Fisher's Relation and the Term Structure: Implications for IS Curves

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Abstract

We derive the new Keynesian IS curve from the Fisher relation and the expectations theory of the term structure, without reference to household preferences. We show that, under certain conditions, parameters of the empirical new Keynesian IS curves need not be estimated but can be calibrated from observed data. We specifically show that the coefficient of relative risk aversion is the steady-state consumption-output ratio and that the interest rate effect on output can be reasonably approximated by the inverse of the average term to maturity of debt instruments. We highlight the implications of these findings for macroeconomic modelling and estimation.

Keywords: IS curve, no-arbitrage, Fisher relation, expectations theory of the term structure.

1. Introduction

The IS curve provides a crucial link between monetary policy actions and aggregate economic activity. Alongside the forward-looking Phillips curve

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and the Taylor rule, the new Keynesian IS curve in particular, forms an important building bloc of modern macro-models. While the empirics of the Phillips curve and the Taylor rule have received the overwhelming attention of researchers, the empirical validity of the IS curve remains under-researched. A few authors, for example, Nelson (2002), Fuhrer and Rudebusch (2004) and Goodhart and Hofmann (2005), Hafer and Jones (2008) and Stracca (2010) have documented problems with the baseline empirical IS curve. In these studies, IS curve is found to produce an insignificant, or wrongly signed, effect of the real interest rate on output. This phenomenon can also be observed in studies of emerging markets (e.g., de Mello and Moccero, 2011).

In an attempt to resolve this problem, Goodhart and Hofmann (2005) propose an extension of the IS curve that features asset prices and the monetary aggregate. In the context of Australia, Paradiso et al.(2013) implement this extension and find that the IS puzzle is resolved, although this is only true for the backward-looking IS curve and not for the forward-looking IS curve. Within the new Keynesian framework, Kara and Nelson (2004) and Nelson and Nikolov (2004) propose augmenting the baseline IS curve with other components of aggregate demand, especially government purchases. Both these extensions to the IS curve improve the real interest rate effect on output. However, the specification by Hafer and Jones (2008), which adds only the growth rate of the monetary aggregate in the IS curve, tends to diminish the real interest rate effect on output.

In this paper, we show that the IS curve can be derived from equilibrium conditions in financial markets, without reference to household preferences. Furthermore, under certain conditions, requisite parameters of the IS curve need not be estimated, but can simply be calibrated on the basis of observable data. The significance of this finding is that errors in estimating reduced-form aggregate demand dynamics can be minimised and the monetary policy transmission mechanism through the interest rate channel can be adequately measured. Secondly, this approach allows for a solid assesment of the various estimates of the interest rate parameter in the IS curve.

The remainder of the paper is structured as follows: section 2 briefly re-states new Keynesian IS curve and then derives this curve from financial market no-arbitrage conditions. Section 3 compares our calibrated IS curves with those that are estimated in the literature. Section 4 concludes with implications of our findings for macroeconomic modelling and estimation.

2. New-Keynesian IS curves

2.1 The pure forward-looking IS curve

The standard derivation of the baseline new Keynesian IS curve begins by postulating a basic utility function to characterise the preferences of households:

$$U_t = E_t \sum_{j=0}^{\infty} \beta^j \frac{C_{t+j}^{1-\sigma}}{1-\sigma}, \tag{1}$$

where $\sigma > 0$ is the coefficient of relative risk aversion, β is the discount factor and C_t is consumption. Furthermore, standard practice in the derivation of the new Keynesian IS curve is to assume a one-period bond, as in Gali (2008: Chapter 2). In our derivation of this curve, we instead assume a $n-$period bond, in order to illustrate the problem in the standard interpretation of the estimated interest rate parameter. In this context, we interpret n to be the average term-to-maturity of debt instruments in the economy.

