CENTRE FOR DYNAMIC MACROECONOMIC ANALYSIS
WORKING PAPER SERIES

CDMA05/10

Optimal Monetary Policy Rules from a Timeless Perspective*

Tatiana Damjanovic†
University of St Andrews

Vladislav Damjanovic‡
University of St Andrews

Charles Nolan§
University of St Andrews

OCTOBER 2005

ABSTRACT

The timelessly optimal monetary policy proposed by Woodford (2003) may be dominated by alternative timeless policies. We provide a formal justification for these alternative policies. We demonstrate why discount rates do not matter and establish that optimizing over the unconditional expectation of the policy criterion function recovers these alternative strategies.

JEL Classification: C61, E30, E52, E58, E61.
Keywords: Time consistency, unconditional expectation, timeless perspective, optimal monetary policy.

* Acknowledgements: We should like to thank Ben McCallum for helpful comments. T. Damjanovic acknowledges the support of the May Wong Smith Foundation. V. Damjanovic acknowledges the support of a Royal Economic Society Research Fellowship.

† School of Economics and Finance, Castlecliffe, The Scores, St Andrews, Fife KY16 9AL, Scotland, UK. Tel: +44 (0) 1334 462482. E-mail: td21@st-andrews.ac.uk. Web: http://www.standrews.ac.uk/economics/staff/pages/t.damjanovic.shtml.

‡ School of Economics and Finance, Castlecliffe, The Scores, St Andrews, Fife KY16 9AL, Scotland, UK. Tel: +44 (0) 1334 462445. E-mail: vd6@st-andrews.ac.uk. Web: www.st-andrews.ac.uk/cdma/v.damjanovic.html.

§ School of Economics and Finance, Castlecliffe, The Scores, St Andrews, Fife KY16 9AL, Scotland, UK. Tel: +44 (0) 1334 462425. E-mail: Charles.Nolan@st-andrews.ac.uk. Web: www.st-andrews.ac.uk/cdma/c.nolan.html.

1. Introduction

Kydland and Prescott (1977) brought into sharp focus the issue of time inconsistency of optimal policy design in macroeconomic models with forward-looking behavior and rational expectations. Taylor (1979) proposed searching for policies, under rational expectations, which maximize the unconditional expectation of the government's objective function. This idea has been exploited many times e.g., Rotemberg and Woodford (1997, 1998), Woodford (1999), Clarida, Gali and Getler (1999), Erceg, Henderson and Levin (2000) and Kollman (2002). However, in most of those papers a numerical approach is adopted to uncover the optimal rule (sometimes restricted to some or other arbitrary parametric class).

Woodford (2003) proposed a dynamic optimization-based method for solving for the optimal policy, which he has labelled a "timeless perspective for optimal policy". However, Blake (2001) and Jensen and McCallum (2002) independently provided a counterexample which implies that alternative feasible timeless policies exist which dominate that proposed by Woodford. In this note, building on the Blake-Jensen-McCallum insight, we provide the first full formal justification of these alternative strategies. We demonstrate why discount rates don't matter in the formulation of our optimal timeless policy, something that a number of economists have asserted, e.g., Taylor, (1979). Using that insight, we pose and solve a policy optimization problem that delivers the Blake-Jensen-McCallum timeless policies.

2. The timeless perspective on optimal policy

2.1. A definition

The timelessly optimal policy is the policy that the government would have decided upon for the current period had such a decision been taking infinitely far in the past. This perspective is attractive for a number of reasons. In particular, in the context of monetary policy rules, as Giannoni and Woodford (2002) note:

> "The selection of a policy rule from this perspective means that it is not necessary to view the choice of the rule as a once and for all commitment, by which the central bank will be bound no matter how unappealing the rule may come to appear at a later time. Instead, the bank need only be committed to determine policy at the later dates by a rule that is optimal from a similar timeless

perspective. Insofar as the bank model of the economy is expected to guide its decision in the future as well, there is no reason to expect future behavior that does not conform to the rule currently adopted - and so there is no inconsistency involved in adopting the rule now because of its desirable properties if the bank is expected to follow it indefinitely."

