Euro Area Quantitative Easing in a Portfolio Balance Model with Heterogeneous Agents and Assets

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What we are doing

- Build a portfolio balance model that allows us to predict the impact of QE on domestic and foreign **asset prices and returns**, **exchange rates**.
- Contribute methodologically by including **heterogeneous agents and assets**, which are absolutely crucial for a meaningful assessment of QE within a portfolio balance model
- **Calibrate** the model to assess the impacy of the ECB's asset purchasing program (APP).
  - compile a data set on asset holdings of international banks and investment funds and use it to calibrate the preferences of agents and the characteristics of assets
  - Conduct policy experiment by introducing QE ranging from EUR 200bn to EUR 2.6tn

Introduction

Evidence from Announcement Effects

March 18, 2009

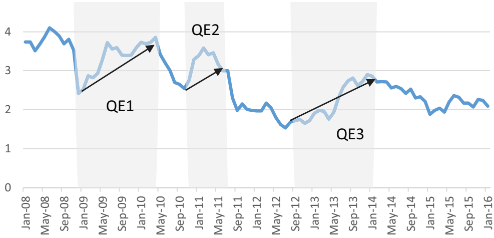
Interest rate on constant-maturity 10-year Treasury bond in the minutes before and after FOMC statement (14:15) about drastically expanding QE1. Source: Greenlaw et al. (2018)

		Euro area	US			UK	Japan	
	All QE episodes	APP 03/15-09/16	LSAP1 12/08-03/10	LSAP2 11/10-06/11	MEP 09/11-12/12	APF1 03/09 - 01/10	CME+ 12/08-08/11	QQE 04/13-09/14
Size (% of GDP)		11%	12%	4%	3%	14%	21%	23%
Median	53	43	76	45	60	67	11	20
Range	10-175	27-64	32-175	33-138	23-175	34-107	10-12	14-26

Based on 24 studies: The median and range of the impact on 10-yrs bond yields, expressed in bps, standardized to purchases of 10% of GDP. Source: Andrade et al. (2016)

Not so Fast

It is unclear through which channel the reductions in yield occur and if they persist.



Interest rate on 10-year Treasury bond during US QE programs.
Source: Datastream

<u>Two main Channels</u>:

- Signaling Channel
  - QE affects expectations of market participants
- Portfolio Balance Channel

  In particular, central bank purchases of longer-term securities work through a portfolio balance channel [...] (Janet Yellen, February 2011)

Portfolio Balance Models

Portfolio balance models allow for a relationship between asset supplies and asset returns through demand and supply mechanisms (Kuttner 2018)

- Original portfolio-balance models, developed by Tobin (1958, 1961), mostly dealt with the substitution between money and bonds

Channel of **imperfect asset substitution**

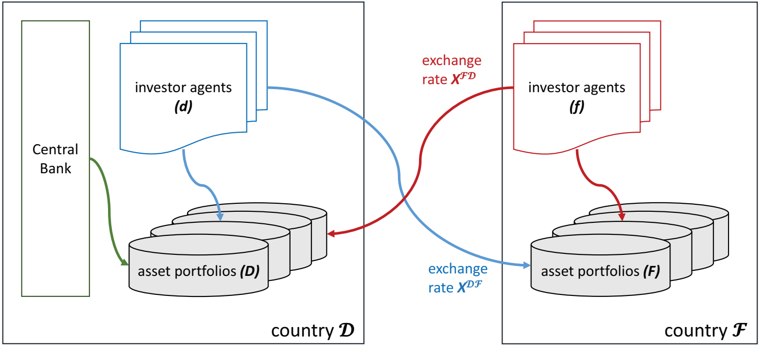
- with imperfect substitutability, each asset class can have its own downward-sloping demand curve
- a shift in the composition of assets can have an impact on expected returns

Model

Why are Assets Imperfect Substitutes?

