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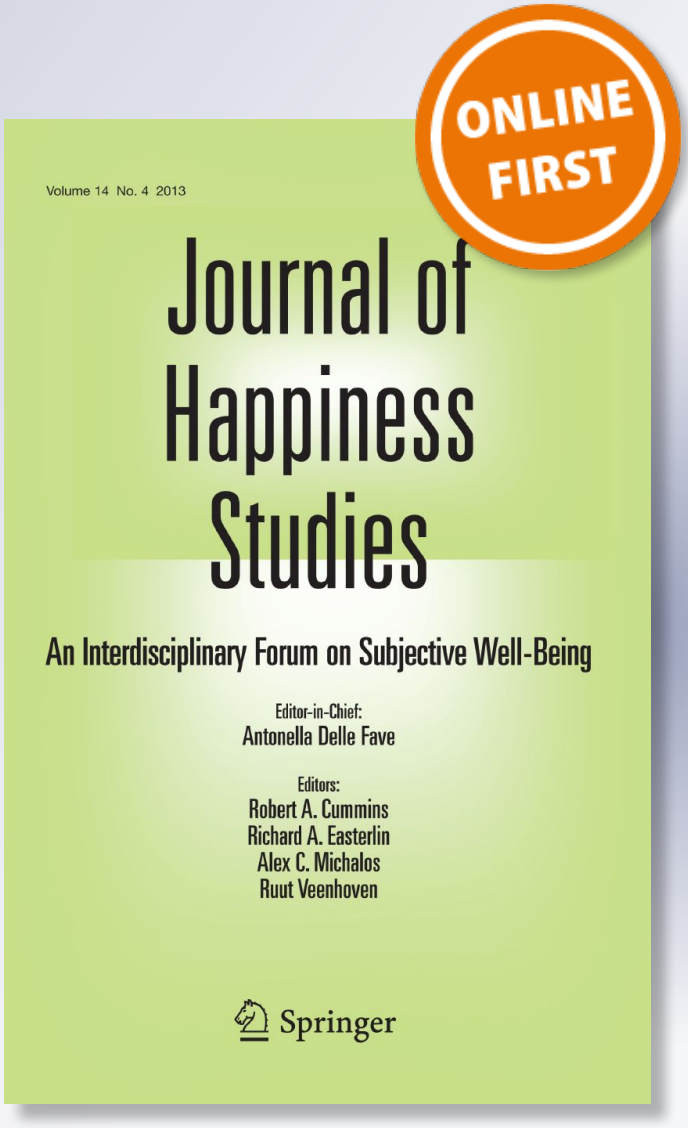

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RESEARCH PAPER

Growth, Inequality and Tunnel Effects: A Formal Mode

Lewis Davis[1]

Abstract Hirschman and Rothschild's (Q J Econ 87(4):544–566, 1973) tunnel effect refers to the propensity for individuals to be pleased by the success of others if they believe this signals an improvement in their own prospects. According to the current literature, tunnel effects may offset the utility losses from increases in peer income levels and income inequality. I develop a simple model of tunnel effects to evaluate these two channels of influence. The analysis confirms that tunnel effects create a positive link between happiness and economic growth. In contrast, rising income inequality generates a tunnel effect that increases the happiness of the rich but decreases happiness among the poor. The analysis confirms Hirschman and Rothschild's informal analysis indicating that that tunnel effects may increase the happiness of the poor in the case of uneven development that involves both growth and rising income inequality. The model also highlights the differential impact of tunnel effects across age and income groups within the population. I close by discussing the model's implications for empirical investigations of tunnel effects.

Keywords Happiness · Subjective wellbeing · Inequality · Social status · Relative income · Tunnel effects

JEL Classification I31 · D31 · Z13

1 Introduction

Hirschman and Rothschild (1973) coined the term *the tunnel effect* to refer to the idea that individuals may be pleased by the success of others if they believe this signals an improvement in their own future prospects. As a result, they argue, the poor may tolerate rising

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income inequality if they believe that income gains among the rich signal a better future for themselves:

> In the early stages of rapid economic development, when inequalities in the distribution of income among different classes, sectors, and regions are apt to increase sharply, it can happen that society's *tolerance* for such disparities will be substantial. (p. 545. Emphasis in the original.)

The term itself is derived from a traffic metaphor: When stuck in a two-lane tunnel, if one lane of cars begins to move, drivers in the other lane may be pleased because they now expect to start moving soon as well. Hirschman and Rothschild (1973) attribute civil unrest in the late 1960s in less developed but rapidly growing economies to the disappointments that occurred when the expectation that growth would eventually be shared was not fulfilled.

