QUANTITATIVE EASING, GLOBAL ECONOMIC CRISIS AND MARKET RESPONSE[+]

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Abstract

We develop a game theoretic model for the central bank's profit and the market's profit dependent on quantitative easing (QE) or no quantitative easing (no QE), where the market responds by lowering interest rates, keeping interest rates unchanged, or raising interest rates. The model is compared with empirical data. We classify 69 QE events and 69 no QE counterfactuals for four central banks, i.e. 17 events for the Federal Reserve, 9 events for Bank of England, 32 events for Bank of Japan, and 11 events for the European Central Bank. The market response to the BoJ and ECB QE is almost exclusively to keep interest rates unchanged. Although this response is most common to the Federal Reserve QE (9 events), the market frequently responds as the Federal Reserve prefers, by lowering interest rates (7 events). For BoE the market response is evenly split across the three outcomes.

Keywords: Central bank; quantitative easing; global economic crisis; market response

JEL Classification Codes: C72; D72; D74

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1 INTRODUCTION

Since the advent of the financial crisis in 2008, some of the world's largest central banks, namely the U.S. Federal Reserve, Bank of England, Bank of Japan and European Central Bank, among others, have embarked on monetary easing or quantitative easing. This is an unorthodox way of pumping money into the economy and aiming to lower the long-term interest rates in order to combat a recession. Since interest rates in industrial countries had declined to near zero in the aftermath of the global crisis, the scope for further monetary easing through lower policy rates became very limited. Quantitative easing (QE) and other asset purchase programs have therefore been adopted under exceptional circumstances. The US started implementing QE in 1932 to combat the great depression. However, this did not yield the desired effects. Japan is credited as the first country that started implementing QE in 2001. But it wasn't until the 2008 financial crisis that central banks of developed countries started using QE regularly to stimulate their economies, increase bank lending, and encourage spending.

The real estate bubble which burst in 2007 in the USA and caused the 2008 financial crisis, and the more recent Eurozone sovereign debt crisis have obliged leading central banks for aggressive monetary actions such as QE in order to prevent financial instability. The USA introduced QE1 in 2008, QE2 in 2010 and "Operation Twist" (OT) in 2011, and more recently the third round of QE (QE3) in 2012, which consisted of a monthly $85 billion injection through the purchase of mortgage-backed securities and longer-term Treasury securities. The Fed buys government or other bonds and then makes this money available for banks to borrow, thereby expanding the amount of money circulating in the economy, which in turn reduces long-term

interest rates. In the UK, the Bank of England incrementally raises the ceiling of its QE asset purchase program to £375 billion, most of which is used to purchase UK government securities. In the euro area, the European Central Bank undertakes a series of longer-term refinancing operations since 2008; two rounds of covered bond purchase programs in 2009 and 2011; an unlimited securities market program in 2010; and open-ended outright monetary transactions in 2012. In Japan, the central bank cumulatively increases the size of its comprehensive monetary easing to as much as ¥101 trillion by the end of 2012. More recently, the Bank of Japan launches perhaps the boldest monetary easing in the modern history with the intention to double the monetary base in two years through aggressively purchasing government bonds, exchange-traded funds as well as real estate investment trusts.

Thus, increasing the size of their balance sheets has become the primary means by which central banks in these economies have intervened to bring relief to the ongoing economic downturn. By adopting unconventional measures of monetary easing, central banks seek mainly to stimulate growth, bring down joblessness to reasonable levels and support their banking systems by pumping more money into the economy to boost spending. However, some critics worry that these measures would fuel inflation and encourage unbridled government spending.

The Fed's QE3 is expected to widely affect global economies and this announcement caused euphoria in the financial markets, with stock prices reaching post-recession highs in the USA. In turn, emerging markets received these extraordinary monetary policy responses with skepticism. While central banks in developed economies have deployed monetary easing to ameliorate the impact of the recession, the collective magnitude of monetary easing may have unintended consequences in other countries, especially in emerging countries. As economies are more integrated, the implementation of QE in developed countries can cause excess flow of liquidity in emerging countries and inadvertently disrupt their currencies, exports, inflation levels.