2.2. Formalization

We formalize the Giannoni-Woodford timeless perspective. Consider a discounted quadratic loss function of the form

$$L_t = \frac{1}{2} E_t \sum_{j=0}^{\infty} \beta^j \left(x_{t+j} - x^*_{t+j} \right)' Q \left(x_{t+j} - x^*_{t+j} \right). \tag{2.1}$$

E_t is the expectations operator *conditional on information up through date* t, β is the time discount factor, x_t is a vector of target variables, x^* is a vector of target values which could depend on disturbance terms, and Q is a symmetric positive definite matrix.

$$x_t = \begin{bmatrix} z_t \\ Z_t \\ i_t \end{bmatrix}$$

Here i_t is a vector of policy instruments, the value of which is chosen in period t, z_t is a vector of non-predetermined endogenous variables, the value of which may depend upon both policy actions and exogenous disturbances at date t, Z_t is a vector of predetermined endogenous variables (lags of variables that are included in z_t and i_t).

We further assume that the evolution of the endogenous variables z_t and Z_t is determined by a system of simultaneous equations

$$\widehat{I} \begin{bmatrix} Z_{t+1} \\ E_t z_{t+1} \end{bmatrix} = A \begin{bmatrix} Z_t \\ z_t \end{bmatrix} + B i_t + C s_t, \tag{2.2}$$

where $B = \begin{bmatrix} 0 \\ B \end{bmatrix}$, $C = \begin{bmatrix} 0 \\ C \end{bmatrix}$ and s_t is a vector of exogenous disturbances.

The policy maker minimizes the loss function (2.1) subject to constraint (2.2). He searches for a policy rule of the general form

$$\phi_i' i_t + \phi_z' z_t + \phi_Z' Z_t + \phi_s' s_t = \overline{\phi}. \tag{2.3}$$

The timeless perspective policy which we seek to justify is to minimize the unconditional expectation of the loss function; this is equal to the expectation over all possible initial states of the economy (Taylor, 1979).

More formally, the optimal policy from a timeless perspective that we are looking for can be defined as a policy rule $\phi' = (\phi'_i, \phi'_z, \phi'_Z, \phi'_s, \overline{\phi},)$ which minimizes the unconditional expectation ($\widetilde{E}$) of the loss function (2.1), subject to constraint (2.2).

$$\phi'^* = \arg\min \widetilde{E} L_t(\phi'), \tag{2.4}$$

2.3. Woodford's methodology

Giannoni and Woodford (2002) proposed the following algorithm for finding the optimal policy from their timeless perspective:

- Step 1: Write the conditionally expected discounted Lagrangian:

$$J_t = E_t \left\{ \sum_{j=0}^{\infty} \beta^j \left[\frac{1}{2} \left(x_{t+j} - x^*_{t+j} \right)' Q \left(x_{t+j} - x^*_{t+j} \right) + \mu'_{t+j} \left(\widetilde{A} x_{t+j} - \widetilde{I} x_{t+j+1} \right) \right] \right\},$$

  where $\widetilde{A} := \begin{bmatrix} A & B \end{bmatrix}, \widetilde{I} := \begin{bmatrix} \widehat{I} & 0 \end{bmatrix}$, and μ_{t+j} is a vector of Lagrange multipliers associated with the constraints (2.2) (see Giannoni and Woodford (2002), p. 28).

- Step 2: Write the first-order conditions with respect to the endogenous variables, x_{t+j}

$$\begin{aligned} \left(x_{t+j} - x^*_{t+j} \right)' Q + \mu'_{t+j} \widetilde{A} - \beta^{-1} \mu'_{t+j-1} \widetilde{I} &= 0, \ for\ j > 0; \\ \left(x_t - x^*_t \right)' Q + \mu'_t \widetilde{A} &= 0, \ for\ j = 0. \end{aligned} \tag{2.5}$$

- Step 3: Ensure commitment to the policy program by ignoring the first-order conditions for period zero (2.5) and replace them with (2.6):

$$\left(x_t - x^*_t \right)' Q + \mu'_t \widetilde{A} - \beta^{-1} \mu'_{t-1} \widetilde{I} = 0. \tag{2.6}$$

The following example demonstrates Giannoni and Woodford's (2002) method.