The tunnel effect has recently gained increasing attention as part of the emerging literature on happiness, in which it has served to motivate two distinct propositions. The literature on social status finds that an individual's happiness is increasing in her social status, as indicated by her income relative to that of some well-defined peer group. More precisely, holding own income constant, happiness is found to decrease as average peer income rises.[1] A number of researchers, however, find that tunnel effects partly or fully offset concerns over the loss of social status. For example, Clark et al. (2009), Senik (2004, 2008) and FitzRoy et al. (2014) find that measures of subjective wellbeing are *increasing* in the average income of people in an individual's firm, occupation and industry, or region. A closely related literature empirically investigates the relationship between inequality and happiness. Here, the tunnel effect is interpreted as giving rise to a positive relationship between individual happiness and the level of income inequality, which may offset the effects of inequality aversion, e.g. as in Alesina et al. (2004), Wunder and Schwarze (2009), Grosfeld and Senik (2010), Verme (2011), and Bjørnskov et al. (2013). In a meta-analysis of this literature, Ngamaba et al. (2018) find that inequality and happiness are negatively related for developed countries, but positively related for poor countries, a pattern that they interpret as support for tunnel effects, though their argument seems to rely on the idea that poor countries are experiencing rapid economic growth.[2]

Because Hirschman and Rothschild's (1973) original argument concerned a situation in which *economic growth was accompanied by rising income inequality*, it is unsurprising that researchers working on how happiness is affected by each of these factors—rising (peer) income levels and rising inequality—would appeal to the logic of tunnel effects. But the coincidence of growth and rising inequality in the original analysis leaves a number of questions unaddressed. For example, what happens to happiness when growth is accompanied by falling inequality, which as Verme (2011, 112) notes occurs when "the upward 'movers' are mostly poor people", or when inequality rises in an environment of economic decline? Are there two separate channels of influence, related to changes in average income

[1] Recent work has found evidence of a preference for status using a variety of comparison groups including co-workers (Brown et al. 2008; Clark and Oswald 1996), siblings (Kuegler 2009), those in the same neighborhood (Luttmer 2005), and others within one's state of residence (Blanchflower and Oswald 2004). See Clark et al. (2008) for a review of the literature.

[2] For example, on page 17, Ngamaba et al., appear to assume that "people in developing countries… [observe] other people's increasingly rapid progression." However, on average, low income countries grow no more rapidly than rich ones, and over the long run, they have grown more slowly, e.g. Pritchett (1997).

and the income distribution respectively, or is the tunnel effect in fact causally related to only one of the two channels, and related to the other only to the degree that growth and rising inequality happen to coincide?

To complicate matters, Hirschman and Rothschild (1973) were also expressly concerned with the how episodes of growth-cum-inequality affected the *happiness of the poor*, raising the question of the degree to which their argument applies to non-poor individuals. The lack of clarity within the literature as to the nature and relative importance of growth and inequality channels and the potential for tunnel effects to have different effects for members of different income groups suggests gains to formal analysis.

In the following section, I present a simple model of tunnel effects that is used to investigate these issues. The economy is comprised of two sectors, rich and poor, which are subject to periodic sector-specific productivity shocks. Agents live for two periods and tunnel effects result from the potential for intersectoral mobility. Any combination of sectoral productivity shocks may also be decomposed into an *income shock*, which is common to both sectors, and a sectoral *inequality shock*, which increases sectoral asymmetries. This decomposition allows the model to identify how growth and inequality interact with tunnel effects to affect individual happiness. In addition, one sector has higher initial productivity, allowing us to separately identify the impact of tunnel effects on rich and poor individuals.

The third section uses the model to investigate the impact of income and inequality shocks, both in isolation and in various combinations. The model identifies two separate tunnel effects, an *own-sector tunnel effect* that is related to the current productivity shock in an agent's sector and an *intersectoral tunnel effect* that is determined by the other sector's productivity shock. In addition, the analysis indicates that the impact of tunnel effects differs by the type of shock and by population subgroup. To begin with, tunnel effects have no impact on the utility of the old. In addition, the tunnel effect associated with an income shock affects the young rich and young poor in a similar fashion. Moreover, this effect is independent of the level of expected social mobility. In contrast, the tunnel effect generated by an inequality shocks raise the utility of the young rich but *lowers the utility of the young poor*, with both effects decreasing in the level of expected social mobility. These results generally support claims about tunnel effects and social status, but they contrast with the interpretation of tunnel effects presented in the literature on tunnel effects and income inequality.

I also consider the tunnel effects that result from *rich-sector growth*, which is a stylized version of the situation that concerned Hirschman and Rothschild, in which economic growth is accompanied by rising intersectoral income inequality. In this case, the analysis bears out their discussion. Tunnel effects partly or fully offset the disutility of reduced social status among the poor, and this effect is increasing in the level of expected social mobility. Thus, while the model confirms the discussion of tunnel effects in Hirschman and Rothschild's original article, it also shows that their analysis concerns the impact of tunnel effects that result from a particular set of income and inequality shocks, those associated with rapid but uneven development.

In the fourth section, I discuss the model's implications for empirical work on tunnel effects. Two recent review articles, Schneider (2016) and Ngamaba et al. (2018), highlight the diversity of methodological approaches as a significant impediment to firm conclusions regarding the relationship between income inequality and subjective wellbeing. These reviews indicate the potential usefulness of theoretical modeling as a guide to selecting an appropriate empirical specification. I use the resulting framework to reflect on existing research and discuss how empirically estimated coefficients may to be used to derive key parameters of the theoretical model, including those for the strength of inequality aversion

and the taste for status. This section also discusses the model's implications for the strength of tunnel effects across societies. The final section concludes.

