Written Exam at the Department of Economics winter 2017

Economic Growth

Final Exam

June 22, 9-12.

(3-hour closed book exam)

SOLUTION GUIDE

A. Verbal questions.

A1. This draws on Jones (2005, Handbook of economic growth). The argument runs as follows. The replication argument says that if we double rival inputs of production total output doubles. Hence, it is an argument for constant returns to scale in K and L in the context of an aggregate production function:

$$\lambda Y = F(\lambda K, \lambda L; A)$$

The Euler theorem tells us (for a function that is homogenous of degree 1) that

$$Y = F_K K + F_L L$$

where F_i, $i = K, L$ are the derivatives wrt to K and L, respectively. Under competitive markets factors are payed the value of the marginal product

$$Y = wL + RK$$

where $F_L = w$ and $F_K = R$ is the wage and rental rate, respectively. Now, since remunerating capital and labor evidently exhaust output, it stands to reason that there are no 'residual funds' left to fund R&D expenses that raise A.

A.2. The authors have access to data on a range of navy ships (57) that were serially produced across 25 different yards during the second world war. This setting is particularly interesting for a couple of reasons. First, no shipyard closed during the war. Hence, the usual selection problems in industry level studies is not present. Second, the war setting makes inputs less endogenous than under usual circumstances; labor flows were severely regulated, and other inputs where restricted as well. Third, a direct measure of productivity (unit labor requirement for each ship) is available. The key question is whether, controlling for capital and labor input and exogenous technological change (calendar date fixed effects), as well as design-by-yard fixed effects, one can find an influence from accumulated production experience. In particular it is possible to examine whether production experience both within yard and design matter (internal learning) for unit labor requirement. More interestingly, it is also possible to see if production experience within a particular yard and design reduces unit labor requirements in other yards and/or in the context of other designs. The latter categories consitute external learning, which if substantial, is the sort of externalities that could motivate government intervention in the form of production subsidies. The study shows that external learning indeed seems to have been at work, albeit the size of the learning effects are not of a mangnitude that would allow us to motivate endogenous growth in standard models.

A.3. This draws on Barro and Sala-i-Martin, Chapter 8, which develops a model where immitations costs increase as the level of knowledge in the follower country rises relative to the frontier. In this setting it holds that when a firm immitates in the follower country, the cost of immiation for future innovators in the follower country increases. This effect is not internalized by the follower and may lead R&D (immitation R&D) to be excessive in equilibrium. It is relevant to observe as discussed in the lectures, and in the textbook, that this model does not allow for a "standing-on-shoulders" effect, which would work to counteract the said negative externality.

A4. This draws on Feyrer (2009). The suez crisis entailed the 1967 closing of the Suez cannel, in the aftermath of the six days war, and re-opening in 1975. The interesting aspect of the crisis, from the point of view of understanding trade patterns, is that it unexpectedly influenced the travel distance (and thereby trade costs) between nations that were trading with each other. Feyrer demonstrates that indeed bilateral trade declines between country pairs where the (exogenously changing) travel distance increases, and vice versa (when the canal is reopenend). He can thereby explot this natural experiment to understand if trade affects growth. Basically the test consists in asking if countries that saw trade decline, exclusively because of the closing of the canal, witness slower growth subseqently; and of course, whether growth was spurred when the canal re-opened. One may see his work as an extension of the approach taken by Frankel and Romer (also on reading list), where bilateral distance between countries is time varying. A potential limitation of the identifcations strategy is that the six day war may have had other – country specific – effects on growth. If, for example, the crisis also unleashed rising oil prices (it certainly did via the Yom Kibur crisis of 73) this could independently affect growth dending on how reliant the country was on oil. Similarly, widespread terrorism, which also arguably ensured as a consequence, could have country specific effects. Feyrer does, however, do his best to dispell such concerns.

A.5. This draws on Jones (2002, AER). (i) First step is to transform the production function into a more useful form, from the point of view of discerning the influence from transitional dynamics

$$\frac{Y}{L} = \left(\frac{K}{L}\right)^{\alpha} (A)^{1-\alpha} = \left(\frac{K}{Y}\right)^{\alpha} \left(\frac{Y}{L}\right)^{\alpha} A^{1-\alpha}$$

isolating Y/L

$$\frac{Y}{L}=\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}A.$$

Hence, at any given point in time growth can be decomposed into a contribution from growth in the capital-output ratio and TFP growth

$$g_y=g_\kappa+g_A$$

where implicitly $\frac{Y}{L}\equiv y$ and $\frac{K}{Y}\equiv\kappa$. Finally, since we assume growth in A is endogenously determined by R&D in a semi-endogenous growth fashion, the steady state growth rate of TFP is pinned down by R&D labor growth (ultimately, population growth). Hence

$$g_A^*=\gamma n$$

for appropriate choice of γ and where n is long-run growth in R&D labor. Since conventional growth theories predict that κ is constant in the steady state, we can calculate the contribution from transitional dynamics (conditional on the value for γ)

$$g_y=\underbrace{g_\kappa+(g_A-\gamma n)}_{\text{transitional dynamics}}+\gamma n$$

(ii) Jones provides a careful analysis of US post WWII growth along these lines (though it also accounts for human capital accumulation etc). His main finding is that at least 80% of past growth is transitional in nature.