Fuhrer and Rudebusch (2004) point out that expenditure on durable consumption goods is the most interest-sensitive component of aggregate consumption. Consequently, long-term interest rates play a significant role in affecting aggregate demand. Taking this observation into account, we postulate that the household maximises eq.(1) subject to the following budget constraint:

$$\frac{B_t}{P_t} = \frac{(1 +^n i_{t-1})\, B_{t-1}}{P_t} + \frac{W_t N_t}{P_t} - C_t, \tag{2}$$

where B_t is the nominal value of the $n-$period bonds, P_t is the price level, ${}^n i_t$ is the one-period nominal interest rate yielded by a $n-$period bond, W_t is the nominal wage and N_t is the level of employment. The first-order conditions are:

$$C_t^{-\sigma} = \lambda_t \tag{3}$$

$$\lambda_t = \beta E_t \lambda_{t+1} \left(\frac{1 +^n i_t}{1 + \pi_{t+1}} \right), \tag{4}$$

where π_t is the inflation rate and λ_t is the Lagrange multiplier. As is now standard in the literature, eqs.(3) and (4) imply the following "consumption-based" IS relation:

$$\widehat{c}_t = E_t\widehat{c}_{t+1} - \frac{1}{\sigma}\left({}^n i_t - E_t\pi_{t+1}\right), \tag{5}$$

It is also standard to convert this consumption-based IS curve into an output-based one by using the macro-balance equation. Suppose:

$$\widehat{y}_t = \alpha\widehat{c}_t + (1-\alpha)\,\widehat{d}_t, \tag{6}$$

where $\widehat{y}_t$ is the percentage deviation of output from trend, α is the steady state consumption-output ratio and $\widehat{d}_t$ is the deviation of other components of aggregate demand from the steady state. In addition, the expectations theory of the term structure of interest rate states that:

$${}^n i_t = \frac{1}{n}i_t + \frac{1}{n}E_t\sum_{j=1}^{n} i_{t+j}, \tag{7}$$

where i_t is the nominal interest rate yielded by a one-period bond. Using eqs.(6) and (7), we can write the output-based IS curve as follows:

$$\widehat{y}_t = E_t\widehat{y}_{t+1} - \frac{\alpha}{\sigma n}\left(i_t - E_t\pi_{t+1}\right) + \epsilon_t, \tag{8}$$

where $\epsilon_t = -(1-\alpha)\,\Delta\widehat{d}_{t+1} - \frac{\alpha}{\sigma}\left(\frac{1}{n}E_t\sum_{j=1}^{n} i_{t+j} - \frac{n-1}{n}E_t\pi_{t+1}\right)$. Eq.(8) is the stripped-down version of the standard new-Keynesian IS curve. The achievement of the above exercise is that, from an economic point of view, the IS parameter is directly linked to the preferences of agents and the shocks have a structural interpretation as well. In addition, aggregate demand dynamics are driven by forward-looking expectations.

Note, however, that the interest rate parameter can no longer be interpreted in a standard way as the intertemporal elasticity of substitution, since it is the product of the intertemporal elasticity of substitution and the inverse of the term to maturity of debt instruments. Standard formulations of the new Keynesian model assume a one-period bond in eq.(2). However, in reality economies have debt instruments of short and long term maturity. It makes sense, therefore, to assume an average term to maturity n. Once this slight modification is made in the budget constraint, as in eq.(2), the interpretation of the interest rate parameter differs from the standard one.

Now in general equilibrium household optimisation corresponds to financial market equilibrium. This allows us to show that eq.(8) is, in fact, the Fisher relation combined with the expectations theory of the term structure, and that the preference parameter is actually the steady-state consumption-output ratio. Assume an agent posesses an amount of money P_t and has a choice of either investing in a n-period bond that yields a one-period gross nominal interest rate $(1 +^n i_t)$ or in a one-period project that produces output. The amount of money P_t purchases one unit of output. At symmetric equilibrium each unit of output grows at the same rate as aggregate output. Under no arbitrage the following condition must hold:

$$E_t\left(\frac{Y_{t+1}}{Y_t}\right) = E_t\left(\frac{1 +^n i_t}{1 + \pi_{t+1}}\right), \tag{9}$$

where Y_t denotes aggregate output. Note that eq.(9) is similar to the output-based non-linear Euler equation (see also Nelson, 2004). Eq.(9) states that the expected growth rate of output from the project must equal the real interest rate. The log-linearised version of eq.(9) is as follows:

$$\widehat{y}_t = E_t\widehat{y}_{t+1} - \left({}^n i_t - E_t\pi_{t+1}\right). \tag{10}$$