To my knowledge, there are three other theoretical treatments of tunnel effects. Clark et al. (2009) model tunnel effects within a single firm, which are closely related to the own-sector tunnel effects analyzed here. They do not consider the role of intersectoral tunnel effects or relate either tunnel effect to observable macroeconomic variables, such as growth and inequality. FitzRoy et al. (2014) and Hirschman and Rothschild (1973) develop models with two sectors or types of people—FitzRoy et al.'s tortoises and hares—that are closer in structure to the model developed here. A key difference is that both papers restrict the analysis to the case of rich-sector growth, which is precisely the case in which income and inequality shocks coincide and are thus likely to be conflated. Thus, unlike the model developed here, these papers do not separately identify or differentiate between the roles of income and inequality shocks in generating tunnel effect. In addition, neither paper explicitly models a taste for future social status, which serves here to tie tunnel effects to incomplete hedonic adaptation.

2 Production and Preferences

This section presents a simple two-sector model to illustrate the role of tunnel effects in the relationships between growth, inequality and happiness. The two-sector structure of the model reflects Hirschman and Rothschild's tunnel analogy as well as their discussion of the class and sectoral cleavages in the remainder of the paper. It is also in keeping with the dominant development paradigm of their day, which viewed developing societies as characterized by some critical divide, e.g. modern-traditional, formal-informal, rural–urban, or agricultural-industrial. Here the two sectors are structurally similar, but workers are assumed to be imperfectly mobile across sectors.

Workers are endowed with a single unit of inelastically supplied labor, the only productive factor, are evenly allocated across the two sectors, indexed by $s \in (R, P)$, and live for two periods during which they are said to be *young* and *old*. Output is perishable, and all income is consumed. Labor productivity is assumed to be higher in sector R, and I will refer to sector R and P participants as "rich" and "poor" respectively.

A tunnel effect is said to exist when (1) an individual's current happiness depends on her expectations regarding her future prospects and (2) the success of others creates positive expectations about an individual's own future income. Defined in this way, the existence of tunnel effects depends on two key assumptions. The first is that current utility depends on both the current and expected future outcomes of the model's variables. I formalize this by assuming that the current utility of an individual i is additively separable in two components, *realized* and *prospective* utility:

$$V_t^i\left(x_t, x_{t+1}\right) = u_t^i\left(x_t\right) + w_t^i\left(x_{t+1}^e\right). \tag{1}$$

Realized utility $u_t^i(x_t)$ shows the relationship between an individual's current happiness and a vector of the current values of the model's variables, while prospective utility $w_t^i(x_{t+1}^e)$ shows the relationship between current utility and expected future values of the models variables. The presence of prospective utility provides a link between current happiness and expected future outcomes and is a necessary condition for the tunnel effect described by Hirschman and Rothschild.

I make two further assumptions that simplify the structure of current utility. First, I assume that individuals know x_t and correctly use this information in forming expectations

about the x_{t+1}, e.g. $x^e_{t+1} = E(x_{t+1}|x_t)$. And, second, I assume that preferences are stable over an individual's lifetime so that prospective utility depends on the expected level of realized utility in the following period. Given these assumptions, the current utility of the young and old in period t are given by

$$V^{ia}_t\left(x_t, x^e_{t+1}\right) = \begin{cases} u^i\left(x_t\right) + \beta u^i\left(x^e_{t+1}\right) & a = Y \\ u^i\left(x_t\right) & a = O \end{cases} \tag{2}$$

where the superscript $a \in (Y, O)$ indicates the age of the individual. Note that the first line of (2) is similar in structure to familiar expressions for expected lifetime utility, but its interpretation is entirely different: it is the current utility of a young individual. In this formulation, the second term in the utility of the young is prospective utility and measures the contribution of expected future utility to *current* happiness. Turning to the second line of (2), note that because they are already in the second (and final) period of their lives, the old do not experience prospective utility. As a result, the utility of the old equals their current realized utility.[3]

Note also that the constant $\beta \in (0, 1)$ is not an intertemporal discount rate but instead reflects the weight of prospective relative to realized utility in determining the current utility of the young. To highlight the distinction, note that second period consumption is enjoyed twice: once as prospective utility when an individual is young, and again as realized utility when the individual is old. That said, the weight placed on of prospective utility is closely linked to the discount rate: both address the relative importance of current and future consumption and, in practice, both are likely to be higher for more forward-looking individuals.[4]

Hirschman and Rothschild argue that the individuals may tolerate rising inequality because the "gratification" generated by tunnel effects "overcomes, or at least suspends, *envy*" (p. 546, emphasis in the original), which they identify with the relative income hypothesis in economics and relative deprivation hypothesis in sociology. While they are concerned with society's tolerance for rising income inequality, they do not posit a separate taste for or aversion to income inequality. Inequality matters because it affects an individual's expectations and social status, and not because individuals have a preference over the level of inequality per se.[5] In keeping with this, realized utility is assumed to reflect preferences over both individual and social outcomes. In particular, realized utility of individual i in period t, is assumed to depend on own income and a taste for social status:

$$u^i_t(x_t) = \ln(y^i_t) - \psi\overline{\ln y_t}, \tag{3}$$

[3] For the sake of symmetry, one could augment to the model to include retrospective utility, or the consumption of memories, for the old.

