Post-Keynesian stock-flow consistent modelling

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Outline

Outline

- Over the past decade, **stock-flow consistent** (SFC) modelling has become a dominant approach in heterodox macro modelling.
- This approach has proved quite successful in formulating the complex interactions between the **financial** and the **real** spheres of the economy.
- The SFC approach has its origins to the work of the **Yale group** of James Tobin and the **Cambridge Economic Policy Group** of Wynne Godley that used SFC structures to analyse the US and the UK economy in the 1970s and the 1980s.

- There is currently a lot of research that takes place on **theoretical SFC modelling**. This is partly explained by the fact that SFC models are characterised by a high flexibility that allows them to be deployed for the analysis of a wide range of topics.
- There is also research on **empirical SFC modelling**. However, it is clear that the empirical SFC literature is much less developed than the theoretical one.
- SFC models are currently viewed as **alternative models to the DSGE models** (especially when they are combined with agent-based structures).

The aims of this lecture are:

1. To provide an introduction to the features and the methodology of SFC models. Particular emphasis will be placed on the **steps** that need to be followed in practice in order to construct and simulate SFC models.
2. To present some research topics in which SFC models have been used, paying particular emphasis to **recent research developments**.

Outline

(1) There are no black holes

'Everything comes from somewhere and goes somewhere'. This is ensured by using two matrices: (i) the balance sheet matrix and (ii) the transactions flow matrix.

(2) The financial and the real spheres are integrated

Following the post-Keynesian tradition on the non-neutrality of money and finance, the SFC models explicitly formulate the various links between financial and real variables.

(3) Behavioural equations are based on post-Keynesian assumptions

The behavioural equations are constructed following post-Keynesian theories.

(1) There are no black holes

Balance sheet matrix

	Households	Firms	Commercial banks	Central bank	Total
Deposits	+M		-M		0
Loans		-L	+L		0
Equities	$+p_e e$	$-p_e e$			0
Capital		+K			+K
High-powered money			+HPM	-HPM	0
Advances			-A	+A	0
Total (net worth)	$+V_h$	$+V_f$	0	$+V_{cb}$	+K

(1) There are no black holes

Transactions flow matrix

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	-C	+C						0
Investment		+I	-I					0
Wages	+W	-W						0
Firms' profits	+DP	-TP	+RP					0
Banks' profits	+BP			-BP				0
Central bank's profits						-CBP	+CBP	0
Interest on deposits	$+r_m M_{-1}$			$-r_m M_{-1}$				0
Interest on loans		$-r_l L_{-1}$		$+r_l L_{-1}$				0
Interest on advances				$-r_{cb} A_{-1}$		$+r_{cb} A_{-1}$		0
Change in deposits	-ΔM				+ΔM			0
Change in loans			+ΔL		-ΔL			0
Change in equities	$-p_e \Delta e$		$+p_e \Delta e$					0
Change in high-powered money					-ΔHPM		+ΔHPM	0
Change in advances					+ΔA		-ΔA	0
Total	0	0	0	0	0	0	0	0

(2) The financial and the real spheres are integrated

- The post-Keynesian SFC models integrate the real with the financial side of the economy.
- All SFC models have **at least one financial asset/liability**.
- Money is introduced both as a **stock** and as a **flow** variable.
- Two **examples** of the real sector-financial sector interlinkages:
  1. Finance of the investment of firms (via loans and equities).
  2. Asset prices effects on consumption and investment.

(2) The financial and the real spheres are integrated

- Consider for example the **finance of firms' investment via loans**.
- We can use Copeland's **quadruple-entry principle** and the **transactions flow matrix** in order to show how this takes place.
- We consider **two steps**. In the *first step* firms ask for finance and, as a result, loans and deposits are created by banks. In the *second step* deposits of firms are transferred by cheques to the workers that provide their labour to firms.

(2) The financial and the real spheres are integrated

First step: Firms ask for finance

	Households	Firms		Commercial banks	Total
		Current	Capital		
Consumption					0
Investment in working capital					0
Wages					0
Change in deposits			$-\Delta M_f$	$+\Delta M$	0
Change in loans			$+\Delta L$	$-\Delta L$	0
Total	0	0	0	0	0

(2) The financial and the real spheres are integrated

Second step: Firms pay the wages to households

	Households	Firms		Commercial banks	Total
		Current	Capital		
Consumption					0
Investment in working capital		+I	-I		0
Wages	+W	-W			0
Change in deposits	$-\Delta M_h$			$+\Delta M$	0
Change in loans			$+\Delta L$	$-\Delta L$	0
Total	0	0	0	0	0

(2) The financial and the real spheres are integrated

- The **portfolio choice** (i.e. the allocation of wealth of households among financial assets) is determined by the (expected) relative rates of return and liquidity preference.
- The portfolio choice can affect the **price of financial assets** (e.g. government bonds or equities) having feedback effects on consumption (since wealth is incorporated in the consumption function) and investment (if, for example, Tobin's q is included in the investment function).

(3) Behavioural equations are based on post-Keynesian assumptions

- Labour and product markets do not clear through changes in wages and prices (as in neoclassical models). On the contrary, they clear via the **adjustment of supply to demand**.
- The **pricing mechanism** only plays a clearing role in the **financial markets**.
- Although the post-Keynesian SFC models are primarily demand-led, it is possibly to introduce **supply-side** effects (e.g. by including a Phillips curve or loan defaults).

(3) Behavioural equations are based on post-Keynesian assumptions

- The **decisions of households** are formulated using **Davidson's** two-step decision process: The **1st step** refers to the decision about the proportion of income that will be saved. The **2nd step** refers to the way that savings will be allocated between the various assets (portfolio choice).
- In many behavioural equations economic agents have **stock-flow targets** (e.g. wealth-to-income ratios, debt-to-income ratios, inventories-to-sales ratios) and **react to disequilibria** in order to achieve these targets.
- There is no **utility maximisation**.

Outline

Steps in developing an SFC model

- **Step 1**: Construct the balance sheet matrix.
- **Step 2**: Construct the transactions flow matrix.
- **Step 3**: Write down the identities from the transactions flow matrix. Use the columns (budget constraints) and the rows with more than two entries. Identify the buffer variables in the identities.
- **Step 4**: Identify the variables that need to be determined based on behavioural equations. Select your behavioural equations.
- **Step 5**: Put together the identities and the behavioural equations.

Suppose that we have an economy with the following features:

- There are four sectors: firms, households, banks and a central bank.
- **Firms** make investment by using retained profits, loans and equity. A part of firms' profits is distributed to households.
- **Households** accumulate savings in the form of deposits and equity.
- **Banks** provide firm loans by creating deposits. Banks' profits are distributed to households.
- **Central bank** holds advances on the asset side of its balance sheet and high-powered money on the liability side.

This is a model with both private bank money and central bank money.

Step 1: Construct the balance sheet matrix.

	Households	Firms	Commercial banks	Central bank	Total
Deposits	+M		-M		0
Loans		-L	+L		0
Equities	$+p_e e$	$-p_e e$			0
Capital		+K			+K
High-powered money			+HPM	-HPM	0
Advances			-A	+A	0
Total (net worth)	$+V_h$	$+V_f$	0	$+V_{cb}$	+K

Step 2: Construct the transactions flow matrix.

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	-C	+C						0
Investment		+I	-I					0
Wages	+W	-W						0
Firms' profits	+DP	-TP	+RP					0
Banks' profits	+BP			-BP				0
Central bank's profits						-CBP	+CBP	0
Interest on deposits	$+r_m M_{-1}$			$-r_m M_{-1}$				0
Interest on loans		$-r_l L_{-1}$		$+r_l L_{-1}$				0
Interest on advances				$-r_{cb} A_{-1}$		$+r_{cb} A_{-1}$		0
Change in deposits	$-\Delta M$				$+\Delta M$			0
Change in loans			$+\Delta L$		$-\Delta L$			0
Change in equities	$-p_e \Delta e$		$+p_e \Delta e$					0
Change in high-powered money					$-\Delta HPM$		$+\Delta HPM$	0
Change in advances					$+\Delta A$		$-\Delta A$	0
Total	0	0	0	0	0	0	0	0

Step 3: Write down the identities from the transactions flow matrix. Use the columns (budget constraints) and the rows with more than two entries. Identify the buffer variables in the identities.