Ugai (2006) surveyed the empirical analyses that examine the effects of the Bank of Japan (BOJ)'s quantitative easing policy (QEP), which was implemented from March 2001 through March 2006.The survey confirms a clear effect whereby the commitment to maintain the QEP fostered the expectations that the zero interest rate would continue into the future, thereby lowering the yield curve centering on the short- to medium-term range. There were also phases in which an increase in the current account balances (CABs) held by financial institutions at the BOJ bolstered this expectation. While the results were mixed as to whether expansion of the monetary base and altering the composition of the BOJ's balance sheet led to portfolio rebalance, generally this effect, if any, was smaller than that stemming from the commitment. When viewing the QEP's impact on Japan's economy through various transmission channels, many of the analyses suggest that the QEP created an accommodative environment in terms of corporate financing. In particular, the QEP contained financial institutions' funding costs from the market and staved off financial institutions' funding uncertainties. The QEP's effect on raising aggregate demand and prices was often limited, due largely to the then progressing corporate balance sheet adjustment, as well as the zero bound constraint on interest rates.

Joyce *et al.* (2011) examine the bank of England's quantitative easing program. As part of its response to the global banking crisis and a sharp downturn in domestic economic prospects, the Bank of England's Monetary Policy Committee (MPC) began a programme of large-scale asset purchases (commonly referred to as QE) in March 2009, with the aim of injecting additional money into the economy and so increasing nominal spending growth to a rate consistent with meeting the CPI inflation target in the medium term. By February 2010, the MPC had made £200 billion of purchases, most of which had been of UK government securities (gilts). Based on analysis of the reaction of financial market prices and econometric estimates, Joyce *et al.* (2011) attempt to assess the impact of the Bank's QE policy on asset prices. The estimates suggest that QE may have

depressed gilt yields by about 100 basis points. On balance the evidence seems to suggest that the largest part of the impact of QE came through a portfolio rebalance channel. The wider impact on other asset prices is more difficult to disentangle from other influences: the initial impact was muted but the overall effects were potentially much larger, though subject to considerable uncertainty.