- Variance-Covariance structure
  - Issuer and asset characteristics
    - default probabilities (bonds and stocks)
    - inflation risk (bonds, currency)
    - exchange rate risk (foreign assets)
- Preferences (preferred habitats)
  - Home bias, e.g.
    - EZ banks $\approx$ 85%
    - EZ funds $\approx$ 45%
  - Maturity, e.g.
    - pension funds and insurance companies hold long term assets
  - Asset class, e.g.
    - equities + inv. trust $\approx$ 46% of total assets for US households
    - equities + inv. trust $\approx$ 13% of total assets for JP households

Overview



Two country model

Overview

Domestic agent balance sheet:

Assets		Liabilities	
Domestic Asset Portfolios,	$\sum_{D=1}^{n^D} Q_{d,t}^{D} P_t^{D}$	Capital,	$S_{d,t}$
Foreign Asset Portfolios,	$\sum_{F=1}^{n^F} Q_{d,t}^{F} (P_t^{F} X_t^{\mathcal{DF}})$		
Domestic Cash,	$C_{d,t}^{\mathcal{D}}$		
Foreign Cash,	$C_{d,t}^{\mathcal{F}} X_t^{\mathcal{DF}}$		

Why Asset Portfolios?

- Parsimony: e.g. one bond portfolio and one equities portfolio representing thousands of single assets.
- It is easier to deal with defaults.
- It is easier to calibrate.
- Include a maturity structure with just one parameter $m \in [0, 1]$.
  - Principal of a portfolio is repaid with a constant rate $(1 - m)$.
  - Average maturity of a portfolio:

$$T_m = \sum_{t=1}^{\infty} (1 - m) m^{t-1} t = \frac{1}{1 - m}$$

  - It fits the data surprisingly well.

Performance

Profit from investing in one unit of a domestic asset portfolio:

$$\Pi_t^D = \underbrace{mat_t^D(\frac{V^D}{\bar{Q}^D} - P_{t-1}^D)}_{\text{repayment effect}} + \underbrace{out_t^D(P_t^D - P_{t-1}^D)}_{\text{price effect}} + \underbrace{all_t^D \frac{V^D}{\bar{Q}^D}\rho^D}_{\text{interest effect}} - \underbrace{\Omega_t^D P_{t-1}^D}_{\text{default effect}}$$

Factors:

$$out_t := m(1 - \Omega_t) \qquad mat_t := (1-m)(1-\Omega_t)$$
$$all_t := out_t + mat_t = (1 - \Omega_t)$$

Π_t^D	profit per portfolio share	V^D	nominal value of portfolio
$\bar{Q}^D$	portfolio shares issued	P_t^D	price of portfolio share
ρ^D	interest on portfolio share	Ω_t	default rate
m	maturity parameter	$(1-m)$	constant repayment rate
out_t	percentage outstanding	mat_t	percentage maturing

Expectations

- Agents form expectations about real portfolio returns:
  - exogenous default rates (we assume agents know the true distribution)
  - exogenous inflation (we assume agents know the true distribution)
  - endogenous prices (agents assume markets are efficient)
  - endogenous exchange rate (agents assume reversion to the PPP)

$$\underset{d,t}{\mathrm{E}}[X_{t+1}^{\mathcal{DF}}] = X_t^{\mathcal{DF}} + \eta \left(\underset{d,t}{\mathrm{E}}[PPP_{t+1}] - X_t^{\mathcal{DF}} \right)$$

- Agents form expectations about the variance-covariance matrix of real returns.
  - They do this by looking at past realizations of real returns and form exponentially weighted moving averages.
  - The covariance structure is dynamic. New observations slowly replace old ones.