[4] I am grateful to an anonymous referee for pointing out this relationship.

[5] Inequality aversion is disutility from observed inequality and may arise from moral, ideological or psychological grounds. It differs from a taste for social status in that a rise in inequality increases the status and utility of the rich while decreasing the status and utility of the poor. In contrast, it reduces the utility of the inequality averse regardless of their position in the distribution of income. The model may be extended to incorporate pure inequality aversion, as was done in earlier versions of the paper. The current approach is preferred here as it facilitates the comparison with Hirschman and Rothschild.

where y_t^i is individual income and $\overline{\ln y_t}$ is the average of log income.[6] The motivation for the negative coefficient on the second term is that, holding own income constant, a rise in average (log) income results in a decrease in an individual's relative income and a corresponding loss of social status. The parameter $\psi > 0$ determines the strength of this effect and, thus, reflects the *taste for social status*.

The coefficient ψ plays a central role in the Easterlin paradox (1974, 1995). Informally, the Easterlin paradox holds that individuals care only about relative income levels: in a growing economy, the increased utility from a rise in own income is fully offset by the disutility from the rise in the average income. In the current context, this occurs when the taste for status is sufficiently strong, $\psi = 1$, resulting in *complete hedonic adaptation*, such that shared growth has no impact on individual utility. In contrast, under partial hedonic adaptation the taste for status is somewhat weaker, $\psi < 1$, the utility gain from the rise in own income dominates the loss of social status. In this case, the individual utility gains from economic growth are not completely dissipated by the increase in average log income, as argued by Stevenson and Wolfers (2008). In keeping with this, I generally assume that $\psi < 1$, though I note whenever this assumption is critical to the results.

2.1 Production

The income level of individual i in sector s and period t is determined by the sectoral productivity level, Π_{st}, and an idiosyncratic element: $\ln\left(y_{st}^i\right) = \Pi_{st} + \lambda_{it}$, where $\lambda_{it} \sim N(0, \sigma_\lambda^2)$ is an individual-period specific income shock. Sectoral productivity evolves iteratively according to $\Pi_{st} = \Pi_{st-1} + \pi_{st}$, where $\pi_{st} \sim N(\mu, \sigma_\pi^2)$ is the current sectoral productivity shock, with $\text{cov}(\pi_{Rt}, \pi_{Pt}) = 0$. Noting that $\Pi_{st} = \ln y_{st}$, individual income may be expressed as

$$\ln\left(y_{st}^i\right) = \overline{\ln y}_{st-1} + \pi_{st} + \lambda_{it} \tag{4}$$

The second assumption underlying the tunnel effect is that there is a *positive intertemporal correlation* between an individual's expected future income and the current incomes of others and reflects expectations of social mobility. According to Hirschman and Rothschild the expectation of social mobility may vary widely across societies and depends on a number of social, political and historical factors. These include the division of economic gains along ethnic, linguistic or religious lines, the significant participation or leading economic role of foreign labor and capital, the presence of a significant shared historical experience, such as a war or revolution, and beliefs about the roles of chance and ethical behavior in economic success.

An important modeling choice regards how broadly one interprets the idea of social mobility. Do Hirschman and Rothschild's references to social mobility refer strictly to *upward mobility* among the poor, or do they also encompass potential *downward mobility* among the rich? This matter is somewhat complicated by the fact that Hirschman and Rothschild are predominately concerned with attitudes toward uneven development among the poor. For example, they cite evidence of the tunnel effect in the attitudes and experiences

[6] Some papers take a macroeconomic perspective, treating status as a function of the log of average income, as measure of the national standard of living. The equation used here is more microeconomic in nature, and may be thought of as deriving from a set of pairwise comparisons between an individual and her peers, where the status is equal to the difference in log income levels: $u_t^i(x_t) = (1-\psi)\ln y_t^i + \psi \frac{1}{N_j} \sum_{j \in J}\left(\ln y_t^i - \ln y_t^j\right) = \ln y_t^i - \psi \overline{\ln y_t}$, where J is the set of an individual's peers.

of people living in Brazil's favelas (p. 548) and "lower-class persons" in Mexico (p. 549) and refer more generally to members of the "group that does not advance" (p. 553) and "the nonmobile group (p. 554). However, at one point, they also discuss a "tunnel effect in reverse" (p. 547), which involves expected downward mobility. This leads me to model social mobility in the more general sense of *intersectoral mobility*, which allows for the poor to become rich and vice versa. This choice also reflects the general turbulence of early development, which includes the potential for large losses, or at least relative losses, among a country's traditional elite.