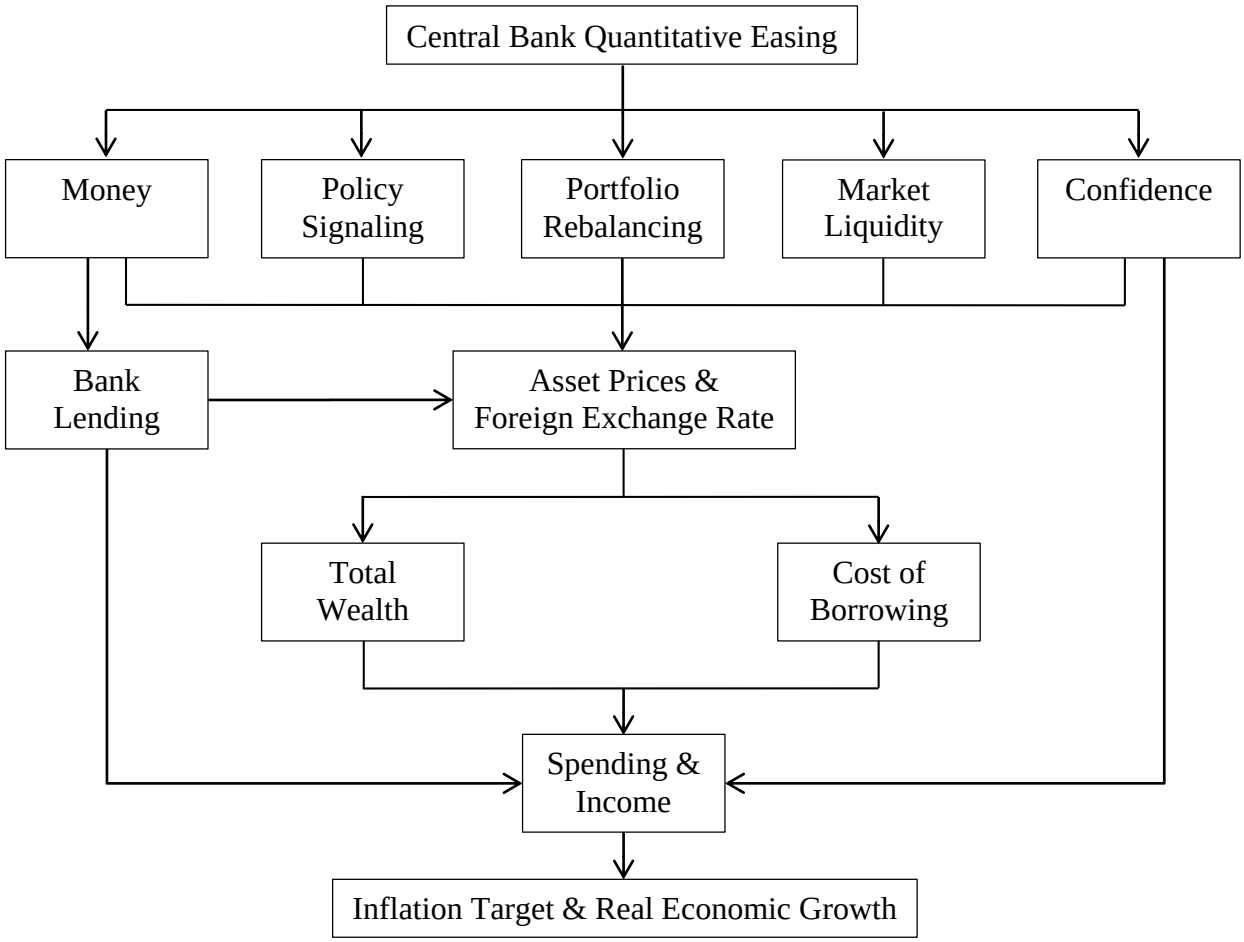
Krishnamurthy and Vissing-Jorgensen (2011) evaluate the effect of the Federal Reserve's purchase of long-term Treasuries and other long-term bonds ("QE1" in 2008-2009 and "QE2" in 2010-2011) on interest rates. Using an event-study methodology they reach two main conclusions. First, it is inappropriate to focus only on Treasury rates as a policy target because QE works through several channels that affect particular assets differently. They find evidence for a signaling channel, a unique demand for long-term safe assets, and an inflation channel for both QE1 and QE2, and a mortgage-backed securities pre-payment channel and a corporate bond default risk channel for QE1. Second, effects on particular assets depend critically on which assets are purchased. The event-study suggests that (a) mortgage-backed securities purchases in QE1 were crucial for lowering mortgage-backed security yields as well as corporate credit risk and thus corporate yields for QE1, and (b) Treasuries-only purchases in QE2 had a disproportionate effect on Treasuries and Agencies relative to mortgage-backed securities and corporates, with yields on the latter falling primarily through the market's anticipation of lower future federal funds rates.

Kurihara (2006) analyze Japan's quantitative easing program and its influence on stock prices for economic recovery. There is much dispute over whether quantitative easing has been effective. Kurihara (2006) investigates the relationship between macroeconomic variables and stock prices. Exchange rate is the main target variable and finds that interest rates have not impacted Japanese stock prices, but exchange rates and U.S. stock prices have. Furthermore, the Bank of Japan's policy for overcoming recession and deflation has been effective.