The Core of our Portfolio Model

- Agents determine their optimal balance sheet composition by maximizing a mean-variance utility function:

$$\mathbf{w}^*_{d,t} = \arg\max_{\mathbf{w}} \mathbf{w}' \mathrm{E}_{d,t}[\mathbf{r}_{d,t+1}] - 0.5\mathbf{w}' \left(\boldsymbol{\lambda}'_d \boldsymbol{\Sigma}_{d,t} \boldsymbol{\lambda}_d\right) \mathbf{w}$$

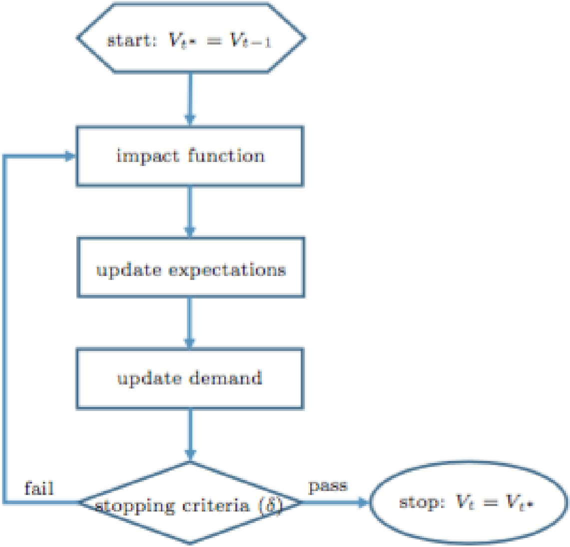
$$\text{s.t.} \qquad \mathbf{w} \geq 0 \quad \text{and} \quad \mathbf{w}'\mathbf{1} = 1$$

- We assume no short selling on portfolio shares.
- We assume asset specific risk aversion parameters to account for heterogeneous preferences.
  - Home bias
  - Preferred habitats (maturity and asset class)

Solving the Model

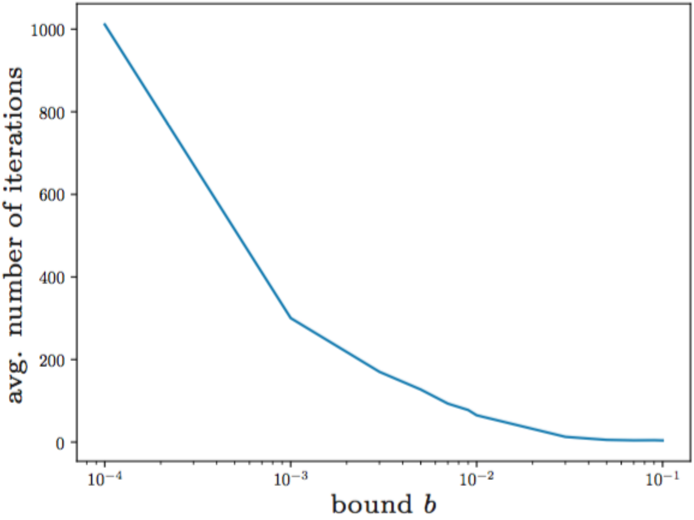
- In equilibrium, prices and exchange rate take values that simultaneously clear the markets of n^D domestic portfolios, n^F foreign portfolios and the currency market
- Heterogeneity in agents and assets, the two country setup complicate solving the model.
- We use a pricing algorithm that builds on iterating an economic intuition (e.g. excess demand increases prices).
- Our algorithm finds prices that come arbitrarily close to market clearing prices.
- There is a trade-off between market efficiency and computational complexity.

Price Adjustments



Stopping criteria

Market clearing is achieved when $\delta_{t^*}^{\{D,F\}} := \Delta Q_{t^*}^{\{D,F\}} / \bar{Q}^{\{D,F\}}$ for all portfolios



Calibration

Calibration Overview

Calibrate to analyze the international portfolio balance effects of the ECB's APP.

- Two regions:
  - Euro area (EZ)
  - Rest of the world (ROW): aggregate of 20 countries
- Two agents per region:
  - Banks': only their securities trading department
  - Investment funds: equity-, bond-, mixed- and hedge funds
- Three assets per country:
  - Bonds: interest rate, default risk, inflation risk, avg. maturity 6.25y
  - Equities: dividend rate, default risk, infinite maturity
  - Currency: interest rate, inflation risk, infinite maturity
- Time: The APP started in March 2015. We take all data from the end of 2014.