Example 2.1. *Following Clarida, Gali and Getler (1999) consider the loss function*

$$L_t = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \pi_t^2 + \alpha y_t^2 \right\}, \tag{2.7}$$

and a forward-looking Phillips curve given by

$$\pi_t = \beta E_t \pi_{t+1} + \lambda y_t + \varepsilon_t, \tag{2.8}$$

where π_t is inflation at time t, y_t is the output gap, and ε_t is an i.i.d. shock process with variance σ^2. The Lagrangian for the policy problem may be written as

$$J_t = \sum_{j=0}^{\infty} \beta^j E_t \left\{ \left(\pi_{t+j}^2 + \alpha y_{t+j}^2 \right) + \mu_{t+j} \left[\pi_{t+j} - \beta E_t \pi_{t+1+j} + \lambda y_{t+j} + \varepsilon_{t+j} \right] \right\}. \qquad (2.9)$$

The commitment solution, or timelessly optimal solution, proposed by Giannoni and Woodford (2002) is simply to ignore the first-order conditions for $j = 0$. So, in any time period, we have the following pair of optimality conditions

$$\begin{aligned} \pi_t &= -\frac{1}{2}\mu_t + \frac{1}{2}\mu_{t-1}; \\ y_t &= \frac{\lambda}{2\alpha}\mu_t. \end{aligned} \qquad (2.10)$$

Hence,

$$\pi_t = -\frac{\alpha}{\lambda}(y_t - y_{t-1}). \qquad (2.11)$$

(2.11) relates the path of inflation and output to one another in a manner that is commonly characterized as the timelessly optimal program, and which is used to back out the optimal value of the interest rate (i.e., policy instrument).

3. What is wrong with this?

Blake (2001) proposed that the optimal timeless policy should in fact maximize the undiscounted sum of temporal utilities. Using his method he demonstrates that if one replaces equation (2.11), with

$$\pi_t = -\frac{\alpha}{\lambda}(y_t - \beta y_{t-1}) \qquad (3.1)$$

then unconditional welfare is higher. To prove his statement he assumes that output and inflation follow the simple dynamic paths

$$\pi_t = f_{11} y_{t-1} + f_{12} u_t; \qquad (3.2)$$

$$y_t = f_{21} y_{t-1} + f_{22} u_t. \qquad (3.3)$$

On the assumption that u_t is white noise, the Phillips curve imposes the following restrictions

$$\begin{aligned} f_{21} &= \frac{f_{11}}{\beta f_{11} + \lambda}; \\ f_{22} &= \frac{(1 - \beta\rho) f_{12} - 1}{\beta f_{11} + \lambda}. \end{aligned}$$

The unconditional expectation of the value of the loss function can be shown to be

$$\widetilde{E}U_t = -\frac{\sigma^2}{1-\beta}\left[\frac{(f_{11}^2 + a)}{1 - f_{21}^2} f\phi_{22}^2 + f_{12}^2\right]$$

where σ is the standard deviation of u_t. Using a numerical algorithm Blake (2001) shows that policy (3.1) satisfies the first-order and second-order conditions for an optimum. Jensen and McCallum (2002) also make this point and offer a simulation-based justification for replacing (2.11) with (3.1).

Blake and Kirsanova (2004), using the methodology described in Soderlind (1999), have also shown that there is a time consistent linear policy which results in smaller losses. However, those numerical simulations only demonstrate that such policies are *conditionally* better than the policy proposed by Woodford's timeless perspective methodology. Both simulations made assumptions concerning the output gap in the preceding period. However, as Soderlind (1999) shows, the optimal (simple) policy parameters depend on initial values, and therefore it is to be expected that under some values of initial conditions some policies perform better than others. For instance, in the example just considered, Woodford's timeless perspective methodology always dominates when $y_{t-1} = 0$, for, in this case, the timeless perspective policy is the same as the optimal (time inconsistent) policy.

The correct numerical comparison of unconditional timeless policies would involve Monte-Carlo simulations which would compare the values of loss functions integrating over all possible initial states; in the current example, of the lagged output gap. None of the numerical work carried out to date has done this. This was pointed out by Woodford 2003, p.508. However, Blake's (2001) counterexample remains without clarification.

3.1. On the optimal timeless policy and the households' time discount factor

In this subsection we shall prove that the optimal unconditionally timeless rule does not depend on the consumers' discount factor. In the next section, we shall use this insight to justify the results of Blake-Jensen-McCallum. The formal statement is provided in Proposition 3.1 which we ascribe to John Taylor as he is the first explicit reference to the issue of unconditionality emphasized above of which we are aware.