Recent literature on unconventional monetary policy has identified a number of potential channels through which QE can potentially have an impact on inflation and economic growth (see, for example, Joyce *et al.*, 2011; Krishnamurthy and Vissing-Jorgensen, 2011). First, by announcing large scale asset purchases, central banks provide information about the likely path of future monetary policies to market participants through a signaling channel. Purchasing a large quantity of long-term assets under QE serves as a credible commitment by central banks to keep interest low in the future. This is because, if the central banks raise interest rate later, they will see huge losses on the assets they purchased under QE. The signaling channel is expected to affect interest rates across the yield curve with effects depending on bond maturities (Krishnamurthy and Vissing-Jorgensen, 2011). Second, by purchasing a large quantity of assets held by the private sector through QE, central banks change the relative supply of the assets being purchased, and thus induce equilibrating changes in their relative yields. Since the base money issued and the financial assets purchased under QE are not perfect substitutes, the sellers of financial assets may attempt to rebalance their portfolios by buying other assets which have similar characteristics to the assets sold. This process, therefore, further push up the prices of the assets purchased under QE as well as the prices of their close substitutes, and push down the associated term premiums and yields. The portfolio rebalance channel is likely to have larger effect for longer-term interest rates which contain higher duration risk premium. Third, central banks increase the liquidity in the hands of investor's by purchasing long-term securities and issuing bank reserves under QE. Joyce *et al.* (2011) assert that increased liquidity and improved market functioning, as the results of central banks' asset purchases, will lower premium for illiquidity, and thus increase asset prices. On the contrary, Krishnamurthy and Vissing-Jorgensen (2011) argue that an expansion in liquidity reduces the liquidity price premium carried by government bonds relative to other less liquid assets and

therefore increase government bond yields. However, it should be noted that the liquidity effect of QE may only persist while the central banks are conducting asset purchases.

Figure 1: Transmission channels of Quantitative Easing



Note: Adopted from Joyce *et al*. (2011).

Apart from the channels work through asset prices, QE may also have an impact on inflation and economic growth through bank lending and confidence effects. Since QE improves the liquidity of banking sector, it encourages banks to finance more new loans than they would have done. But this bank lending channel is expected to have very limited effect given the strains in the financial system in the wake of the crisis. Banks are likely to choose to hold central bank injections of money

as a cushion rather than pass liquidity onto the real economy through lending. QE is also expected to improve economic outlook and thus have a broader confidence effects. The boosted confidence, on the one hand, may encourage investment and spending directly; on the other hand, it may further increase asset prices by reducing risk premium. Various channels through which QE may support investment and spending are summarized in Figure 1. In this paper, we highlight the importance of signaling of portfolio rebalancing effects of QE on interest rates with different maturities, which in turn impact the broader economy.

A crucial question for a central bank is whether to conduct quantitative easing, hereafter referred to as easing quantitatively, or that the central bank eases quantitatively. A second question is to determine the impact of quantitative easing on market interest rates. The aim of the paper is to analyze these questions and try to explain the reaction of the market to the central bank's actions in a game-theoretic framework. We link the model to observed empirics in the market. For related literature see Barro and Gordon (1983a), Baumeister and Benati (2010), Beetsma, and Jensen (1999), Berkmen (2012), Christensen and Rudebusch (2012), Chung et al. (2012), Clarida et al. (1999), Estrella (2005), Fawley and Neely (2013), Gagnon et al. (2011), Lam (2011), Rogoff (1985), Shirai (2013), Svensson (1997), Ueda (2012), Woodford (1999a).

Section 2 presents the model. Section 3 provides intuition for the model. Section 4 compares the model with the empirical data. Section 5 concludes.