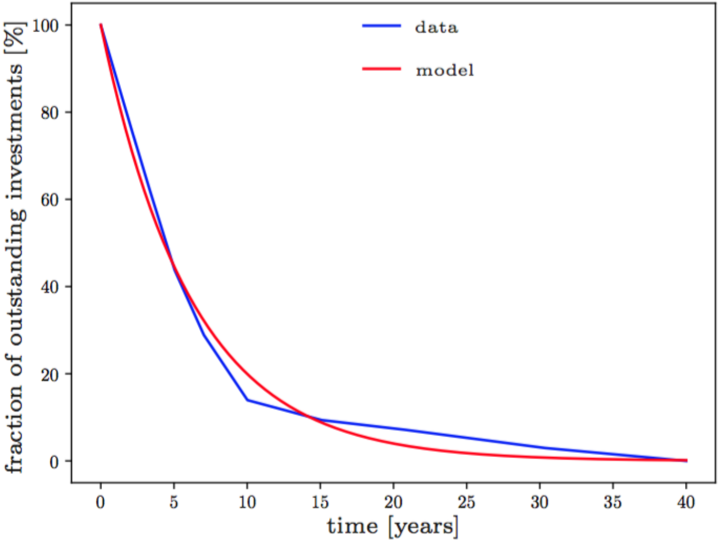
Balance Sheets (in trillion EUR)

	Debt Securities (DS)			Equities (Eq)		
	EZ DS	ROW DS	sum DS	EZ Eq	ROW Eq	sum Eq.
EZ Funds	1.961	1.651	3.612	0.930	1.821	2.751
EZ Banks	3.204	0.656	3.860	0.571	0.075	0.646
ROW Funds	0.263	7.045	7.308	0.556	8.461	9.017
ROW Banks	0.568	10.009	10.577	0.078	1.692	1.770
sum	5.996	19.361	25.357	2.135	12.049	14.184

	Currencies (C)		
	EZ C	ROW C	sum C
EZ Funds	0.411	0.218	0.629
EZ Banks	0.08	0.016	0.096
ROW Funds	0.063	1.202	1.265
ROW Banks	0.136	2.4	2.536
sum	0.69	3.836	4.526

Sources: ECB Investment fund balance sheet statistics, CBD2, Bankscope, IMF Coordinated Portfolio Investment Survey, Morning Star Direct, Fred database and FSB Global Shadow Banking Monitoring Report.

Maturity



Model fit to EZ funds bond holdings

Interest Rates, Dividends, Inflation and Defaults

	nominal rate cash	nominal yield bond portfolio	nominal yield equity portfolio	expected inflation
EZ	-0.20%	0.93%	5.73%	1%
ROW	0.85%	1.92%	4.33%	2.1%

Sources: Central banks, OECD, Absolute Strategy Research, Datastream, World Bank, S&P

Stochastic processes:

- Expected inflation: normal distribution
  - Mean calibrated to inflation expectations at the end of 2014 for 2015.
  - Variance estimated from historical inflation data.
- Default process:
  - Expected default events modeled as an AR(1) process estimated with historical default event data.
  - Loss rate per default event is a constant: 0.5% p.a. for bonds and 2% p.a. for equities.

Preferences

- Agents' balance sheet composition, prices (returns) and the variance-covariance structure are endogenous in the model.
- Iteratively compute asset specific risk aversions for each agents (24 parameters) to match data (balance sheets and returns)

Results

Simulations

- Starting in period 0, the central bank has a QE-target. $QE = \{0, 200, 400, ..., 2600\}$ billion Euro (nominal value).
- Each period the central bank compares its holdings with the QE-target and attempts to purchase the outstanding amount.
- Each simulation run lasts for 1000 periods, i.e. 4trading years, and is repeated 20 times with differentrandom seeds
- The repetition of simulations is important to makesure that results are valid for different manifestations of stochastic processes, in particular the default processes, which reflect different states of the economy
- Variables of interest: expected returns, prices, exchange rate