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	-C	+C						0
Investment		+I	-I					0
Wages	+W	-W						0
Firms' profits	+DP	-TP	+RP					0
Banks' profits	+BP			-BP				0
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Interest on deposits	$+r_m M_{-1}$			$-r_m M_{-1}$				0
Interest on loans		$-r_l L_{-1}$		$+r_l L_{-1}$				0
Interest on advances				$-r_{cb} A_{-1}$		$+r_{cb} A_{-1}$		0
Change in deposits	-ΔM				+ΔM			0
Change in loans			+ΔL		-ΔL			0
Change in equities	$-p_e \Delta e$		$+p_e \Delta e$					0
Change in high-powered money					-ΔHPM		+ΔHPM	0
Change in advances					+ΔA		-ΔA	0
Total	0	0	0	0	0	0	0	0

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	-C	+C						0
Investment		+I	-I					0
Wages	+W	-W						0
Firms' profits	+DP	-TP	+RP					0
Banks' profits	+BP			-BP				0
Central bank's profits						-CBP	+CBP	0
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Interest on advances				$-r_{cb} A_{-1}$		$+r_{cb} A_{-1}$		0
Change in deposits	-ΔM				+ΔM			0
Change in loans		+ΔL			-ΔL			0
Change in equities	$-p_e \Delta e$		$+p_e \Delta e$					0
Change in high-powered money					-ΔHPM		+ΔHPM	0
Change in advances					+ΔA		-ΔA	0
Total	0	0	0	0	0	0	0	0

- $M=M_{-1}+YD-C-p_e \Delta e$
- $TP=Y-W-r_l L_{-1}$
- $L=L_{-1}+I-RP-p_e \Delta e$
- $BP=r_l L_{-1}-r_m M_{-1}-r_{cb} A_{-1}$
- $A=A_{-1}+\Delta HPM+\Delta L-\Delta M$
- $CBP=r_{cb} A_{-1}$
- $A_{red}=A_{-1}+\Delta HPM+CBP$
- $DP=TP-RP$

Step 4: Identify the variables that need to be determined based on behavioural equations. Select your behavioural equations.

- Wage income of households: **W**
- Disposable income of households: YD
- Consumption expenditures: **C**
- Wealth (identity): V_h
- Deposits (identity): M
- Income: Y
- Total profits of firms (identity): TP
- Retained profits: **RP**
- Distributed profits (identity): DP
- Investment: **I**
- Capital stock: **K**
- Loans (identity): L
- Number of equities: **e**
- Price of equities: $\mathbf{p}_e$
- Profits of banks (identity): BP
- High-powered money: **HPM**
- Advances (identity): A
- Profits of central bank (identity): CBP

- Wage income of households: $W=s_w Y$
- Consumption expenditures: $C=c_1 YD_{-1}+c_2 V_{h-1}$
- Retained profits: $RP=s_f TP$
- Investment: $I=g_k K_{-1}$
- Capital stock: $K=K_{-1}+I$
- High-powered money: $HPM=hM$
- Value of equity held by households: $E=(\lambda_0+\lambda_1 r_{e-1}+\lambda_2 r_m+\lambda_3(YD_{-1}/V_{h-1}))V_{h-1}$
- Number of equities: $e=e_{-1}+\frac{xI_{-1}}{p_e}$
- Price of equities: $p_e=\frac{E}{e}$

Step 5: Put together the identities and the behavioural equations.
Households

- Wage income of households: $W=s_w Y$
- Disposable income of households: $YD=W+DP+BP+r_m M_{-1}$
- Consumption expenditures: $C=c_1 YD_{-1}+c_2 V_{h-1}$
- Wealth (identity): $V_h=M+p_e e$
- Value of equity held by households: $E=(\lambda_0+\lambda_1 r_{e-1}+\lambda_2 r_m+\lambda_3(YD_{-1}/V_{h-1}))V_{h-1}$
- Deposits (identity): $M=M_{-1}+YD\text{-}C\text{-}p_e \Delta e$

Firms

- Income: $Y=C+I$
- Total profits of firms (identity): $TP=Y-W-r_l L_{-1}$
- Retained profits: $RP=s_f TP$
- Distributed profits (identity): $DP=TP-RP$
- Investment: $I=g_k K_{-1}$
- Capital stock: $K=K_{-1}+I$
- Loans (identity): $L=L_{-1}+I-RP-p_e \Delta e$
- Number of equities: $e=e_{-1}+\frac{xI_{-1}}{p_e}$
- Price of equities: $p_e=\frac{E}{e}$
- Rate of return of firms: $r_e=\frac{DP}{p_{e-1}e_{-1}}+\frac{\Delta p_e}{p_{e-1}}$

Commercial banks

- Profits of banks (identity): $BP=r_l L_{-1}-r_m M_{-1}-r_{cb} A_{-1}$
- High-powered money: $HPM=hM$
- Advances (identity): $A=HPM+L-M$

Central bank

- Profits of central bank (identity): $CBP=r_{cb} A_{-1}$
- Advances (identity): $A_{red}=A_{-1}+\Delta HPM+CBP$

Useful tips - Consistency

- In order for your model to be consistent you need to ensure that:
  1. In the initial period all the stocks in the model satisfy the restrictions of the balance sheet matrix.
  2. The identities from the transactions flow matrix and balance sheet matrix are correctly written.
  3. If your model includes portfolio allocation, then ensure that the adding-up constraints are satisfied.

- If the model is consistent, the redundant equation is satisfied.

Useful tips - Wealth and capital gains

- **Deposits** are determined by the following identity:
  $M=M_{-1}+YD-C-p_e\Delta e$ (1)
- Equation (1) can be rewritten as follows:
  $\Delta M+p_e\Delta e=YD-C$ (2)
- We know from the balance sheet matrix that the **wealth of households** is:
  $V_h=M+p_e e$ (3)
- Therefore, the change in the wealth of households is:
  $\Delta V_h=\Delta M+p_e\Delta e+e_{-1}\Delta p_e$ (4)
- By combining equations (2) and (4) we get:
  $V_h=V_{h-1}+YD-C+e_{-1}\Delta p_e$ **(identity)**

Useful tips - Equity market

Equations of the **portfolio choice**:

$$E=(\lambda_{10}+\lambda_{11}r_{e-1}+\lambda_{12}r_b+\lambda_{13}r_m+\lambda_{14}(YD_{-1}/V_{-1}))V_{-1}$$

$$B=(\lambda_{20}+\lambda_{21}r_{e-1}+\lambda_{22}r_b+\lambda_{23}r_m+\lambda_{24}(YD_{-1}/V_{-1}))V_{-1}$$

$$M=(\lambda_{30}+\lambda_{31}r_{e-1}+\lambda_{32}r_b+\lambda_{33}r_m+\lambda_{34}(YD_{-1}/V_{-1}))V_{-1}$$

where E is the value of equity, B are Treasury bills, M are deposits, V is wealth, YD is disposable income, r_e is the rate of return on equities, r_m is the interest rate on deposits and r_b is the interest on Treasury bills.