2 THE MODEL

The central bank loss function implies that the central bank's benefit of QE is that of reputation enhancement of controlled inflation and strong economic growth. The loss function is quadratic capturing the deviation of the actual inflation and actual GDP from their socially desirable targets. The loss function at any time t is given by

$$L_t = \frac{1}{2}\left[\left(\pi_t - \pi^*\right)^2 + \theta\left(y_t - y^*\right)^2\right], \tag{1}$$

where π_t is the actual inflation rate at time t and π^* is the socially desirable and targeted inflation rate, and y_t is the actual GDP at time t and y^* is the social desirable or targeted GDP, and $\theta \geq 0$ is the relative weight placed on output stabilization against inflation stabilization.

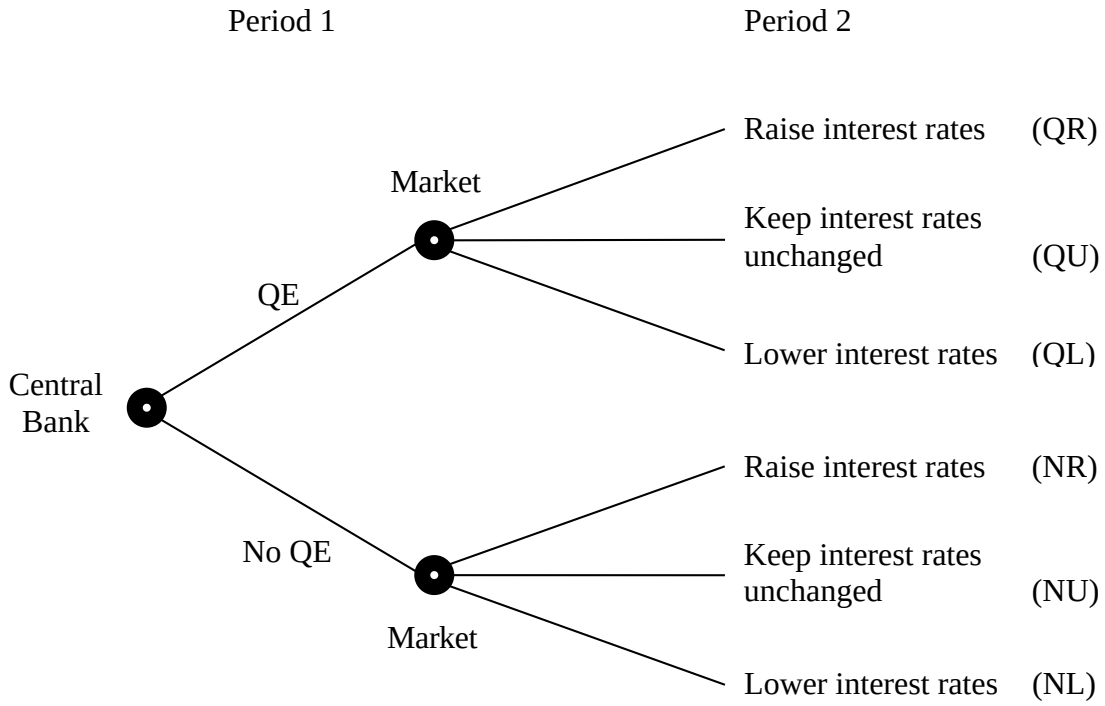
Svensson (1997) posits that society minimizes the expected value of some discounted intertemporal loss function into the future, i.e.

$$E\left(\sum_{t=1}^{\infty} \beta^{t-1} L_t\right), \tag{2}$$

where $0<\beta<1$ is the discount factor and E is the expectations operator, and L_t is the loss function. When the central bank eases quantitatively it believes actual realized inflation in the future will not deviate too much from the target, but output will increase significantly to approach its target. QE is thus stimulatory to the economy.

Consider two time periods and two unitary players which are the central bank and the market. In period 1 the central bank chooses either quantitative easing (Q) or no quantitative easing (N). In period 2 the market chooses either to lower interest rates (L), keep interest rates unchanged (U), or raise interest rates (R). The tree structure for the strategic form two-period game is shown in Figure 2. The six outcomes at the right, each expressed with two letters, follow from combining the players' strategies.