Applying the expectations theory of the term structure, we can write eq.(10) to yield the following "IS type" relation:

$$\widehat{y}_t = E_t\widehat{y}_{t+1} - \frac{1}{n}\left(i_t - E_t\pi_{t+1}\right) + \zeta_t \tag{11}$$

where $\zeta_t = -\left(\frac{1}{n}E_t\sum_{j=1}^{n} i_{t+j} - \frac{n-1}{n}E_t\pi_{t+1}\right)$. General equilibrium implies that eqs.(11) and (8) are identical, which means that $\sigma = \alpha$. That is to say, the coefficient of relative risk aversion is equal to the steady state consumption-output ratio. Thus, we have shown from eq.(11) that the canonical new-Keynesian IS curve can be derived without reference to household preferences and that the intertemporal elasticity of substitution can be calibrated using observable data.

In addition, since the average term to maturity is also observable, it follows that the interest rate parameter in the IS curve can be directly calibrated from the data as well. This means that even if we do not have adequate data on the interest rate and output, as long as we know the average term-to-maturity of debt instruments in the economy, we can obtain a reasonably accurate IS curve by calibration.

2.2 The hybrid IS curve

Does the finding that the coefficient of relative risk aversion is the inverse of the consumption-output ratio change in the presence of consumption habits? In this part of the paper, we show that this result remains true even in the context of the hybrid IS curve. The new Keynesian hybrid IS invokes habits as proposed by Fuhrer (2000), to capture the persistence of output fluctuations in response to shocks. The IS curve with lagged output can be found in Clarida et al.(1999), Rudebusch (2002), Ehrmann and Smets (2003) and Smets and Wouters (2003) among others. In the following derivation, we re-state the reduced-form IS curve by specifying habits that enter multiplicatively in the utility function, as in Smets and Wouters (2003), as follows:

$$U_t = E_t\sum_{j=0}^{\infty}\beta^j \frac{1}{1-\sigma}\left(C_{t+j} - hC_{t-1+j}\right)^{1-\sigma}, \tag{12}$$

where $h > 0$ is the habit formation parameter. Eq.(12) is maximised subject to eq.(2). Consequently, Smets and Wouters (2003) obtain the following first-order condition:

$$(C_t - hC_{t-1})^{-\sigma} = \beta (C_t - hC_{t-1})^{-\sigma} \left(\frac{1 +^n i_t}{1 + \pi_{t+1}} \right) \tag{13}$$

Log-linearising eq.(13) and abstracting from trend growth we obtain:

$$\widehat{c}_t = \left(\frac{1}{1+h} \right) E_t \widehat{c}_{t+1} + \left(\frac{h}{1+h} \right) \widehat{c}_{t-1} - \frac{1-h}{\sigma (1+h)} ({}^n i_t - E_t \pi_{t+1}) \tag{14}$$

Applying the macro-balance equation, eq.(6), to eq. (14), we can now express this IS relationship in terms of output as follows:

$$\widehat{y}_t = \left(\frac{1}{1+h} \right) E_t \widehat{y}_{t+1} + \left(\frac{h}{1+h} \right) \widehat{y}_{t-1} - \frac{\alpha (1-h)}{\sigma n (1+h)} (i_t - E_t \pi_{t+1}) + \epsilon_t \tag{15}$$

where $\epsilon_t = (1-\alpha) \widehat{d}_t - \left(\frac{1-\alpha}{1+h} \right) \widehat{d}_{t+1} - \left(\frac{h(1-\alpha)}{1+h} \right) \widehat{d}_{t-1} + \zeta_t$ and ζ_t is as defined in eq.(11). It is easy to show that this type of IS curve can also be derived from the no-arbitrage condition implied by the Fisher relation combined with the expectations theory of the term structure of interest rate.