A6. This draws on Jones and Klenow (2016, AER). Jones and Klenow considers an agent acting under a "Rawlsian veil". That is, we imagine that a person has access to all relevant data (including knowledge of the utility function) but does not know where (i.e., in which country) he or she will be born. Under standard assumptions about preferences (including risk aversion), inequality will work to lower expected utility of this individual, ceteris paribus. Hence, in countries with greater inequality expected utility will be lower, all other things equal. The answer can usefully be accompined by an illustration of how expected utility declines as a result of a mean preserving spred, as long as the utility function is concave.

B. Analytical questions.

B1. These are standard computations. The student should write down the Hamiltonian; provide the first order conditions wrt c and a, respectively, and then combine them to obtain the consumption euler.

B2. The student should bring up the motivation for adding G to the production function. Productive government expenditures involve (but is not limited to) infrastructure; law and order (police, courts etc). These types of expenditures are non-rival in nature (over sime range, at least: e.g., infrastructure can be subject to congestion), which the model captures since all firms simultanously benefit from G. (ii) The profit optimization problem leads to the first order conditions

$$w=(1-\alpha)\frac{Y_i}{L_i}$$

$$r = \alpha \frac{Y_i}{K_i}$$

this means

$$\frac{K_i}{L_i} \equiv k_i = k \text{ for all } i.$$

Next, the aggregate production function

$$\sum_i Y_i = \sum_i K_i^{\alpha} \left(G L_i\right)^{1-\alpha} = k^{\alpha} G^{1-\alpha} \sum L_i = k^{\alpha} G^{1-\alpha} = K^{\alpha} G^{1-\alpha},$$

where the two last equalities use $\sum_i L_i = 1$.

B3. (i) Total revenue for the government is

$$\tau r a + \tau w = \tau \left(r k + w\right) = \tau \frac{Y}{\sum_i L_i} = \tau Y.$$

The first equality uses that the economy is closed, so wealth of the represenative household equals per capita capital. The second follows from constant returns to capital and labor, and the last equality follows since total labor supply (equal to total population) is normalized to one.

(ii) Inserting the balanced budget constraint into the aggregate production function from B2

$$Y = K^{\alpha} \left(\tau Y\right)^{1-\alpha}$$

Isolating Y leads to the result stated in the equation. Finally, the FOC from firm's profit max

$$r = \alpha \frac{Y_i}{K_i} = \alpha \frac{Y}{K} = \alpha \tau^{\frac{\alpha}{1-\alpha}}.$$

Where the second equality follows since all firms face the same factor cost, and the last uses the aggregate production function.

B4. The "intuitive" argument runs as follows. The present model is an AK-type model. That is, the aggregate production function reduces to a constant multiplied by K. In this class of models balanced growth obtains, that is

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{C}}{C}.$$

The first equality follow immediately from the aggregate production function. The last equality requires a further argument. Inserting r into the consumption euler it is clear that consumption, along and optimal trajectory, grows at a positive rate (provided, of course, $r > \rho$). Suppose the growth rate of capital is slower than that of consumption. In that case, since "$Y = AK$", the consumption ratio C/Y approaches 1. Ultimately, all capital is consumed, and consumption is no longer feasible since capital is an essential input. After this point the consumption euler is no longer fulfilled, which thus violates a nessesary condition for an optimal path. Suppose the growth rate in K is faster than C. In this case C/Y approaches zero. In the end, consumers therefore prospone consumption indefinitely. This inevitably violates the transversality condition.

As a result, balanced growth must arise along an optimal path. Accordingly, since $\frac{\dot{Y}}{Y} = \frac{\dot{C}}{C}$ holds, and population growth is zero, it follows that growth in per capita income is given by.

$$\gamma = \frac{1}{\theta}\left((1-\tau)\,\alpha\tau^{\frac{\alpha}{1-\alpha}} - \rho\right).$$

B5. Naturally, this question focuses on the positive implications of the theory. A full answer involves:

(i) The observation that – in reduced form – there is no unambigious effect of taxes on growth. This may motivate why its empirically been difficult to establish the expected negative impact of taxes on growth in a cross-country setting. Similarly, the permanent increase in income taxes around the second world war does not seem to have been accompined by slower growth.

(ii) At a deeper level the non-linear link hides two seperate effects: (i) the distortionary effect of taxes on the incentive to accumulate, and (ii) the productive effects of the use of the revenue. This should lead to a careful discussion of the study by Kneller et al. (1999, JPubE), which attempts to seperate the two effects by way of panel data regressions for the OECD area. The issue of identification should be raised.