The potential for social mobility is formalized by assuming that there is a non-negative probability, γ, that each worker switches sectors from the first to the second period.[7] In addition, I assume that $\gamma < 1/2$, which implies that the persistence of sectoral membership is the norm. Expected future income for an individual i in sectors R and P can be expressed as follows:

$$\begin{aligned} E_{Rt}\left(\ln\left(y^i_{t+1}\right)\right) &= (1-\gamma)E_t\left(\ln\left(y^i_{Rt+1}\right)\right) + \gamma E_t\left(\ln\left(y^i_{Pt+1}\right)\right) \\ &= (1-\gamma)\overline{\ln y}_{Rt-1} + \gamma\overline{\ln y}_{Pt-1} + (1-\gamma)\pi_{Rt} + \gamma\pi_{Pt} + \mu \\ E_{Pt}\left(\ln\left(y^i_{t+1}\right)\right) &= (1-\gamma)E_t\left(\ln\left(y^i_{Pt+1}\right)\right) + \gamma E_t\left(\ln\left(y^i_{Rt+1}\right)\right) \\ &= (1-\gamma)\overline{\ln y}_{Pt-1} + \gamma\overline{\ln y}_{Rt-1} + (1-\gamma)\pi_{Pt} + \gamma\pi_{Rt} + \mu \end{aligned} \tag{5}$$

The second line of (5) indicates that expected future income of the rich depends on the current shocks in both sectors. These effects correspond to two separate tunnel effects, an *own-sector tunnel effect*, which depends on the rich-sector productivity shock π_{Rt}, and an *intersectoral tunnel effect*, which depends on the poor sector productivity shock, π_{Pt}. The weights on these shocks reflect the strength of social mobility, as captured by the probability that a rich individual i will be in each sector the following period. The final term in the second line is the expected sectoral productivity shock the following period: $\mu = E_t(\pi_{st+1})$. The expression for the expected future income of a poor individual is parallel in structure.

3 Income Shocks, Inequality Shocks and Tunnel Effects

As noted in the introduction, the original exposition of the tunnel effect regards an increase in inequality that results from asymmetric growth and, because of this, understandings of the tunnel effect may confound the effects of growth and rising inequality on happiness. In this section, I attempt to disentangle these effects by considering income and inequality shocks in isolation. I then consider two cases discussed by Hirschman and Rothschild in which income and inequality shocks coincide, rich sector growth and poor sector decline.

To better distinguish between the roles of growth and inequality in tunnel effects, I decompose the sectoral productivity shocks into shocks to average and relative productivity:

$$\begin{aligned} \pi_{Rt} &= \pi_t + \omega_t \\ \pi_{Pt} &= \pi_t - \omega_t \end{aligned} \tag{6}$$

[7] It may also be that mobility refers to the poor sector as a whole rather than its members. See Davis (2014) for a model along these lines.

where $\pi_t = (\pi_{Rt} + \pi_{Pt})/2$ is the average productivity shock or *income shock* and $\omega_t = (\pi_{Rt} - \pi_{Pt})/2$ is the relative productivity shock or *inequality shock*.

Substituting (4) and (6) into (2) provides expressions for the happiness of the young in each sector as functions of individual income, the contemporaneous income and inequality shocks, and lagged measures of average log income in each sector:

$$\begin{aligned} V_{Rt}^{iY}\left(y_t^i, \pi_t, \omega_t, \ldots\right) &= ln(y_t^i) - \psi\left[\overline{\ln y}_{t-1} + \pi_t\right] \\ &\quad + \beta\left[(1-\gamma)\overline{\ln y}_{Rt-1} + \gamma\overline{\ln y}_{Pt-1} + \mu + \pi_t + (1-2\gamma)\omega_t\right] \\ &\quad - \beta\psi\left(\overline{\ln y}_{t-1} + \pi_t + \mu\right) \\ V_{Pt}^{iY}\left(y_t^i, \pi_t, \omega_t, \ldots\right) &= ln(y_t^i) - \psi\left[\overline{\ln y}_{t-1} + \pi_t\right] \\ &\quad + \beta\left[\gamma\overline{\ln y}_{Rt-1} + (1-\gamma)\overline{\ln y}_{Pt-1} + \mu + \pi_t - (1-2\gamma)\omega_t\right] \\ &\quad - \beta\psi\left(\overline{\ln y}_{t-1} + \pi_t + \mu\right) \end{aligned} \tag{7}$$

In these expressions, the first line reflects realized utility, and the next two lines reflect the impact on current utility of expected future income and status preferences. Equivalent expressions for the happiness of the old are obtained by setting $\beta = 0$ in (7):

$$V_{st}^{iO}\left(y_t^i, \pi_t, \omega_t, \ldots\right) = ln\left(y_{st}^i\right) - \psi\left[\overline{\ln y}_{t-1} + \pi_t\right] \tag{8}$$

These equations highlight the central role of age in tunnel effects: there are no tunnel effects for the old. Note also that income shocks affect the utility of the young rich and young poor in an identical fashion, while inequality shocks enter asymmetrically.

3.1 Income Shocks

I turn now to the relationship between tunnel effects, economic growth and happiness. In investigating the role of income and inequality shock in individual utility, I consider partial derivatives, computed while holding current individual income constant. While it is clear that the level of current income depends on the contemporaneous sectoral productivity shock, empirical work on tunnel effects tends to control for individual income in computing the effect of inequality and reference income levels on happiness. Thus, holding the level of current individual income constant facilitates the comparison of the model's predictions with empirical work on tunnel effects.

Differentiating (7) and (8) with respect to the income shock, one has

$$\frac{\partial V_{st}^{ai}}{\partial \pi_t} = \begin{cases} -\psi + \beta - \beta\psi & a = Y, s = R, P \\ -\psi & a = O, s = R, P \end{cases} \tag{9}$$

The results indicate that controlling for the current level of individual income, the effect of an income shock on individual happiness is uniform across income groups but varies with age.