Figure 2: Quantitative Easing and Interest Rate Changes as a Tree Structure for the Strategic Form Two-Period Game



Note: The six outcomes at the right, each expressed with two letters, follow from combining the players' strategies.

Consider an economy where the central bank has utilized most instruments to stimulate economic growth including lowering interest rates as close to zero as possible. The central bank also prefers the market to lower interest rates as close to zero as possible, which does not necessarily happen since the market adjusts interest rates to maximize profit.

3 INTUITION FOR THE MODEL

To provide intuition for equation (1), assume a typical initial condition of no QE, desirable inflation $\pi_t = \pi^*$ and low GDP $y_t < y^*$. QE beneficially increases y_t towards y^*, thus beneficially lowering L_t. However, QE can cause increased inflation directly and can cause increased interest rates which

can also cause increased inflation π_t, thus increasing L_t. Consequently, QE causes decreased loss L_t in (1) only when y_t increases so that $\left(y_t - y^*\right)^2$ decreases more than $\left(\pi_t - \pi^*\right)^2$ increases. Thus QE is a double edged sword. It can beneficially increase GDP, but detrimentally increase inflation.

To link this reasoning to Figure 1 assume that the six outcomes cause six different inflation levels $\pi_{t6} \geq \pi_{t5} \geq \pi_{t4} \geq \pi_{t3} \geq \pi_{t2} \geq \pi_{t1}$ and GDP levels y_t so that the central bank's losses ordinally ranked from 1 to 6 are

$$\begin{aligned}
&E(QR: y_t = y^*, \pi_{t6} > \pi^*) \sim 6, \quad M(QR) \sim 6 \\
&E(QU: y_t = y^*, \pi_{t4} > \pi^*) \sim 4, \quad M(QU) \sim 5 \\
&E(QL: y_t = y^*, \pi_{t2} > \pi^*) \sim 2, \quad M(QL) \sim 4 \\
&E(NR: y_t < y^*, \pi_{t5} > \pi^*) \sim 5, \quad M(NR) \sim 3 \\
&E(NU: y_t < y^*, \pi_{t3} > \pi^*) \sim 3, \quad M(NU) \sim 2 \\
&E(NL: y_t < y^*, \pi_{t1} > \pi^*) \sim 1, \quad M(NL) \sim 1
\end{aligned} \tag{3}$$

where M is the market's ordinally ranked profits. Converting losses to profits by reversing the central bank ranking, equation (3) is expressed as Table 1, where 6 means most preferred and 1 means least preferred, for the central bank and the market. Bold numbers express preferred profits for each player.

Table 1: Players' Common Ordinal Profits

		Market		
		Lower interest rates	Keep interest rates unchanged	Raise interest rates
Central bank	Quantitative easing	5,4	3,5	1,**6**
	No quantitative easing	**6**,**3**	**4**,2	**2**,1

That is, the central bank prefers no QE over QE, and prefers low interest rates. In contrast, with QE, the market prefers high interest rates expressed with 6, to benefit from the high liquidity, and

with no QE, the market prefers low interest rates expressed with 3, since liquidity is low. The Nash equilibrium in Table 1 is (No QE, Lower interest rates) with payoffs (6, 3). This means that no QE occurs in equilibrium.

4 COMPARING THE MODEL WITH THE EMPIRICAL DATA

Let us compare Table 1 with the data in Table 2 which classifies 69 QE events and 69 no QE counterfactuals for four central banks, i.e. 17 events for the Federal Reserve, 9 events for Bank of England, 32 events for Bank of Japan, and 11 events for the European Central Bank.

