-EXP.INSP.H	+INC.INSP.F			-EXP.INSP.N		-EXP.INSP.G		-EXP.INSP.R
Consumption		-EXP.C.H			+INC.C.N			-EXP.C.G		
Capital Transfers	+INC.CAPT.H		+INC.CAPT.F		+INC.CAPT.N			-EXP.CAPT.G	+INC.CAPT.R	
Gross capital formation		-EXP.GFCF.H		-EXP.GFCF.F	+INC.GFCF.N	-EXP.GFCF.N		-EXP.GFCF.G		
Net Exports					+INC.NX.N	-EXP.NX.N			+INC.NX.R	-EXP.NX.R
Social contributions		-EXP.SCON.H	+INC.SCON.F					-EXP.SCON.G	+INC.SCON.R	
Net Lending/Borrowing		EXP.NL.H		EXP.NL.F		EXP.NL.N		EXP.NL.G		EXP.NL.R

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Further reading

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