A positive income shock reduces realized happiness of the young and old by increasing average income and, thereby, reducing their social status. The strength of this effect is increasing in the taste for status, ψ.

Income shocks also have two effects on prospective utility of the young. The second term in the first line of (9), β, reflects the current pleasure at the prospect that the income shock will increase an individual's future income. This is the *tunnel effect of an income shock*. Note that with an income shock, social mobility does not affect the size of the tunnel effect. This is because the income shock is common to both sectors, and thus raises the expected future income of an individual by the same amount regardless of their future sectoral membership. Indeed, the tunnel effect of an income shock may be decomposed into two separate effects, an own-sector tunnel effect of magnitude $(1-\gamma)$ that occurs is the individual continues their initial sectoral membership, and an intersectoral tunnel effect of magnitude γ that is realized if the individual switches sectors.

The final term in (9), $-\beta\psi$, reflects the impact of the current income shock on an individual's expected future level of social status. To the best of my knowledge, this effect has not previously been noted in the literature on tunnel effects.

The link between income shocks and expected future social status also reveals a previously unidentified relationship between tunnel effects and hedonic adaptation. In the absence of complete hedonic adaptation, $\psi < 1$, the net effect of a positive income shock on prospective utility is strictly positive, $\beta(1-\psi) > 0$. In addition, the net effect of an income shock on utility is positive provided $\beta > \frac{\psi}{1-\psi}$, which will hold when the weight on prospective utility is large relative to the taste for social status. This result confirms the ability of tunnel effects to partly or fully offset status concerns in a context of rising peer incomes, as found for example by Senik (2004, 2008) and Clark et al. (2009).

In contrast, under complete hedonic adaptation, $\psi = 1$, a positive income shock income shock has no impact on prospective utility. This occurs because the resulting tunnel effect is exactly offset by the disutility from the expected loss of future social status. The result depends sensitively on the assumption of perfect foresight. In this case, the effect of an income shock on the utility of the young and old will be the same and strictly negative: $\frac{\partial V_{st}^{Yi}}{\partial \pi_t} = \frac{\partial V_{st}^{Oi}}{\partial \pi_t} = -1$. The greater scope for tunnel effects among the young, as noted for example by FitzRoy et al. (2014) and Davis and Wu (2014), therefore provides additional evidence against complete hedonic adaptation. The inability for income shocks to affect prospective utility in the presence of complete hedonic adaptation also has important implications for policy, e.g. Frank (1985, 2005).

These comments are summarized in the following proposition:

Proposition 1 (*Income Shocks and Tunnel Effects*)

1. Controlling for the level of individual income, a positive income shock reduces the realized utility of the young and old by reducing social status.
2. A positive income shock affects the prospective utility of the young by increasing the expected future levels of individual and average income. With incomplete hedonic adaptation, the former effect dominates and income shocks increase prospective utility of the young. However, given complete hedonic adaptation, positive income shocks have no effect on prospective utility.

3. The magnitude of the tunnel effect may be decomposed into own-sector and intersectoral tunnel effects. However, the magnitude of tunnel effect generated by an income shock is independent of the level of social mobility.
4. The net effect of an income shock on current utility will tend to be positive when the weight on prospective is high, and the taste for status is weak.

3.2 Inequality Shocks

Next I consider the role of tunnel effects in the relationship between inequality and happiness. Differentiating the expression for current utility with respect to the contemporaneous inequality shock, while holding current income constant, yields

$$\frac{\partial V_{st}^{ai}}{\partial \omega_t} = \begin{cases} \beta(1-2\gamma) & a = Y, s = R \\ -\beta(1-2\gamma) & a = Y, s = P \\ 0 & a = O, s = R, P \end{cases} \tag{10}$$

Note first that, on their own, inequality shocks do not affect an individual's social status, as indicated by the absence of the parameter ψ in the expressions above. This is because inequality shocks raise log income levels among the rich by the same amount that they lower log income levels among the poor. Thus, they leave current and future average log income unchanged. As a result, unlike income shocks, inequality shocks have no impact on the current utility of the old.

Inequality shocks do, however, generate a tunnel effect, and it is asymmetric across sectors. Inequality shocks generate a positive tunnel effect among the rich of magnitude $\beta(1-2\gamma)$. This effect is comprised of two separate effects. There is a positive *own-sector tunnel effect* of size $\beta(1-\gamma)$, which is the prospective utility from the persistence of the rich sector shock times the probability of the individual remaining rich. The rich also experience a negative *intersectoral tunnel effect* of magnitude $-\beta\gamma$, which occurs if the individual becomes poor, in which case their expected future income is affected by the poor sector's current negative productivity shock. Since the persistence of sectoral membership is the norm, $\gamma < 1/2$, the own-sector tunnel effect dominates and the net effect is positive: $\beta(1-2\gamma) > 0$.

The same two effects are present for the poor, but in this case the signs are reversed. The prospective utility of the poor experience a negative *own-sector tunnel effect* with probability $(1-\gamma)$ and a positive *intersectoral tunnel effect* with probability γ. The net effect in this case is negative, reflecting the relative persistence of sectoral membership. Note also that both tunnel effects are decreasing in the level of social mobility, and equal zero when the sectoral membership of the old is random, e.g. $\gamma = 1/2$.