Table 2: Classification of Outcome (Frequency and average change in the benchmark 10-year government bond yields)

Central Bank	Policy Choice	Forecast Method	**Market**		
			Lower interest rates	Keep interest rates unchanged	Raise interest rates
Federal Reserve	QE	–	7 (-27 bps)	9 (-1 bp)	1 (28 bps)
	No QE	Naïve	0 (N.A.)	17 (0 bp)	0 (N.A.)
		AR(1)	1 (-13 bps)	16 (-1 bp)	0 (N.A.)
		AR(2)	1 (-13 bps)	15 (1 bp)	1 (29 bps)
Bank of England	QE	–	3 (-38 bps)	3 (-3 bps)	3 (11 bps)
	No QE	Naïve	0 (N.A.)	9 (0 bp)	0 (N.A.)
		AR(1)	0 (N.A.)	9 (0 bp)	0 (N.A.)
		AR(2)	0 (N.A.)	9 (0 bp)	0 (N.A.)
Bank of Japan	QE	–	1 (-10 bps)	31 (-1 bp)	0 (N.A.)
	No QE	Naïve	0 (N.A.)	32 (0 bp)	0 (N.A.)
		AR(1)	1 (-14 bps)	31 (0 bp)	0 (N.A.)
		AR(2)	0 (N.A.)	32 (-1 bp)	0 (N.A.)

European Central Bank	QE	–	1 (-16 bps)	6 (0 bp)	4 (10 bps)
	No QE	Naïve	0 (N.A.)	11 (0 bp)	0 (N.A.)
		AR(1)	0 (N.A.)	11 (0 bp)	0 (N.A.)
		AR(2)	0 (N.A.)	11 (0 bp)	0 (N.A.)
Summary of Outcomes	QE	–	12 (-27 bps)	49 (-1 bp)	8 (13 bps)
	No QE	Naïve	0 (N.A.)	69 (0 bp)	0 (N.A.)
		AR(1)	2 (-14 bps)	67 (0 bp)	0 (N.A.)
		AR(2)	1 (-13 bps)	67 (0 bp)	1 (29 bps)

Notes: The classification of QE outcomes and no QE counterfactuals is based on observed and simulated changes in yield of benchmark 10-year government bond over a two-day event window, respectively. The frequency of each possible outcome is reported in the corresponding cell alongside the average change in 10-year government bond yield of the events fall into the category. Three forecast methods are used to produce the no QE counterfactuals for the changes in 10-year government bond yield, namely naïve, AR(1) and AR(2). The methodologies are described in detail in Section 4.4. The 5^{th} and 95^{th} percentiles of the distribution of two-day changes in 10-year government bond yield in normal time (2003-2007) are used as the critical values to classify the QE outcomes and their no QE counterfactuals.

The no QE counterfactuals in Table 2 almost exclusively cause unchanged interest rates. Hence we interchange the profits 2 and 3 for the market as in Table 3 causing one Nash equilibrium with payoffs (4,3) and no QE.

Table 3: Players' Common Ordinal Profits

		Market		
		Lower interest rates	Keep interest rates unchanged	Raise interest rates
Central bank	Quantitative easing	5,4	3,5	1,**6**
	No quantitative easing	**6**,2	**4**,**3**	**2**,1

Since QE indeed occurs in practice, assume that the central bank prefers QE if the market responds by lowering interest rates or keeping interest rates unchanged, but not if the market raises interest rates. This means interchanging 6 and 5 and interchanging 4 and 3 for the central bank causing Table 4 which has no Nash equilibrium (no cell has two bold numbers), illustrating the tension between the two players. We get a perpetual dance around the matrix. The central bank chooses QE and we get the upper left cell. Then the market responds by raising interest rates and we get the upper right cell. The central bank then prefers no QE to earn 2 rather than 1, which gives the lower right cell. The market responds causing (3,3)->(4,5)->(1,6)->(2,1)->(3,3)-> etc.