Proposition 3.1. *(Taylor, 1979) The consumer's time preference parameter is not important for the timeless policymaker. That is, the best timeless policy minimizes losses (3.4)* *for all discount factors* $\gamma \in (0,1)$

$$\widetilde{E}L_t(\gamma) = \widetilde{E}E_t \sum_{j=0}^{\infty} \gamma^j l_{t+j} \tag{3.4}$$

Here, l_t *denotes the period loss function. It follows immediately that,*

$$\arg\min_{\phi'} \widetilde{E}L_t(\gamma) = \arg\min_{\phi'} \frac{1}{1-\gamma}\widetilde{E}l_t = \arg\min_{\phi'} \widetilde{E}l_t.$$

Hence, we have proved that the same policy is unconditionally optimal for $L_t(\gamma)$ *for any* $\gamma \in (0,1)$

The Lagrangian constructed in Woodford's timeless perspective methodology depends on the consumers' discount factor, but the optimal policy which minimizes unconditional losses does not.

Proposition 3.1 is additionally interesting as it demonstrates that the same policy is unconditionally optimal for all households, regardless of their individual time discount factors.

4. The Solution

The problem with the timeless perspective methodology proposed by Giannoni and Woodford (2002) is that it proposes first to find the optimality conditions for a time inconsistent or (time) conditional policy and then make the rule "time less" by ignoring first period constraints. In other words, it is as if one were trying to find an optimum of the composite function $\arg\min f(g(x))$ by writing the first order condition for $g(x)$ only. The correct approach would appear to be to apply the unconditional expectation operator in formulating the policy Lagrangian and then deriving the optimality conditions. As we shall see, this is exactly the justification required for the Blake-Jensen-McCallum result to go through.

Hence, we propose the following methodology:

- Step 1: Write the (time) conditional Lagrangian (2.9).
- Step 2: Re-formulate this as an unconditional Lagrangian:

$$J = \widetilde{E}J_t;$$

$$J = \frac{1}{1-\beta}\widetilde{E}\left(\frac{1}{2}(x_t - x_t^*)' Q (x_t - x_t^*) + \mu_t' \widetilde{A} x_t - \mu_{t-1}' \widetilde{I} x_t\right).$$

- Step 3: Write the first-order conditions for the optimal timeless policy with respect to all endogenous variables;

$$\frac{\partial J}{\partial x_t} = \frac{1}{1-\beta}\widetilde{E}\left((x_t - x_t^*)' Q + \mu_t' \widetilde{A}_t - \mu_{t-1}' \widetilde{I}\right) = 0. \tag{4.1}$$

Condition (4.1) implies the following dynamics for the Lagrange multipliers

$$(x_t - x_t^*)' Q + \mu_t' \widetilde{A}_t - \mu_{t-1}' \widetilde{I} = 0. \tag{4.2}$$

The general conclusion can be formulated in the following proposition.

Proposition 4.1. *The first order conditions (4.2) are the necessary conditions for problem (2.4, 2.2)*

The proof follows immediately by applying Pontryagin's Maximum Principle.

We contrast these with the Giannoni and Woodford (2002) dynamics, (2.6) above.

4.1. Example

Example 4.2. *We search for a timeless policy which minimizes the loss function*

$$U = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \pi_{t+j}^2 + \alpha y_{t+j}^2 \right\}, \tag{4.3}$$

subject to the constraint

$$\pi_t = \beta E_t \pi_{t+1} + \lambda y_t + u_t.$$

We formulate the time-dependant Lagrangian

$$L_t = E_t \sum_{j=0}^{\infty} \beta^j \left(\left(\pi_{t+j}^2 + \alpha y_{t+j}^2 \right) + \mu_{t+j} \left(\pi_{t+j} - \beta E_t \pi_{t+j+1} - \lambda y_{t+j} - u_{t+j} \right) \right).$$

Since we search for the timeless optimal policy, we need to minimize the "timeless" Lagrangian, which means we must formulate the problem using the unconditional expectation of the Lagrangian L_t :

$$L = \widetilde{E} L_t = \widetilde{E}\left(E_t \sum_{j=0}^{\infty} \beta^j \left(\left(\pi_{t+j}^2 + \alpha y_{t+j}^2 \right) + \mu_{t+j} \left(\pi_{t+j} - \beta E_t \pi_{t+j+1} - \lambda y_{t+j} - u_{t+j} \right) \right) \right).$$