Assume a fraction ϕ of projects is expected to yield Y_{t+1} of output while another fraction $(1-\phi)$ yields Y_{t-1}. No arbitrage implies:

$$E_t \left(\frac{\phi Y_{t+1} + (1-\phi) Y_{t-1}}{Y_t} \right) = E_t \left(\frac{1 +^n i_t}{1 + \pi_{t+1}} \right) \tag{16}$$

Linearising eq.(16), abstracting from trend growth and applying the expectations theory of the term structure, we obtain the following "IS-type" relation:

$$\widehat{y}_t = \frac{1}{1+h} E_t \widehat{y}_{t+1} + \left(\frac{h}{1+h} \right) \widehat{y}_{t-1} - \frac{1}{n} (i_t - E_t \pi_{t+1}) + \zeta_t^{'}, \tag{17}$$

where:

$$h = \frac{(1-\phi)}{\phi},\ \zeta_t^{'} = -\left(\frac{1}{n}E_t\sum_{j=1}^{n} i_{t+j} - \frac{n-1}{n}E_t\pi_{t+1}\right).$$

We immediately observe that eq.(17) is similar to eq.(15). In fact, these equations imply that $\sigma = \alpha\left(\frac{1-h}{1+h}\right)$. The coefficient of relative risk aversion is the steady state consumption-output ratio if habit formation is absent. The larger is habit formation, the smaller is the coefficient of relative risk aversion and hence the larger is the elasticity of intertemporal substitution.

2.3 Do we need to estimate the IS curve?

The results in section 2.1 have shown that we do not need to estimate the pure forward-looking IS curve if we have data on the average term to maturity of debt instruments in the economy. We further found in section 2.2 that the elasticity of intertemporal substitution cannot be identified unless we know the habit formation parameter. However under the assumption of log utility, as in Christiano et al.(2005), DiCecio and Nelson (2007) and Quint and Rabanal (2013), we can identify the habit-formation parameter since $\sigma = 1$.

Equating the interest rate parameter in eqs.(17) and (14), and setting $\sigma = 1$, we can back out the habit formation parameter, as follows, without econometrically estimating it:

$$h = \frac{\alpha n - 1}{1 + \alpha n} \tag{18}$$

We can then substitute the habit formation parameter in eq.(18) into eq.(17) to get the following IS curve:

$$\widehat{y}_t = \left(\frac{1}{2} + \frac{1}{2\alpha n}\right) E_t\widehat{y}_{t+1} + \left(\frac{1}{2} - \frac{1}{2\alpha n}\right)\widehat{y}_{t-1} - \frac{1}{n}\left(i_t - E_t\pi_{t+1}\right) + \zeta_t^{'}, \tag{17}$$

Since α and n are observable and can be approximated by taking simple historical averages, it follows from eq.(18) that the habit formation parameter

need not be estimated but can be calibrated with reasonable accuracy. Note that eq.(17) shows that, with log utility, the parameter that is associated with the forward-looking component of the IS curve will be higher than the one associated with the backward-looking component. In the next section, we compare our calibrated interest rate and habit formation parameters with the estimated ones that are found in prior studies.

3. Empirical IS curves: estimated and calibrated parameters

Our derivation of the IS curve from financial market equilibrium shows that, in the case of the baseline model, it is enough to know the steady state consumption output ratio and the average term to maturity in order to determine an empirical IS curve. In the context of log-utility, we have also shown that habit formation need not be estimated as well. In this section of the paper, we consider data from selected developed and emerging market economies to illustrate the closeness of the IS formulated from financial market equilibrium and those derived from household optimisation. Table 1 uses data from the OECD and the Bank for International Settlements on average term to maturity of outstanding central government debts. Also drawn from the OECD database, Table 1 reports average consumption-output ratios over the period 1980–2010. For some emerging markets data starts from 1995.