Table 4: Players' Profits

		Market		
		Lower interest rates	Keep interest rates unchanged	Raise interest rates
Central bank	Quantitative easing	**6**,4	**4**,5	1,**6**
	No quantitative easing	5,2	3,**3**	**2**,1

To explain the 8 QE events in Table 2 where the market responds to QE by raising interest rates, we interchange 2 and 1 for the central bank in Table 4 causing Table 5 which indeed has a Nash equilibrium in the upper right cell. This outcome occurred only 1 out of 16 times for the Federal Reserve, 3 out of 9 times for BoE, never for BoJ, and 4 out of 11 times for the ECB.

Table 5: Players' Profits

		Market		
		Lower	Keep interest	Raise

		interest rates	rates unchanged	interest rates
Central	Quantitative easing	**6**,4	**4**,5	**2**,**6**
bank	No quantitative easing	5,2	3,**3**	1,1

To explain the most common 49 QE events in Table 2 where the market responds to QE by keeping interest rates unchanged, we interchange 6 and 5 in Table 5 for the market causing Table 6 which has a Nash equilibrium in the upper middle cell. This outcome occurred 9 out of 16 times for the Federal Reserve, 3 out of 9 times for BoE, overwhelmingly 31 out of 32 times for BoJ, and 6 out of 11 times for the ECB.

Table 6: Players' Profits

		Market		
		Lower interest rates	Keep interest rates unchanged	Raise interest rates
Central	Quantitative easing	**6**,4	**4**,**6**	**2**,5
bank	No quantitative easing	5,2	3,**3**	1,1

Finally, to explain the intermediately common 12 QE events in Table 2 where the market responds to QE by lowering interest rates, we interchange 6 and 4 in Table 5 for the market causing Table 7 which has a Nash equilibrium in the upper left cell. This outcome occurred 7 out of 16 times for the Federal Reserve, 3 out of 9 times for BoE, only 1 out of 32 times for BoJ, and only 1 out of 11 times for the ECB.

Table 7: Players' Profits

		Market

		Lower interest rates	Keep interest rates unchanged	Raise interest rates
Central bank	Quantitative easing	**6**,**6**	**4**,5	**2**,4
	No quantitative easing	5,2	3,**3**	1,1

5 CONCLUSION

We develop a game theoretic model for the central bank's profit and the market's profit dependent on quantitative easing (QE) or no quantitative easing (no QE), where the market responds by lowering interest rates, keeping interest rates unchanged, or raising interest rates.

The model is compared with empirical data. We classify 69 QE events and 69 no QE counterfactuals for four central banks, i.e. 17 events for the Federal Reserve, 9 events for Bank of England, 32 events for Bank of Japan, and 11 events for the European Central Bank. The market response to the BoJ and ECB QE is almost exclusively to keep interest rates unchanged. Although this response is most common to the Federal Reserve QE (9 events), the market frequently responds as the Federal Reserve prefers, by lowering interest rates (7 events). For BoE the market response is evenly split across the three outcomes.

The unconventional measures undertaken by the Federal Reserve and Bank of England, which focus primarily on bond purchases, are much more effective in lowering interest rates than those undertaken by the Bank of Japan and European Central Bank, which have relied more heavily on lending to private financial institutions. Although the unconventional monetary policies adopted by the Federal Reserve and Bank of England are similarly designed and both are proven to be effective, our empirical results show that they affect interest rates through distinct transmission

mechanisms. Specifically, the decomposition of market responses to the QE-related events suggests that the decline in US Treasury yields largely reflects changes in policy expectations, and the decline in UK gilt yields is mainly attributable to the reductions in term premiums. Therefore, the signaling channel is dominant in the QE program conducted by the Federal Reserve, while the portfolio rebalance channel plays a more important role in the conduct of the Bank of England's QE program.

From our empirical analysis, the UK and US show that over 80% of the cumulative changes in government bond yields are attributable to the first around of their QE. The market responses to the subsequent rounds of QE are much less significant. This research thus uncovers new insight that the effectiveness of the unconventional monetary policies tends to diminish once they have been used.

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