This discussion is summarized in the following proposition:

Proposition 2 (*Inequality Shocks and Tunnel Effects*)

1. The effect of inequality shocks on current utility differs across age and income groups. An inequality shock lowers the utility of the young poor, raises the utility of the young rich, and has no impact on the utility of the old.

2. Inequality shocks increase the expected future income of the rich and decrease the expected future income of the poor. These are net effects, reflecting both own-sector and intersectoral tunnel effects.
3. The tunnel effects generated by an inequality shock are decreasing in the level of social mobility and vanish when sectoral membership is randomly assigned.

The analysis of inequality shocks presented here contrasts rather strongly with the usual interpretation of the tunnel effect. To begin with, this effect is not uniform across individuals: it is absent for the old, and it differs in sign for the young rich and young poor. In particular, an inequality shock increases expected future income for the rich, while decreasing it for the poor. Thus, for the poor, who were to focus on Hirschman and Rothschild's analysis, the sign of the effect is the opposite of what was predicted. Thus, *the model does not confirm claims that inequality shocks raise the utility of the poor by increasing their expected future incomes*. To see why this is so, recall that with a positive inequality shock, the sectoral productivity shocks are equal in magnitude but opposite in sign: $\pi_{Rt} = -\pi_{Pt} > 0$. For the poor, the persistence of the negative inequality shock in their own sector more than offsets the expected future gains from intersectoral social mobility. While persistence dominates mobility for the rich as well, in this case the persistent shock is positive, so the net effect is positive.

3.3 Combined Shocks: Rich Sector Growth and Poor Sector Decline

To better illustrate the relationships between growth, inequality and happiness, I next consider a number of cases in which income and inequality shocks are combined in different ways. By accounting for simultaneous income and inequality shocks, the model largely validates Hirschman and Rothschild's original analysis. However, the model also highlights the degree to which claims about the role of tunnel effects are contingent in that they depend both on the relative magnitudes of the two shocks and on the identity—rich or poor, young or old—of the individuals whose happiness one considers.

I begin by considering the case of *rich-sector growth* in which the high productivity sector grows and the low productivity sector is stagnant: $\pi_{Rt} > 0$ and $\pi_{Pt} = 0$. I interpret this case as a stylized version of the growth-*cum*-inequality phenomenon that motivated Hirschman and Rothschild's original paper. The stagnant poor sector fits well with Hirschman and Rothschild references, noted above, to "those left behind" and the "nonmobile group" as well as with the initial traffic metaphor, in which one line of cars is immobile.

In this case, income and inequality shocks are positive and equal in magnitude: $\pi_t = \omega_t = \pi_{Rt}/2 > 0$, so that the effect on the happiness is given by

$$dV_{st}^{ai} = \left[\frac{\partial V_{st}^{ai}}{\partial \pi_t} + \frac{\partial V_{st}^{ai}}{\partial \omega_t}\right]\frac{d\pi_{Rt}}{2} = \begin{cases} \beta(1-\gamma) - (1+\beta)\psi/2 & s = R, a = Y \\ \beta\gamma - (1+\beta)\psi/2 & s = P, a = Y \\ -\psi/2 & a = O \end{cases} \tag{11}$$

For both the rich and the poor, rich sector growth raises expected future income, raising prospective utility. This effect is reflected in the first term of (11), while the second term reflects the impact of rich-sector growth on the current and future levels of social status.

Rich sector growth generates a tunnel effect, increasing the expected future income of young in both sectors. The rich young experience an *own-sector tunnel effect*, based on the positive current shock to their sector and weighted by the probability of continued sectoral membership. In keeping with this, the magnitude of this effect $\beta(1-\gamma)$ is decreasing in the level of social mobility. The young poor experience a smaller *intersectoral tunnel effect*, $\beta\gamma$, which is increasing in the probability of intersectoral mobility. Because rich-sector growth affects the social status of the young rich and young poor in an identical fashion, rich-sector growth benefits the young rich more than the young poor, even controlling for its effect current income levels.

The results presented in (11) bear out the intuition behind Hirschman and Rothschild's description of the tunnel effect. Rich-sector growth will raise the utility of the poor provided the tunnel effect, which is positive, is sufficiently strong to offset the loss of social status among the poor. In particular, this occurs provided

$$\gamma > \frac{(1+\beta)}{2\beta}\psi, \tag{12}$$

a condition that is more likely to hold in societies with (1) high levels of expected social mobility, (2) a strong emphasis on future outcomes, and (3) relatively little subjective weight on social comparisons.

Broadly speaking, the model confirms the central message of Hirschman and Rothschild: in the presence of rich sector growth the economy-wide tunnel effect produces an expectation of higher future income for the poor, which partly or fully offsets their disutility from rising income inequality. The exact mechanism at work, however, has little to do with rising inequality per se. In particular, note that for the poor, the two simultaneous shocks affect expected future income differently: As is evident from Eqs. (10) and (9), the inequality shock decreases expected future income while the income shock increases it. The effect of the income shock dominates, however, such that the net effect of rich sector growth on the expected future income of the poor is positive. Thus, in the situation considered by Hirschman and Rothschild (1973), *it is economic growth rather than rising inequality that signals a brighter future for the poor*.