Table 1: Average term to maturity and the consumption-output ratio

Country	Maturity OECD	Maturity BIS	Cons-GDP Ratio
	Developed Economies		
Australia	6.96	9.54	0.57
Canada	5.79		0.56
Germany	5.50	10.75	0.57
Sweden	3.53		0.49
UK	12.0		0.63
US	5.15		0.67
Euro-area	9.0		0.65
	Emerging markets		
Israel	6.59	9.67	0.58
Mexico	6.83		0.67
Czech	5.56	7.75	0.50
S.Africa		17.34	0.60
S.Korea	4.05	7.02	0.67
Turkey	3.49	3.54	0.70

As can be seen, there are differences in the average terms to maturity between the OECD and the BIS databases (with average maturities from BIS being consistently longer than those from the OECD for all countries) and there are gaps in the BIS database on some countries. Given these discrepances we report the results for both these maturity terms. The next step is to calibrate the habit formation parameter, under the assumption of log-utility function, using eq.(18). We then compare our calibrated habit formation parameter with the one that is estimated in prior studies for each sample country. Table 2 reports the results.

We find that for the UK, US and the Euro-area and Germany, our calibrated habit formation parameters based on the OECD database are very close to the ones that are estimated. Note that the Euro-area estimate by Quint and Rabanal (2013) is close to the one reported by Adolfson et al.(2007), which is 0.69. The calibration that is based on the BIS database is closer to the estimated parameter for Australia and Israel. For the rest of the countries there are discrepancies between our calibrated parameter and the one that is estimated.

	DSGE Models	Estimated Habit	Caliberated Habit (OECD)	Caliberated Habit (BIS)†
		Developed Economies		
Australia	Jääskelä and Nimark (2011)	0.76	0.60	0.69
Canada	Vukotić (2007)	0.74	0.53	
Germany	Pytlarczyk (2005)	0.57	0.52	0.72
Sweden	Adolfson et al. (2011)	0.63	0.27	
UK	DiCecio and Nelson (2007)	0.77	0.77	
US	Christiano et al. (2005)	0.52	0.55	
Euro-area	Quint and Rabanal (2013)	0.72	0.71	
		Emerging markets		
Israel	Argov et al.(2012)	0.71	0.59	0.70
Mexico	Garcia-Cicco (2008)	0.83	0.64	
Czech	Beneš et al.(2005)	0.80	0.47	0.59
S.Africa	Steinbach et al.(2009)	0.70		0.82
S.Korea	An and Kang (2009)	0.26	0.46	0.65
Turkey	Alp and Elekdag (2011)	0.90	0.42	0.42

Once the habit formation parameter is estimated, it is straightforward to derive the interest rate effect on output by computing the parameter in eq.(15). Therefore, our calibrated interest rate effect is just the inverse of the average term to maturity. In Table 3 we also consider estimates from reduced-form new Keynesian IS curves. The results suggest that for some economies the interest rate has almost twice the effect that is estimated by DSGE models (see for example Australia and Canada). Reduced-form estimates tend to under-estimate the interest rate effect by almost half in some cases (see for example the US and Euro-Area).

Overall, there are clear cases where our calibrated estimate of the interest rate effect on output as simply the inverse of the average term to maturity of debt instruments is very close to estimated parameters. Germany, the UK, US, Euro-Area and Israel fall in this category. For the rest of the countries there are discrepancies sometimes due to the data source of maturity terms and models (see Australia and Mexico). In the South African case, the DSGE habit formation parameter was calibrated and not estimated by Steinbach et al.(2009).

Table 3: Estimated and calibrated interest rate effect in the IS curve

	Small NK Models	Estimated	Large-Scale DSGE Models	Estimated	Calibrated*	Calibrated**
			Developed markets			
Australia	Buncic and Melecky (2008)	0.02	Jääskelä and Nimark (2011)	0.08	0.14	0.10
Canada	Berg et al.(2006)	0.10	Vukotić (2007)	0.08	0.17	
Germany	Berg et al.(2006)	0.10	Pytlarczyk (2005)	0.16	0.18	0.09
Sweden	Castelnuovo (2008)	0.15	Adolfson et al. (2011)	0.11	0.28	
UK	Nelson and Nikolov (2004)	0.09	DiCecio and Nelson (2007)	0.08	0.08	
US	Rudebusch (2005)	0.09	Christiano et al. (2005)	0.21	0.19	
Euro-area	Smets (2003)	0.06	Quint and Rabanal (2013)	0.11	0.11	
			Emerging markets			
Israel	Argov et al.(2007)	0.15	Argov et al.(2012)	0.10	0.15	0.10
Mexico	Espada and Ramos-Francia (2009)	0.11	Garcia-Cicco (2008)	0.06	0.15	
Czech	Melecky and Melecky (2008)	0.03	Beneš et al.(2005)	0.06	0.18	0.13
S.Africa	Harjes and Ricci (2008)	0.09	Steinbach et al.(2009)	0.11		0.06
S.Korea	Piao and Joo (2011)	0.02	An and Kang (2009)	0.39	0.25	0.14
Turkey	Us (2007)	0.11	Alp and Elekdag (2011)	0.04	0.29	0.28