Useful tips - Equity market

The **adding-up constraints** must hold. First, the following **vertical conditions** must hold:

$$\lambda_{10}+\lambda_{20}+\lambda_{30}=1$$
$$\lambda_{11}+\lambda_{21}+\lambda_{31}=0$$
$$\lambda_{12}+\lambda_{22}+\lambda_{32}=0$$
$$\lambda_{13}+\lambda_{23}+\lambda_{33}=0$$
$$\lambda_{14}+\lambda_{24}+\lambda_{34}=0$$

Useful tips - Equity market

- Second, the **horizontal conditions** must be satisfied:
  λ_{11}=-λ_{12}-λ_{13}
  λ_{22}=-λ_{21}-λ_{23}
  λ_{33}=-λ_{31}-λ_{32}

- Finally, the **symmetry conditions** must be fulfilled:
  λ_{12}=λ_{21}
  λ_{13}=λ_{31}
  λ_{23}=λ_{32}

Useful tips - Equity market

- In the equity market we assume equilibrium:

$$e = \frac{E}{p_e}$$

- By using the equation for the number of equities in the previous equation we get:

$$e_{-1} + \frac{xI_{-1}}{p_e} = \frac{E}{p_e}$$

- By rearranging we have the following equation for the price of equities:

$$p_e = \frac{E - xI_{-1}}{e_{-1}}$$

Useful tips - Steady state of the model

At the steady state all flow-stock, stock-flow, flow-flow and stock-stock ratios (e.g. Y/K, L/K, M/Y) are constant.
For example:
$$\Delta\left(\frac{Y}{K}\right)=\frac{Y}{K}-\frac{Y_{-1}}{K_{-1}}=\frac{Y}{K}-\frac{Y_{-1}(1+g_k)}{K}=\frac{\Delta Y-g_k Y_{-1}}{K}=\frac{\Delta Y}{K}-\frac{Y}{K}\frac{g_k}{(1+g_k)}$$

Since Y/K should be constant at the steady state, we need $\Delta\left(\frac{Y}{K}\right)=0$.

Outline

- SFC models can be simulated using various **software programmes** (e.g. EViews, R, Excel or MATLAB).
- SFC models can be either **discrete-time** or **continuous-time** models.
- When SFC models are **small** we can solve them analytically (e.g. by finding the steady-states and conducting stability analysis).
- When SFC models are **large** in most cases we use numerical simulations.

Steps in simulating an SFC model

- **Step 1**: Identify the endogenous variables of the model (as well as some auxiliary variables).
- **Step 2**: Identify the baseline scenario and select the parameter values (see the table below).

Category	Description
(A)	**Econometrically estimated parameters**
(B)	**Directly calibrated parameters**
(Bi)	Based on data
(Bii)	Based on previous studies
(Biii)	Selected from a reasonable range of values
(C)	**Indirectly calibrated parameters**
(Ci)	Calibrated such that the model matches the data
(Cii)	Calibrated such that the model generates the baseline scenario

Steps in simulating an SFC model

- **Step 3**: Select the initial values using the data for your economy or the equations of the model.
- **Step 4**: Write down the equations and run the model.
- **Step 5**: Report your results by using tables and graphs.
- **Step 6**: Validate the model by using your baseline scenario. Validation can be conducted, for example, by estimating the volatility, the auto-correlation and the cross-correlation for some key variables.
- **Step 7**: Re-run the simulations by changing key parameters (sensitivity analysis).
- **Step 8**: Re-run the simulations by changing parameters that correspond to policies/institutional structures.

Outline

Shadow banking

- Most SFC models assume a simple banking sector.
- However, a realistic formulation of the modern banking system needs to include **shadow banking activities**.
- There have been some recent attempts to analyse shadow banking by using an SFC framework (see Eatwell et al., 2008; Pilkington, 2008; Lavoie, 2014; Bhaduri et al., 2015; Nikolaidi, 2015; Botta et al., 2016).

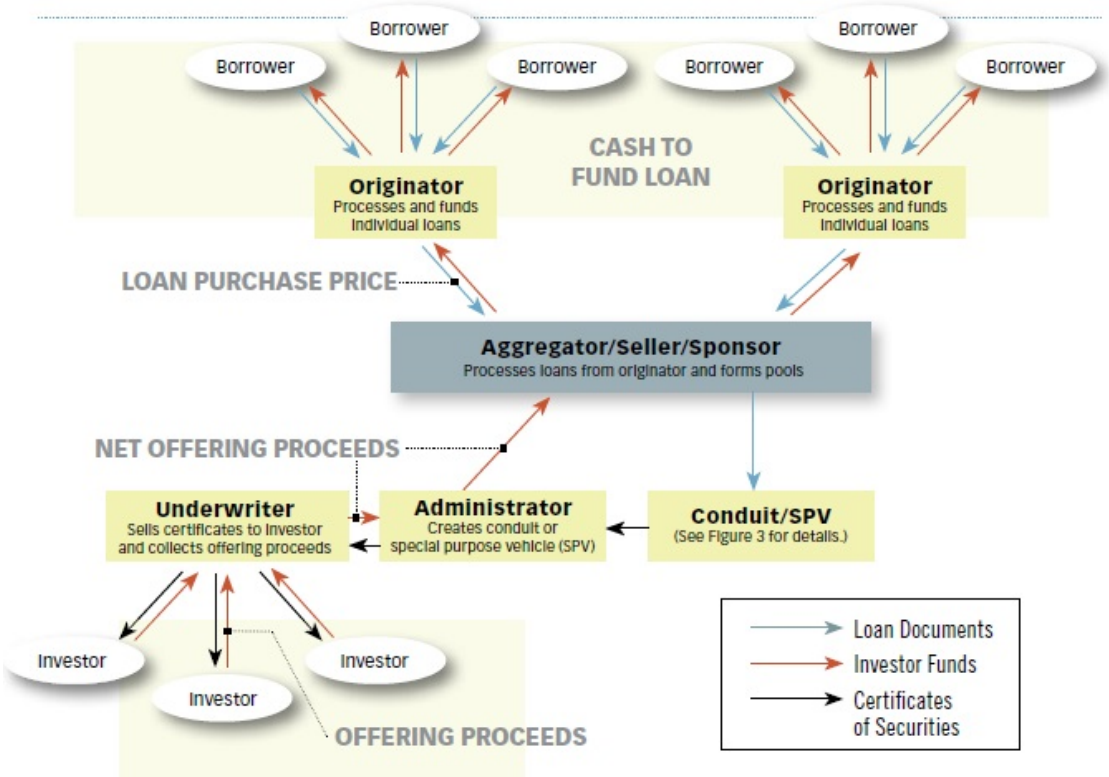
Shadow banking

Securitisation process

- Securitisation is a technique that transforms illiquid assets into liquid tradable instruments.
- In its more widespread form, this technique allows banks to remove loans from the asset side of their balance sheets and distribute the associated risks to other financial units.
- Securitisation is a complex process. However, its basic structure can be described by the next figure:

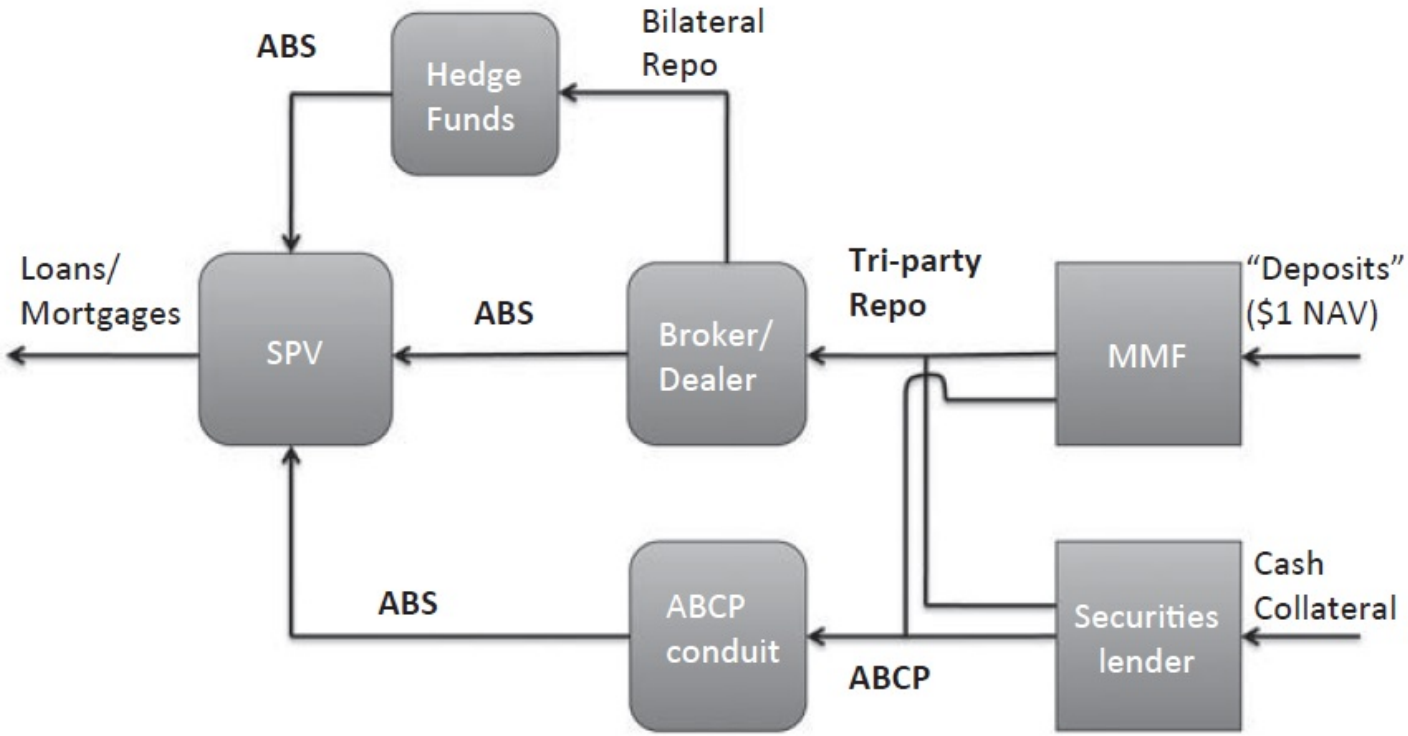
Shadow banking

Securitisation process (Noeth and Sengupta, 2011, p. 10)



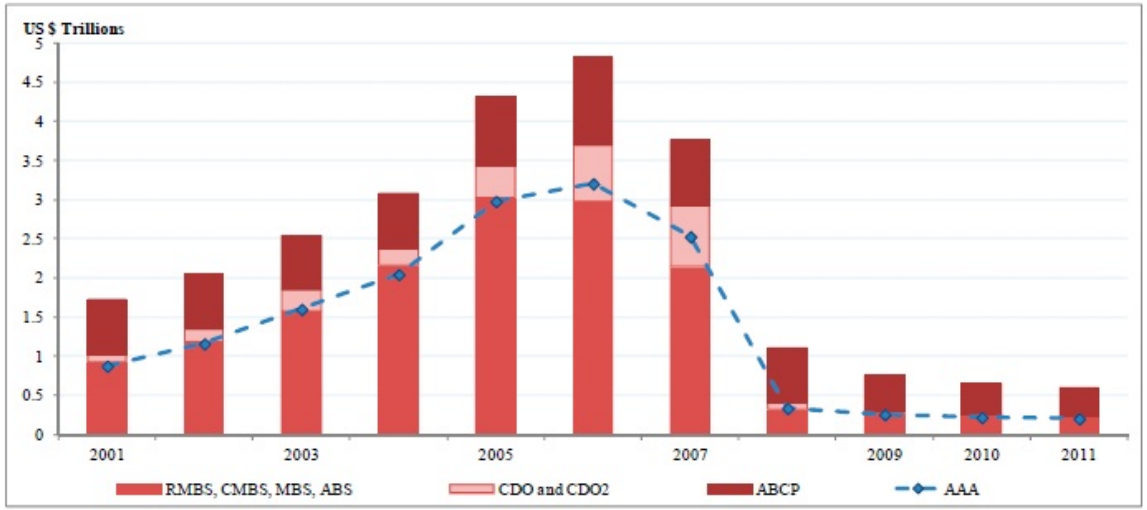
Shadow banking

Short-term funding flows in the shadow banking system (Krishnamurthy et al., 2014, p. 2383)



Shadow banking

US private label securitisation market, 2000-11 (Claessens et al., 2012, p. 9)



Sources: IMF staff estimates based on data from JPMorgan Chase & Co., Board of Governors of the Federal Reserve Systems, the Commercial Real Estate Finance Council, and *Inside Mortgage Finance*.

Notes: MBS = mortgage-backed security; RMBS = residential MBS; CMBS = commercial MBS; ABS = asset-backed security; CDO = collateralized debt obligation; CDO2 = CDO-squared and CDOs backed by ABS and MBS; ABCP = asset-backed commercial paper. All year-end outstandings.

Shadow banking

Lavoie (2014)

Citybank		Goldman Sachs (GS)		IBM		PIMCO hedge fund	
Assets	Liabilities	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
	IBM deposit −100 GS deposit +100	Deposit +100	Repos +100	Deposit −100 Repos +100			
Securitized loans −100	IBM deposit −100	MBS +100	Repos +100	Deposit −100 Repos +100			
Securitized loans −100	IBM deposit −100	MBS +100	Repos +100	Deposit −100		Deposit at City bank +100	Loan from City bank +100
New loan to PIMCO +100	PIMCO deposit +100			Repos +100			

Shadow banking

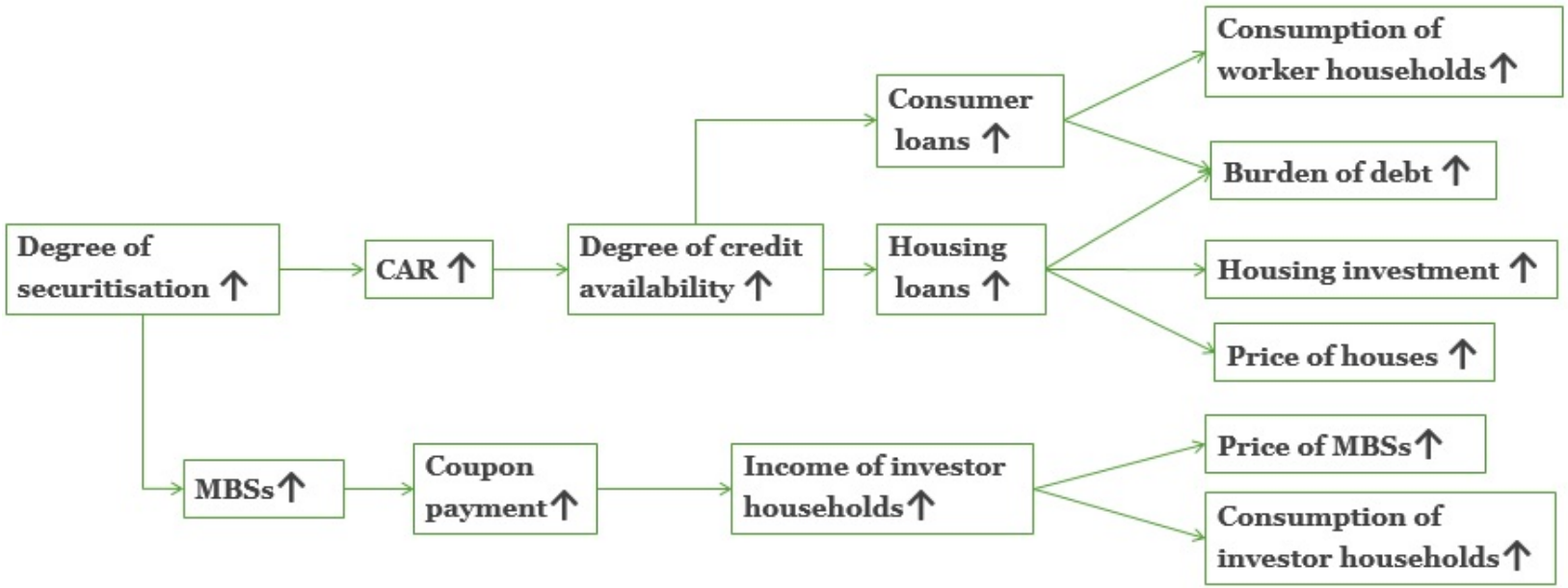
Based on Nikolaidi (2015)

