Economic Modelling 41 (2014) 119–123

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

Advertising, economic development, and global warming

Gary M. Erickson *

Foster School of Business, University of Washington, Box 353200, Seattle, WA 98195-3200, USA

ARTICLE INFO

Article history:
Accepted 2 May 2014
Available online 24 May 2014

Keywords:
Advertising
Endogenous growth
Global warming
Optimal control

ABSTRACT

Advertising is tied to global warming through an endogenous growth model. The model allows for the possibility that the environment can become a source rather than a sink for greenhouse gases. Optimal control analysis of the model shows that a feasible steady state is possible for which the environment remains a sink, and identifies a sufficient condition for such to be the case. Comparative-static analysis shows that, for sufficiently small values of steady-state anthropogenic greenhouse gas concentration, global surface temperature and advertising in steady state are negative functions of parameters that measure the damaging effects of global warming.

1. Introduction

Advertising plays a prominent role in the overall economy. Measured advertising spending in the U.S. alone totaled $144 billion in 2011 (kantarmediana.com, 2012). Advertising amounts to roughly 2% of GDP in the U.S., a relatively constant percentage over the years (galbithink.org/ad-spending.htm, 2008). Advertising is a key economic factor.

The model in the present paper adopts the view of Becker and Murphy (1993), that advertising does not serve to change tastes, but is a good that enters the fixed preferences of consumers, and is a complement to the goods advertised. This allows advertising to have a direct role to play in economic development and utility maximization.

Economic growth in the industrial age has brought unprecedented wealth to the planet. In the U.K., the birthplace of the industrial revolution, real GDP per capita has grown by 12 times since 1830, from 1838 to 22,440 British pounds in 2010 (a drop-off from a peak of 23,774 pounds per capita in 2007) (measuringworth.com, 2012). Growth in economic activity has also come at a cost, as concentration of greenhouse gases (GHG) in the atmosphere has increased since 1750 (cdiac.ornl.gov, 2012), and it is accepted that this growth in GHG concentration is leading to global warming, an increase in global surface temperatures (Dutta and Radner, 2006; Nordhaus, 1991).

The model herein assumes that global warming has a direct and negative influence on consumer utility. Furthermore, there is a growing realization that the warming in the atmosphere is having a deleterious effect on the ability of the environment to absorb GHG emissions (Cox et al., 2000; Lewis et al., 2011; Schaphoff et al., 2006), and the model recognizes this influence.

The present paper offers an optimal control model to assess the relationships involving advertising, economic development, GHG concentrations, and global warming in an endogenous growth setting with environmental consequences. It should be noted that other control and state variables could also be included—e.g. welfare, natural disasters, industrial output, political decisions, and institutional regulatory framework. In particular, the model could include the role of the government in enhancing transfer of environmental technology as in Greiner and Franza (2003), or accumulation of physical and human capital as in Ikefuji and Horii (2012).

The remainder of the paper proceeds as follows. The following section provides a review of the literature on endogenous growth models that involve environmental considerations. This is followed by sections that present and analyze the model. A conclusions section ends the paper.

2. Endogenous growth and the environment

The present paper contributes to the literature on endogenous growth that takes environmental considerations into account. Smulders (1999) provides an overview of the literature. In particular, various studies (e.g. Keeler et al., 1971; Tahvonen and Kuuluvainen, 1993; Bovenberg and Smulders, 1995; Hofkes, 1996; also see Feenstra et al., 1999) have considered the optimal control of economic growth and pollution/environmental quality. The present study extends this literature by considering a model that departs from existing models in three distinct ways. One is that advertising is included in the model in a manner consistent with Becker and Murphy (1993); the only other

* Tel.: +1 206 661 6112.
E-mail address: erick@uw.edu.

http://dx.doi.org/10.1016/j.econmod.2014.05.004
0264-9993/

study of which the author is aware that links advertising to economic growth is that of Brekke and Howarth (2002), who model advertising as affecting preferences through a social status mechanism, and not according to Becker and Murphy (1993). The second departure from existing models is that the model considers a specific and critical type of pollution, GHG and its influence on global warming. Finally, the model incorporates a feedback effect of global warming on the absorptive ability of the environment.

3. Model

The model has three state variables: capital K, anthropogenic GHG concentration G, and temperature increase over pre-industrial level T. In addition, there are two control variables: consumption c and advertising a.

To be consistent with Becker and Murphy (1993), advertising is assumed to enter the utility function directly, and to be complementary with consumption. Also entering the utility function, negatively, is the increase in temperature due to global warming. The utility function assumed for the representative customer is (control and state variables are functions of time, and the time notation t is suppressed for expositional convenience)

$$U(c,a,T) = c^{\alpha}a^{\beta} - \frac{d}{2}T^2 \tag{1}$$

where $0 < \alpha, \beta < 1$ and $d > 0$, and the objective assumed for the social planner is to maximize

$$\int_0^{\infty} e^{-rt}U(c,a,T)dt \tag{2}$$

for a positive discount rate r.