*OECD database, **BIS database

Lastly, it is also useful to compare our calibration to the estimates from models that do not have habit-formation. Few models have been estimated that exhibit this feature, since the introduction of habit formation in DSGE modelling. For this comparison, we use the OECD measures of average term to maturity. In the case of the US, a prominent model in this class is McCallum and Nelson (1999), which estimates the interest rate effect in the pure forward-looking IS curve (eq.8) to be 0.19 (see also Casares and McCallum, 2006). Interestingly our calibration delivers the same magnitude, which is the inverse of the average term to maturity of 5.15 years. In the case of the Euro area, Rabanal and Rubio-Ramírez (2008) estimate the interest rate effect to be 0.11. We get the same magnitude with our calibration, which is the inverse of the average term to maturity of 9 years. Lastly, Dib (2003) estimates the interest rate effect for Canada to be 0.17, which corresponds to our calibrated inverse of 5.79 years.

The above results show that the no arbitrage IS curves are empirically similar to the utility-based IS curves. To be theoretically consistent in this context, we have to equate the coefficient of relative risk aversion to the steady-state consumption-output ratio. The discrepancies that we have observed for some economies may be due to a) the quality of data that was used to estimate the models, b) differences in the calibration of the steady-state consumption ratio and c) differences in the sample periods; in our calibration many countries have their terms to maturity data beginning in the mid-1990's, whereas estimated models may use data with a different sample size. Lastly, discrepancies may arise because the average term to maturity that we have used may not include the term to maturity for private corporate debt. In instances where corporate and household debt are significant, the average term to maturity of debt instruments in the economy may be slightly different to the one reported here.

4. Conclusion

Recent literature continues to underline the considerable uncertainty regarding the empirical validity of the reduced-form IS curve. The interest rate effect on output, which is an important parameter for the transmission of monetary policy, is found to be insignificant or carries the wrong sign, a phenomenon termed the IS puzzle. In this paper we have shown that, under certain conditions, this important parameter of the new Keynesian IS curve

need not be estimated but can simply be calibrated as the inverse of the average term to maturity of debt instruments in the economy. One of the conditions necessary for our caliberation approach is that households in the economy must be purely forward-looking, so that there would be no need to estimate habit formation. However, the sluggish response of consumption and output to monetary shocks has prompted researchers to introduce habit formation in the new Keynesian model.

Given that habit formation is now a standard feature of new Keynesian macro models, it is essential that our approach responds to this requirement. Therefore, in the context where households exhibit habit formation, the condition that is required for the IS curve to be calibrated is that households must exhibit log utility. This requirement dispenses with the identification of the coefficient of relative risk aversion, since such a coefficient is set to be one. This allows us to express the habit formation parameter as the product of the steady-state consumption-output ratio and the average term to maturity of debt instruments in the economy.

Our finding has important implications for macroeconomic modelling and estimation. Firstly, in the context where data is of low quality, our approach can improve the measurement of the monetary transmission mechanism by providing reasonably good approximations of the reduced-form new Keynesian IS curve. Secondly, our approach provides a straightforward structural explanation of the determinant of the interest rate effect on output as the average term to maturity of debt instruments. Lengthening the maturity of debt instruments expectedly reduces the effect of short term interest rates on output, while shortening the maturity of debt instruments increases the interest rate effect. Lastly, in the context where a large number of parameters is estimated, our approach can improve the efficiency of the estimation of the other parameters, since reformulating the IS curve reduces the set of parameters to be estimated and thereby raises the degrees of freedom.

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