	Worker households	Firms	Commercial banks	SPVs	Hedge funds	ABCP conduits	MMMFs	Investor households	Government	Central bank	Total
Houses	$+p_H H_{DW}$	$+p_H HU$						$+p_H H_{DI}$			$+p_H H$
Productive capital		$+K_F$									$+K_F$
High-powered money			$+HPM_B$					$+HPM_I$		$-HPM$	0
Consumer loans	$-LC$		$+LC$								0
Housing loans	$-LH$		$+LH_{NS}$	$+LH_S$							0
Firms' loans		$-LF$	$+LF$								0
Treasury bills			$+B_B$		$+B_{HF}$		$+B_M$	$+B_I$	$-B$	$+B_{CB}$	0
MBSs				$-p_M MBS$	$+p_M MBS_{HF}$	$+p_M MBS_{ABCP}$					0
Repo			$+repo$		$-repo$						0
ABCPs			$+p_{CP} cp_B$			$-p_{CP} cp$	$+p_{CP} cp_{MMMF}$				0
Deposits			$-D$					$+D$			0
Money markets' shares							$-SH$	$+SH$			0
Firms' equities		$-p_E e$						$+p_E e$			0
Advances			$-A$							$+A$	0
Total (net worth)	$+V_W$	$+V_F$	$+V_B$	$+V_{SPV}$	$+V_{HF}$	$+V_{ABCP}$	$+V_{MMMF}$	$+V_I$	$-B$	0	$+K_F+p_H H$

Shadow banking

Based on Nikolaidi (2015)

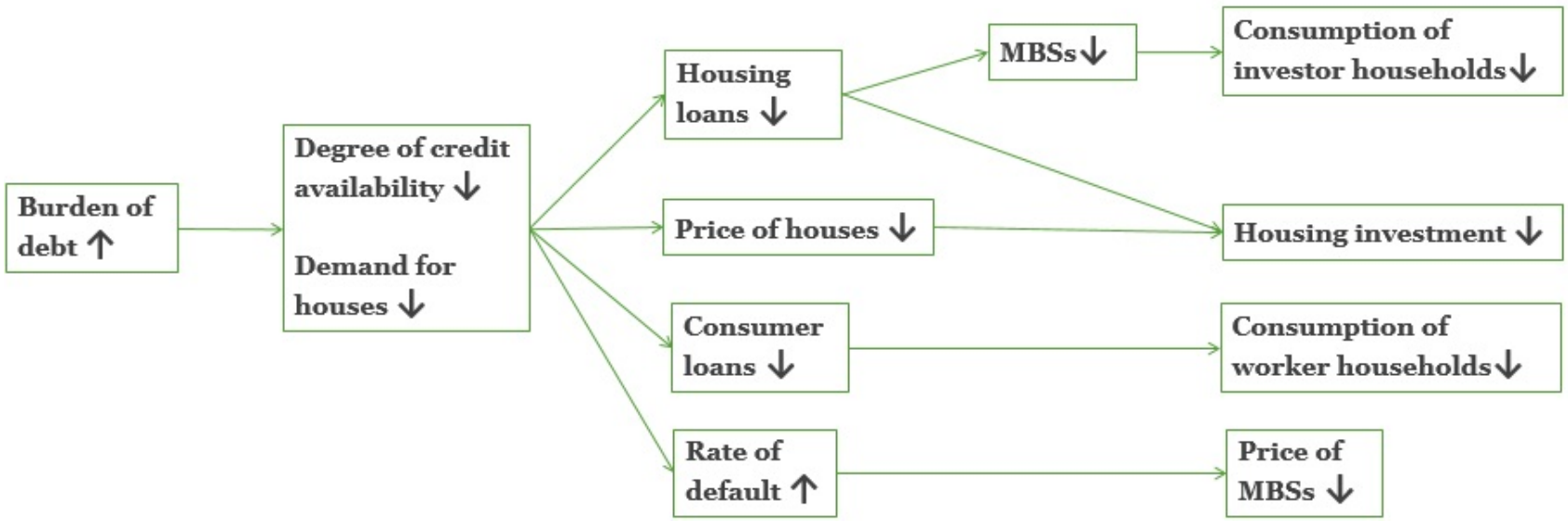
First-round potential effects of securitisation



Shadow banking

Based on Nikolaidi (2015)

Second-round potential effects of securitisation



Household heterogeneity and distribution

Some SFC papers that incorporate household heterogeneity are:

- van Treeck (2009) and Caversazi and Godin (2015) who pay attention to financialisation issues.
- Zezza (2008) and Kapeller et al. (2016) who focus on household debt.
- Dafermos and Papatheodorou (2015) who analyse the links between functional and personal income distribution.

Household heterogeneity and distribution

van Treeck (2009)

Balance sheet matrix

	Households		Firms	Banks	Total
	Workers	Rentiers			
Money		$+M_r$		$-M_s$	0
Equities		$+e_r p_e$	$-e_s p_e$		0
Loans		$-L_r$	$-L_f$	$+L_s$	0
Capital			$+K$		K
Total	0	V	$K - e_s p_e - L_f$	0	K

Household heterogeneity and distribution

Caversazi and Godin (2015)

Balance sheet matrix

	Workers	Rentiers	Firms	Banks	Σ
Deposits	$+D_h$	$+D_r$	$+D_f$	$-D$	0
Loans	$-L_h$		$-L_f$	$+L$	0
Capital			$+K$		$+K$
Houses	$+p_h \cdot H_h$	$+p_h \cdot H_r$			$+p_h \cdot H$
Equities		$+p_e \cdot E_r$	$-p_e \cdot E^s + (p_e \cdot E_f)$		0
Net worth	V_h	V_r	V_f	V_b	V

Household heterogeneity and distribution

Zezza (2008)

Balance sheet matrix

	Housing (top 5 percent)	Housing (bottom 95 percent)	Firms	Banks	Central bank	Government	Total
1. Productive capital			$+ p \cdot K$				$+ p \cdot K$
2. Homes	$+ ph \cdot Hc$	$+ ph \cdot Ho$	$+ ph \cdot HU$				$+ ph \cdot H$
3. Cash	$+ HP_{hc}$	$+ HP_{ho}$		$+ HP_b$	$- HP$		0
4. Central bank advances				$- A$	$+ A$		0
5. Banks deposits	$+ M_c$	$+ M_o$		$- M$			0
6. Loans to firms			$- L$	$+ L$			0
7. Mortgages		$- MO$		$+ MO$			0
8. Treasury bills	$+ B_h$			$+ B_b$	$+ B_c$	$- B$	0
9. Equities	$+ pe \cdot E$		$- pe \cdot E$				0
Total	$+ Vc$	$+ Vo$	$+ V_f$	0	0	$- B$	$+ p \cdot K$ $+ ph \cdot H$

Household heterogeneity and distribution

Kapeller et al. (2016)