Since advertising is a good that is consumed, it, along with consumption, affects capital accumulation, which is assumed to develop according to

$$\dot{K} = AK - \delta K - c - a, K(0) = K_0 \geq 0 \tag{3}$$

where A is a positive constant that indicates the level of technology, and δ is a depreciation parameter such that $0 < \delta < 1$.

GHG emissions are assumed to be a byproduct of production, and add to the stock variable G. The environment is able to absorb GHG to an extent. However, the increasing temperature is assumed to negatively affect the absorptive capacity of the environment, and the stock of GHG is assumed to develop as follows[1]:

$$\dot{G} = \gamma AK - (\varepsilon - \theta T)G = \gamma AK - \varepsilon G + \theta GT, G(0) = G_0 \geq 0 \tag{4}$$

where $\gamma > 0$, $0 < \varepsilon < 1$, and $\theta > 0$. The relationship in Eq. (4) indicates that, for a large enough T, the ability of the environment to absorb GHG can reverse itself, that is, the environment can become a source rather than a sink for GHG.

Temperature increase is assumed to evolve according to a partial adjustment process (Nordhaus, 1991):

$$\dot{T} = \zeta(\eta G - T), T(0) = T_0 \geq 0 \tag{5}$$

where $0 < \zeta < 1$ and $\eta > 0$. In Eq. (5), ηG is the equilibrium temperature, and the equation indicates that the current amount of temperature change is a fraction of the difference between current and equilibrium temperature, that is, that the earth's temperature responds with a delay to increases in GHG. Nordhaus (1991) reports estimates of the delay that range from 6 to 95 years.

4. Analysis

The model (1)–(5) comprises an optimal control problem. The current-value Hamiltonian for the problem is

$$H = c^{\alpha}a^{\beta} - \frac{d}{2}T^2 + \lambda(AK - \delta K - c - a) + \mu(\gamma AK - \varepsilon G + \theta GT) + \nu\zeta(\eta G - T) \tag{6}$$

where λ, μ, ν are costate variables. The first-order conditions for the problem are the following:

$$\begin{aligned} c &= \left(\frac{\alpha^{1-\beta}\beta^{\beta}}{\lambda}\right)^{\frac{1}{1-\alpha-\beta}} \\ a &= \left(\frac{\alpha^{\alpha}\beta^{1-\alpha}}{\lambda}\right)^{\frac{1}{1-\alpha-\beta}} \\ \dot{\lambda} &= (r + \delta - A)\lambda - A\gamma\mu \\ \dot{\mu} &= (r + \varepsilon - \theta T)\mu - \zeta\eta\nu \\ \dot{\nu} &= (r + \zeta)\nu + dT - \theta G\mu. \end{aligned} \tag{7}$$

The parameter constraint $\alpha + \beta < 1$ is assumed to assure that the Hamiltonian is maximized.

Note in Eq. (7) that optimal consumption and advertising are both inverse functions of λ, indicating that the higher (lower) the shadow price of capital, the lower (higher) the optimal level of consumption and advertising. That is, with a higher (lower) shadow price, more (less) capital is formed through lower (higher) consumption and advertising.

We have the following proposition regarding steady state of the problem:

Proposition 1. At steady state,

$$\begin{aligned} \nu_{\infty} &= \frac{d\eta G_{\infty}(r + \varepsilon - \eta\theta G_{\infty})}{\eta\theta(r + 2\zeta)G_{\infty} - (r + \varepsilon)(r + \zeta)} \\ \mu_{\infty} &= \frac{d\zeta\eta^2 G_{\infty}}{\eta\theta(r + 2\zeta)G_{\infty} - (r + \varepsilon)(r + \zeta)} \\ \lambda_{\infty} &= \frac{Ad\gamma\zeta\eta^2 G_{\infty}}{(A - r - \delta)((r + \varepsilon)(r + \zeta) - \eta\theta(r + 2\zeta)G_{\infty})} \\ T_{\infty} &= \eta G_{\infty} \\ K_{\infty} &= \frac{(\varepsilon - \eta\theta G_{\infty})G_{\infty}}{A\gamma} \end{aligned} \tag{8}$$

where G_{∞} is such that

$$A^{\alpha+\beta}d\alpha^{-\alpha}\beta^{-\beta}(\alpha + \beta)^{\alpha+\beta-1}\gamma^{\alpha+\beta}\zeta\eta^2(A - \delta)^{1-\alpha-\beta}(\varepsilon - \eta\theta G_{\infty})^{1-\alpha-\beta}G_{\infty}^{2-\alpha-\beta} = (A - r - \delta)((r + \varepsilon)(r + \zeta) - \eta\theta(r + 2\zeta)G_{\infty}). \tag{9}$$

[1] An alternative approach is to model absorptive capacity as an additional state variable (El Ouardighi et al., 2011).