The unconditional expectation operator has the following property $\forall t, j$, $\widetilde{E}x_t = \widetilde{E}x_{t+j}$ *which implies that* $\widetilde{E}E_t\mu_{t+j}\pi_{t+j+1} = \widetilde{E}\pi_t\mu_{t-1}$. *The timeless Lagrangian may then be rewritten as*

$$L = \frac{1}{1-\beta}\widetilde{E}\left[\left(\pi_t^2 + \alpha y_t^2\right) + \mu_t\left(\pi_t - \lambda y_t - u_t\right) - \widetilde{E}\beta\pi_t\mu_{t-1}\right]$$

The first order conditions follow:

$$\frac{\partial L}{\partial \pi_t} = \frac{1}{1-\beta}\left(2\pi_t + \mu_t - \beta\mu_{t-1}\right) = 0;$$

$$\frac{\partial L}{\partial y_t} = \frac{1}{1-\beta}\left(2\alpha y_t - \lambda\mu_t\right) = 0.$$

These relations can be written as $\pi_t = -\frac{\alpha}{\lambda}y_t + \beta\frac{\alpha}{\lambda}y_{t-1}$. *This is the optimal program proposed by Blake-Jensen-McCallum.*

5. Conclusion

We provided a rationale for the numerical-based conclusions of Jensen and McCallum (2002), and a formal justification for the arguments in Blake (2001). We showed how one can justify and formulate timelessly-optimal policy programs using unconditional expectations.

References

[1] Blake, A.P., 2001, A "Timeless Perspective" on Optimality in Forward-Looking Rational Expectations Models," Papers 188, *National Institute of Economic and Social Research*

[2] Blake, A.P. and T. Kirsanova, 2004, A Note on Timeless Perspective Policy Design, *Economics Letters*, 85, 1, pp. 9-16.

[3] Clarida, R., J. Gali, and M. Gertler, 1999, The Science of Monetary Policy: A New Keynesian Perspective *Journal of Economic Literature*, 37, 3 1661-1707.

[4] Erceg, C. J., D. W. Henderson, and A. T. Levin, 2000, Optimal Monetary Policy with Staggered Wage and Price Contracts, *Journal of Monetary Economics*, 46, 2, pp. 281-313

[5] Giannoni M. P., and M. Woodford, 2002, Optimal Interest-Rate Rules 1: General Theory, NBER Working Paper No. 9419.

[6] Jensen, C., and B. T. McCallum, 2002, The Non-optimality of Proposed Monetary Policy Rules under Timeless Perspective Commitment, *Economic Letters*, 77, pp163-168.

[7] Kydland F.E. and E. C. Prescott, 1977, Rules rather than Discretion: The Inconsistency of Optimal Plans, *The Journal of Political Economy*, 85, 3, pp. 473-492.

[8] Kollmann, R., 2002, Monetary Policy Rules in the Open Economy: Effect on Welfare and Business Cycles, *Journal of Monetary Economics*, 49, pp. 989-1015.

[9] Rotemberg J. J. and M. Woodford, 1999, Interest-Rate Rules in an Estimated Sticky Price Model, published in *Monetary Policy Rules*, Taylor, J. B., ed., Chicago: The University of Chicago Press.

[10] Rotemberg J. J. and M. Woodford, 1998 An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy: Expanded Version, NBER Technical Working Paper No. 233

[11] Soderlind P., 1999, Solution and Estimation of RE Macromodels with Optimal Policy, *European Economic Review*, 43, pp. 813-823.

[12] Taylor, J. B., 1979, Estimation and Control of a Macroeconomic Model with Rational Expectations, *Econometrica*, 47, 5, pp. 1267-1286.

[13] Woodford, M., 1999, Optimal Monetary Policy Inertia, NBER Working Paper No. 7261..