Transactions flow matrix

	Households			Firms		Government		Banks		Bank Fund	
	Worker 1	*Worker 2*	*Capitalists*	*Current*	*Capital*	*Current*	*Capital*	*Current*	*Capital*		∑
Consumption	$-C_{1,t}$	$-C_{2,t}$	$-C_{c,t}$	$+C_t$							0
Investment				$+I_t$	$-I_t$						0
Gov. expenditure				$+G_t$		$-G_t$					
[Production]				$[Y_t]$							
				$-w_1N_{1,t}$							
Wages	$+w_1N_{1,t}$	$+w_{2,t}N_{2,t}$		$-w_{2,t}N_{2,t}$							0
Taxes and Bank Fund			$-\sigma_c[\pi_{f,t}\Pi_{f,t}+$								
contributions	$-\sigma_w w_1N_{1,t}$	$-\sigma_w w_{2,t}N_{2,t}$	$\pi_{b,t}\Pi_{b,t}]$			$+T_t$		$-\Omega_t$		$+\Omega_t$	0
								$-r_{t-1}M_{1,t-1}$			
								$-r_{t-1}M_{2,t-1}$			
								$-r_{t-1}M_{c,t-1}$			
								$-r_{t-1}M_{f,t-1}$			
						$+r_{t-1}M_{g,t-}$		$-r_{t-1}M_{f,t-1}$			
Interest	$+r_{t-1}M_{1,t-1}$	$+r_{t-1}M_{2,t-1}$	$+r_{t-1}M_{c,t-1}$	$+r_{t-1}M_{f,t-1}$		1		$-r_{t-1}M_{q,t-1}$			0
	$+\varphi M_{1,t-1}$	$+\varphi M_{2,t-1}$	$+\varphi M_{c,t-1}$	$+\varphi M_{f,t-1}$		$+\varphi M_{g,t-1}$					
Repayment	$-\varphi M_{1,t-1}$	$-\varphi M_{2,t-1}$	$-\varphi M_{c,t-1}$	$-\varphi M_{f,t-1}$		$-\varphi M_{g,t-1}$					0
								$-$			
Debt cancelation		$+cancel_{2,t}$						$cancel_{2,t}$			0
							$-bailout_{b,t}$		$+bailout_{b,t}$	$-$	
Bailouts		$+bailout_{2,t}$					$-bailout_{2,t}$		$+bailout_{bf,t}$	$bailout_{bf,t}$	0
			$+\pi_{f,t}\Pi_{f,t}+$						$+(1-$		
Profits			$\pi_{b,t}\Pi_{b,t}$	$-\Pi_{f,t}$	$+(1-\pi_{f,t})\Pi_{f,t}$	$-B_t$	$+B_t$	$-\Pi_{b,t}$	$\pi_{b,t})\Pi_{b,t}$		0
Δ Deposits	$-\Delta M_{1,t}$	$-\Delta M_{2,t}$	$-\Delta M_{c,t}$		$-\Delta M_{f,t}$		$-\Delta M_{q,t}$		$-\Delta E_t$	$-\Delta M_{bf,t}$	0
∑	0	0	0	0	0	0	0	0	0	0	0

Household heterogeneity and distribution

Dafermos and Papatheodorou (2015)

Transactions flow matrix

	Households of					Firms			Commercial banks		
	Low-skilled employed workers	Low-skilled unemployed workers	High-skilled employed workers	High-skilled unemployed workers	Entrepreneurs-capital owners	Current	Capital	Unemployment fund	Current	Capital	Total
Consumption	$-C_{LE}$	$-C_{LU}$	$-C_{HE}$	$-C_{HU}$	$-C_E$	$+C$					0
Investment						$+I$	$-I$				0
Wages	$+w_L \cdot N_{LE}$		$+w_H \cdot N_{HE}$			$-W$					0
Unemployment benefits		$+ub \cdot N_{LU}$		$+ub \cdot N_{HU}$				$-UB$			0
Firms' profits					$+DP$	$-TP$	$+RP$				0
Commercial banks' profits					$+BP$				$-BP$		0
Contributions	$-\tau_W \cdot w_L \cdot N_{LE}$		$-\tau_W \cdot w_H \cdot N_{HE}$			$-\tau_F \cdot W$		$+CO$			0
Deposit transfers			$+MT$	$-MT$							0
Interest on deposits			$+r_M \cdot M_{HE-1}$	$+r_M \cdot M_{HU-1}$	$+r_M \cdot M_{E-1}$			$+r_M \cdot M_{F-1}$	$-r_M \cdot M_{-1}$		0
Interest on loans						$-r_L \cdot L_{-1}$			$+r_L \cdot L_{-1}$		0
Δdeposits			$-\Delta M_{HE}$	$-\Delta M_{HU}$	$-\Delta M_E$			$-\Delta M_F$		$+\Delta M$	0
Δequities					$-\Delta e \cdot p_e$		$+\Delta e \cdot p_e$				0
Δloans							$+\Delta L$			$-\Delta L$	0
Total	0	0	0	0	0	0	0	0	0	0	0

Ecological macroeconomics

- In SFC models economic growth can continue for ever. **Environmental constraints play no role**.
- However, in reality the energy and matter are not infinite and climate change causes non-trivial economic damages.
- In a recent paper (Dafermos, Nikolaidi and Galanis, 2017a) we have developed an SFC model that incorporates environmental aspects, using insights from the flow-fund model of Georgescu-Roegen and the climate change literature.
- For other SFC models with ecological considerations see Berg et al. (2015), Jackson and Victor (2015), Naqvi (2015) and Richters and Siemoneit (2017).

Nicholas Georgescu-Roegen (1906-1994)

Ecological macroeconomics

- In Dafermos, Nikolaidi and Galanis (2017b) we develop an **ecological macroeconomic model** that sheds light on these financial stability effects of climate change.
- The model builds on the stock-flow-fund model of Dafermos, Nikolaidi and Galanis (2017a). We call our model **DEFINE** (Dynamic Ecosystem FINance Economy); for more information, see: www.define-model.org

Ecological macroeconomics

Physical flow matrix

	Material balance	Energy balance
Inputs		
Extracted matter	$+M$	
Renewable energy		$+ER$
Non-renewable energy	$+CEN$	$+EN$
Oxygen	$+O2$	
Outputs		
Industrial CO_2 emissions	$-EMIS_{IN}$	
Waste	$-W$	
Dissipated energy		$-ED$
Change in socio-economic stock	$-\Delta SES$	
Total	0	0

Ecological macroeconomics

Physical stock-flow matrix

	Material reserves	Non-renewable energy reserves	Atmospheric CO_2 concentration	Socio-economic stock	Hazardous waste
Opening stock	$REV_{M\text{-}1}$	$REV_{E\text{-}1}$	$CO2_{AT\text{-}1}$	$SES_{\text{-}1}$	$HWS_{\text{-}1}$
Additions to stock					
Resources converted into reserves	$+CONV_M$	$+CONV_E$			
CO_2 emissions			$+EMIS$		
Production of material goods				$+MY$	
Non-recycled hazardous waste					$+haz\bar{W}$
Reductions of stock					
Extraction	$-M$	$-EN$			
Net transfer to oceans/biosphere			$+(\phi_{11}-1)CO2_{AT-1}+\phi_{21}CO2_{UP-1}$		
Demolished/disposed material goods				$-DEM$	
Closing stock	REV_M	REV_E	$CO2_{AT}$	SES	HWS

Ecological macroeconomics

Transactions flow matrix

	Households	Firms		Commercial banks		Government sector	Central banks		Total
		Current	Capital	Current	Capital		Current	Capital	
Consumption	$-C$	$+C$							0
Government expenditures		$+G$				$-G$			0
Conventional investment		$+I_C$	$-I_C$						0
Green investment		$+I_G$	$-I_G$						0
Wages	$+wN$	$-wN$							0
Taxes	$-T_H$	$-T_F$				$+T$			0
Firms' profits	$+DP$	$-TP$	$+RP$						0
Commercial banks' profits	$+BP_D$			$-BP$	$+BP_U$				0
Interest on deposits	$+int_D D_{-1}$			$-int_D D_{-1}$					0
Capital depreciation		$-\delta K_{-1}$	$+\delta K_{-1}$						0
Interest on conventional loans		$-int_C L_{C-1}$		$+int_C L_{C-1}$					0
Interest on green loans		$-int_G L_{G-1}$		$+int_G L_{G-1}$					0
Interest on conventional bonds	$+coupon_C b_{CH-1}$	$-coupon_C b_{C-1}$					$+coupon_C b_{CCB-1}$		0
Interest on green bonds	$+coupon_G b_{GH-1}$	$-coupon_G b_{G-1}$					$+coupon_G b_{GCB-1}$		0
Interest on government securities	$+int_S SEC_{H-1}$			$+int_S SEC_{B-1}$		$-int_S SEC_{-1}$	$+int_S SEC_{CB-1}$		0
Interest on advances				$-int_A A_{-1}$			$+int_A A_{-1}$		0
Central bank's profits						$+CBP$	$-CBP$		0
Bailout of banks					$+BAILOUT$	$-BAILOUT$			
Δdeposits	$-\Delta D$				$+\Delta D$				0
Δconventional loans			$+\Delta L_C$		$-\Delta L_C$				0
Δgreen loans			$+\Delta L_G$		$-\Delta L_G$				0
Δconventional bonds	$-p_C \Delta b_{CH}$		$+p_C \Delta b_C$					$-p_C \Delta b_{CCB}$	0
Δgreen bonds	$-p_G \Delta b_{GH}$		$+p_G \Delta b_G$					$-p_G \Delta b_{GCB}$	0
Δgovernment securities	$-\Delta SEC_H$				$-\Delta SEC_B$	$+\Delta SEC$		$-\Delta SEC_{CB}$	0
Δadvances					$+\Delta A$			$-\Delta A$	0
Δhigh-powered money					$-\Delta HPM$			$+\Delta HPM$	0
Defaulted loans			$+DL$		$-DL$				0
Total	0	0	0	0	0	0	0	0	0