Regression

To obtain estimates of the portfolio balance effect of QE on asset returns, we regress the change between returns with and without central bank purchases on the size of these purchases:

$$\underset{\text{seed}}{\Delta}\,\mathrm{E}[r|_{\text{QE}}] = \alpha + \beta \frac{\text{QE}}{\text{100bn EUR}} + \epsilon_{\text{seed}}, \qquad \text{with}$$

$$\underset{\text{seed}}{\Delta}\,\mathrm{E}[r|_{\text{QE}}] = \left(\underset{\text{seed}}{\mathrm{E}}[r|_{\text{QE}}] - \underset{\text{seed}}{\mathrm{E}}[r|_{\text{QE}=0}]\right) * 250 * 100 * 100 \qquad (1)$$

Summary Statistics

QE-effect	Variable	Mean	Standard deviation	5% percentile	95% percentile
Yields:	exp. return EZ bonds	-0.62	0.33	-1.09	-0.22
Effect in bps	exp. return EZ equities	-1.89	1.55	-3.88	0.11
per 100 bn EUR	exp. return ROW bonds	-0.02	0.11	-0.15	0.13
assets bought	exp. return ROW equities	-0.12	0.77	-1.06	0.88
Prices:	EZ bond price	0.036	0.019	0.013	0.063
Effect	EZ equity price	0.244	0.195	-0.013	0.493
in percentage	ROW bond price	0.001	0.006	-0.007	0.009
per 100 bn EUR	ROW equity price	0.013	0.085	-0.096	0.115
assets bought	exchange rate	0.019	0.022	-0.006	0.055

Impact on Expected Returns

Results in basis points per 100bn EUR of QE:

VARIABLES	(1) EZ bond portfolio	(2) EZ equity portfolio	(3) EZ currency
QE	-0.598***	-1.96***	0.206***
	(0.000124)	(0.000489)	(0.000119)
Constant	-0.178	0.787	0.742***
	(0.180)	(0.280)	(0.166)
Observations	260	260	260
R-squared	0.897	0.866	0.515

VARIABLES	(4) ROW bond portfolio	(5) ROW equity portfolio	(6) ROW currency
QE	-0.027***	-0.143***	-0.205***
	(3.67e-05)	(8.78e-05)	(0.000125)
Constant	0.0420	0.145	-0.745***
	(0.0604)	(0.381)	(0.165)
Observations	260	260	260
R-squared	0.162	0.116	0.515

Impact on Prices and the Exchange Rate

Results in percent per 100bn EUR of QE:

VARIABLES	(1) EZ bond portfolio	(2) EZ equity portfolio	(3) ROW bond portfolio	(4) ROW equity portfolio
QE	0.0348***	0.260***	1.43e-03***	0.0014***
	(6.24e-06)	(4.07e-05)	(8.35e-07)	(9.95e-06)
Constant	0.008	-0.180	-0.00237	-0.0172
	(0.00798)	(0.0575)	(0.00152)	(0.0172)
Observations	260	260	260	260
R-squared	0.897	0.869	0.161	0.115

VARIABLES	(5) exchange rate
QE	0.0138***
	(7.92e-06)
Constant	0.049***
	(0.0110)
Observations	260
R^2	0.237

Impact of the APP (2.6 tn EUR)

Announcement studies (Andrade et al., 2006):

- 37 - 88 bps reduction in 10-year government yields

Our model (mean results):

- EZ bonds: -16 bps in yields, +0.9% in price
- EZ equities: -50 bps in yields, +6.6% in price
- ROW bonds: -1 bps in yields, +0% in price
- ROW equities: -3 bps in yields, +0.4 in price
- EUR/ROW exchange rate: -0.4%

Conclusion

Conclusion

Asset purchases decrease both domestic and foreign yields through the portfolio balance channel
But:

Magnitude of effects of QE on domestic yields and the exchange rate are rather modest and smaller than commonly assumed in the literature

However, domestic stock prices increase substantially

- The spillovers into the rest of the world (as a whole!) seem negligible.
- Questions:
  - robustness of calibration
  - market size - what have me missed?
  - comparison to other countries' QE programs?