[14] Woodford, M., 2003, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

ABOUT THE CDMA

The **Centre for Dynamic Macroeconomic Analysis** was established by a direct grant from the University of St Andrews in 2003. The Centre funds PhD students and facilitates a programme of research centred on macroeconomic theory and policy. The Centre has research interests in areas such as: characterising the key stylised facts of the business cycle; constructing theoretical models that can match these business cycles; using theoretical models to understand the normative and positive aspects of the macroeconomic policymakers' stabilisation problem, in both open and closed economies; understanding the conduct of monetary/macroeconomic policy in the UK and other countries; analyzing the impact of globalization and policy reform on the macroeconomy; and analyzing the impact of financial factors on the long-run growth of the UK economy, from both an historical and a theoretical perspective. The Centre also has interests in developing numerical techniques for analyzing dynamic stochastic general equilibrium models. Its affiliated members are Faculty members at St Andrews and elsewhere with interests in the broad area of dynamic macroeconomics. Its international Advisory Board comprises a group of leading macroeconomists and, ex officio, the University's Principal.

RECENT WORKING PAPERS FROM THE CENTRE FOR DYNAMIC MACROECONOMIC ANALYSIS

Number	Title	Author(s)
CDMA04/01	Interest Rate Bounds and Fiscal Policy	Jagjit S. Chadha (St Andrews) and Charles Nolan (St Andrews)
CDMA04/02	The Impact of Imperfect Credibility in a Transition to Price Stability	Anamaria Nicolae (Durham) and Charles Nolan (St Andrews)
CDMA04/03	Monetary Policy Rules, Asset Prices and Exchange Rates	Jagjit S. Chadha (St Andrews), Lucio Sarno (Warwick and CEPR) and Giorgio Valente (Warwick)
CDMA04/04	Tax Policy and Irreversible Investment	Sumru Altug (Koç, CEPR and Economic Research Forum), Fanny S. Demers (Carleton and McGill) and Michel Demers (Carleton and McGill)
CDMA04/05	The Role of Preference Shocks and Capital Utilization in the Great Depression	Mark Weder (Humboldt)
CDMA04/06	Optimal Simple Rules for the Conduct of Monetary and Fiscal Policy	Jagjit S. Chadha (St Andrews) and Charles Nolan (St Andrews)
CDMA04/07	Money, Debt and Prices in the UK 1705-1996	Norbert Janssen (Bank of England), Charles Nolan (St Andrews) and Ryland Thomas (Bank of England)
CDMA05/01	Labour Markets and Firm-Specific Capital in New Keynesian General Equilibrium Models	Charles Nolan (St Andrews) and Christoph Thoenissen (St Andrews)
CDMA05/02	The Impact of Simple Fiscal Rules in Growth Models with Public Goods and Congestion	Sugata Ghosh (Cardiff) and Charles Nolan (St Andrews)
CDMA05/03	Inflation Targeting, Committee Decision Making and Uncertainty: The Case of the Bank of England's MPC	Arnab Bhattacharjee (St Andrews) and Sean Holly (Cambridge)

CDMA05/04	How to Compare Taylor and Calvo Contracts: A Comment on Michael Kiley	Huw Dixon (York) and Engin Kara (York)
CDMA05/05	Aggregate Dynamics with Heterogeneous Agents and State-Dependent Pricing	Vladislav Damjanovic (St Andrews) and Charles Nolan (St Andrews)
CDMA05/06	Aggregation and Optimization with State-Dependent Pricing: A Comment	Vladislav Damjanovic (St Andrews) and Charles Nolan (St Andrews)
CDMA05/07	Finance and Growth: A Critical Survey	Alex William Trew (St Andrews)
CDMA05/08	Financial Market Analysis Can Go Mad (in the search for irrational behaviour during the South Sea Bubble)	Gary S. Shea (St Andrews)
CDMA05/09	Some Welfare Implications of Optimal Stabilization Policy in an Economy with Capital and Sticky Prices	Tatiana Damjanovic (St Andrews) and Charles Nolan (St Andrews)
CDMA05/10	Optimal Monetary Policy Rules from a Timeless Perspective	Tatiana Damjanovic (St Andrews), Vladislav Damjanovic (St Andrews) and Charles Nolan (St Andrews)

For information or copies of working papers in this series, or to subscribe to email notification, contact:

Alex Trew
Castlecliffe
School of Economics and Finance
University of St Andrews
Fife, UK, KY16 9AL

Email: awt2@st-and.ac.uk; Phone: +44 (0)1334 462445; Fax: +44 (0)1334 462444.