Ecological macroeconomics

Balance sheet matrix

	Households	Firms	Commercial banks	Government sector	Central banks	Total
Conventional capital		$+K_C$				$+K_C$
Green capital		$+K_G$				$+K_G$
Durable consumption goods	$+DC$					$+DC$
Deposits	$+D$		$-D$			0
Conventional loans		$-L_C$	$+L_C$			0
Green loans		$-L_G$	$+L_G$			0
Conventional bonds	$+p_C b_{CH}$	$-p_C b_C$			$+p_C b_{CCB}$	0
Green bonds	$+p_G b_{GH}$	$-p_G b_G$			$+p_G b_{GCB}$	0
Government securities	$+SEC_H$		$+SEC_B$	$-SEC$	$+SEC_{CB}$	0
High-powered money			$+HPM$		$-HPM$	0
Advances			$-A$		$+A$	0
Total (net worth)	$+V_H$	$+V_F$	$+K_B$	$-SEC$	$+V_{CB}$	$+K_C +K_G +DC$

Ecological macroeconomics

Calibration/estimation of the model:

- We use a mix of calibration and estimation techniques.
- We estimate some functions (such as investment and consumption) using panel data for the global economy.
- We calibrate some parameter values using data or other studies.
- We develop a baseline scenario and then conduct sensitivity and policy analysis.

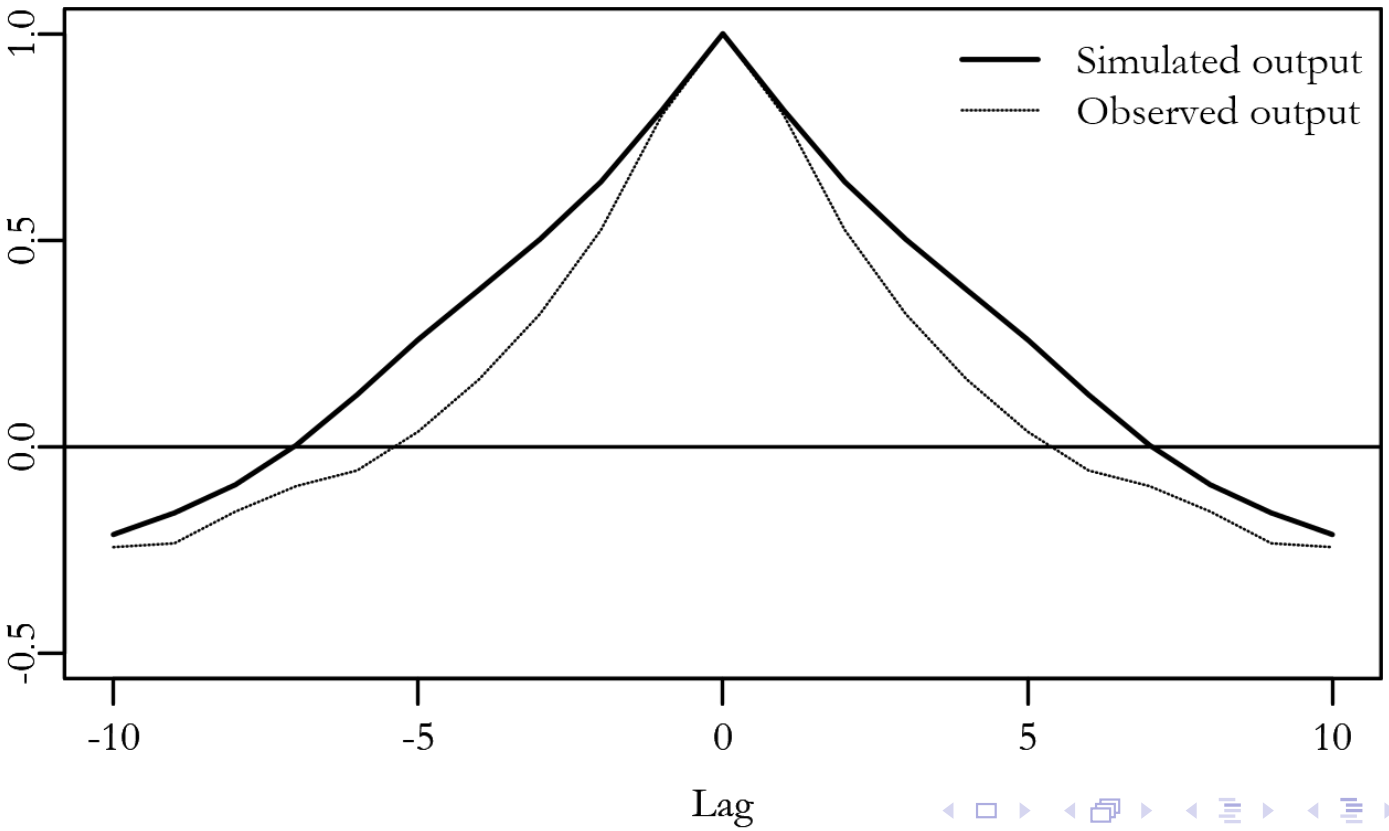
Ecological macroeconomics

Baseline scenario:

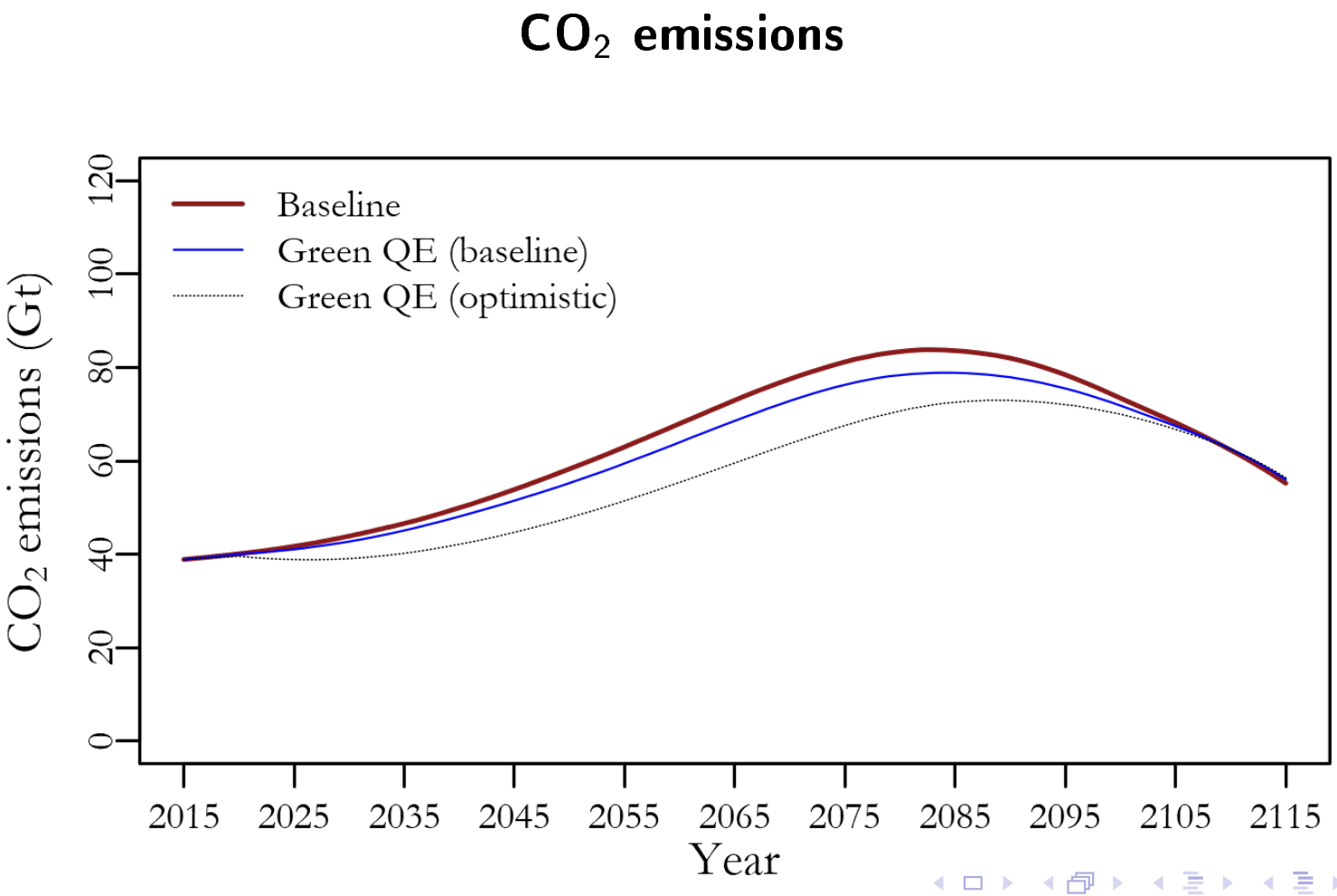
- Economic growth is, on average, around 2.5-2.7% till 2050.
- Population becomes 9.7bn people in 2050.
- Very slow transition to a low-carbon economy.
- Share of renewable energy increases (from 14% in 2015) to 18% in 2050.
- Energy intensity improves by 25% till 2050.
- The price of conventional bonds remains, on average, close to its current level till 2050.

Ecological macroeconomics

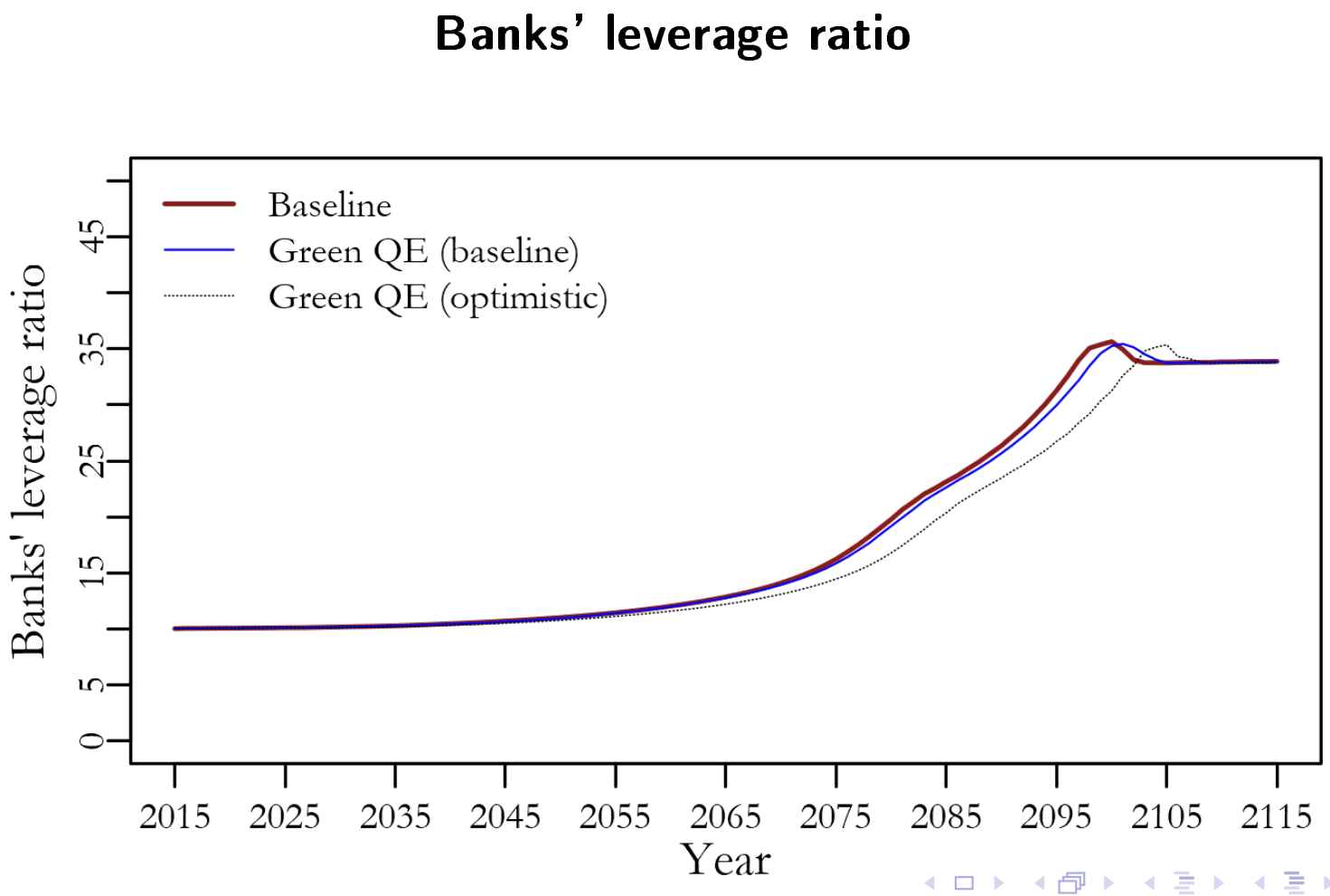
Cross-correlation: output



Ecological macroeconomics



Ecological macroeconomics



Other topics

Theoretical SFC models include:

- **Monetary and fiscal policy**: Zezza and Dos Santos (2004), Godley and Lavoie (2007), Le Heron and Mouakil (2008), Le Heron (2009, 2012), Ryoo and Skott (2013), Greenwood-Nimmo (2014).
- **Credit rationing/liquidity preference**: Le Heron and Mouakil (2008), Chatelain (2010), Dafermos (2012).
- **Minskyan analyses**: Taylor (2004, ch. 9), Tymoigne (2009, ch. 5), Ryoo (2010), Passarella (2012), Keen (2013), Nikolaidi (2014), Dafermos (2017).
- **Open economy issues**: Duwicquet and Mazier (2010), Lavoie and Zhao (2010), Lavoie and Daigle (2011), Mazier and Tiou-Tagba Aliti (2012), Bortz (2014), Greenwood-Nimmo (2014).

Other topics

Empirical SFC models include:

- **Levy model for US**: Godley (1999), Godley et al. (2007), Zezza (2009), Papadimitriou et al. (2013, 2016).
- **Levy model for Greece**: Papadimitriou et al. (2013, 2014).
- **Model for Ireland**: Kinsella and Tiou-Tagba Aliti (2012).
- **Model for Austria**: Miess and Schmelzer (2016a, 2016b).
- **Model for Colombia**: Escobar-Espinoza (2016).
- **Models for the UK**: Burgess et al. (2016), Couts and Gudgin (2016).

Outline

- SFC models constitute a flexible tool for analysing complex issues that involve an active role of finance.
- They have the capability of forming a solid alternative to the DSGE models.
- More progress needs to be made in the way that these models are calibrated, validated and simulated.

Promising areas for future research:

- Shadow banking, inequality and ecological macroeconomics
- Empirical applications of SFC models
- Combination of SFC with agent-based modelling