To further differentiate between the roles of income and inequality shocks, next I consider the case in which inequality rises due to *poor-sector decline*. In this case, sector R is stagnant, while sector P experiences a negative productivity shock: $\pi_{Rt} = 0$ and $\pi_{Pt} < 0$. As in the case of rich-sector growth, discussed above, this pattern of productivity shocks also results in greater inequality, though in this case rising inequality is accompanied by negative growth: $\omega_t = -\pi_t = -\frac{\pi_{Pt}}{2} > 0$. The impact of poor sector decline on the happiness of the young of each sector is given by

$$dV_{st}^{ai} = \left[\frac{\partial V_{Pt}^{Yi}}{\partial \omega_t} - \frac{\partial V_{Pt}^{Yi}}{\partial \pi_t}\right]\left[\frac{-d\pi_P}{2}\right] = \begin{cases} -\beta\gamma + \psi(1+\beta)/2, & s = R \\ -\beta(1-\gamma) + \psi(1+\beta)/2, & s = P \end{cases} \tag{13}$$

As seen in (13), in the case of *poor-sector decline* rising inequality is associated with reductions in the expected future income of both the rich and the poor. The intersectoral tunnel effect generates a reduction in the expected income of the rich, while the own-sector tunnel effect generates a reduction in the expected incomes of the poor. In both sectors, lower expected future income is at least partially offset by an increase in current and future social status. For the poor, however, the increase in status due to the fall in (current and future) average income is more than offset by negative effect of the shock on their

own income levels. This effect is not captured by the comparative statics in (13), since the impact of poor sector decline is computed holding own income constant.

This second case corresponds closely to a situation discussed by Hirschman and Rothschild (1973, p. 547) in which a "neighbor or acquaintance … experiences a bad setback, such as losing his job while I am keeping mine." As they note, this gives rise to a "tunnel effect in reverse: once again I shall take what is happening to my neighbor as an indicator of what the future might have in store for me, and hence I will be apprehensive or worried." Thus, Hirschman and Rothschild's discussion supports one of the central findings of the analysis presented here: income shocks appear to matter more than inequality shocks in determining whether tunnel effects raise or lower prospective utility.

To sum up, in cases involving single sector productivity shocks, the income channel dominates the inequality channel. Thus, while tunnel effects produce a link between sectoral productivity shocks and the expected future incomes of the young, this effect appears to have more to do with how such shocks affect economic growth than how they affect inequality.

4 Implications for Empirical Specifications

This section discusses the model's implications for empirical models of tunnel effects. I begin by highlighting some issues related to the specification of empirical models designed to identify or measure tunnel effects. Second, I consider parameter restrictions and the recovery on key model parameters from empirical coefficient estimates. Finally, I consider the role of parameter heterogeneity in tunnel effects.

The empirical specification suggested by the model is given by:

$$h_{isact} = \theta_c + \theta_y \ln(y_{it}) + \theta^O_{\overline{\ln y}} \overline{\ln y}_{ct} + \theta^Y_{\overline{\ln y}} \overline{\ln y}_{ct} + \theta^O_I I_{ct} + \theta^{RY}_I I_{ct} + \theta^{PY}_I I_{ct} + \varepsilon_{it} \qquad (14)$$

where i, s, a, c, t index individuals, sectors, age groups, countries and time, respectively, I_{ct} is a measure of income inequality, and other variables are identified in the presentation of the model. Below, I note four key aspects of this specification and briefly discuss the degree to which they are present in existing empirical work. It should be noted that, derived as it is from a simple model, the specification above is not intended to be comprehensive. For example, the model has nothing to say about which individual-level variables, other than income, should be included in the model, or whether period effects are necessary to obtain consistent estimates of the model's coefficients. Rather it is intended as a building block for future empirical research.

Four characteristic of the empirical model are worth highlighting. First, the model suggests that tunnel effects operate through their impact on prospective utility, and thus only affect the happiness of the young. Because of this, income and inequality shocks affect the young and old differently, indicating the need to interact these variables with age or estimate key coefficients from age-restricted subsamples. In the existing literature, a number of papers have noted the importance of age for the identification of tunnel effects. This relationship is central to the analysis of FitzRoy et al. (2014), and both Senik (2004) and Grosfeld and Senik (2010) conduct robustness test that show that the effect of inequality on happiness differs across age groups.

Second, the analysis suggests that empirical models should include cross-sectional fixed effects. In a fixed effects specification, the coefficients on inequality and average log

income will be identified by the time variation of these variables within a given cross-sectional unit. This allows us to relate the estimated coefficients to the comparative statics of the model above. Most researchers already employ a fixed effects specification to control for unobserved country or regional level heterogeneity, and Verme (2011) notes that empirical results regarding inequality aversion depend critically on whether a fixed effect or pooled regression is used. The model provides a theoretical rationale for including regional fixed effects to identify the role of tunnel effects.

Third, the empirical specification should control for both income and inequality shocks if the role of tunnel effects is to be correctly identified. This is particularly important because productivity and inequality shocks are likely to be correlated in practice (Forbes 2000, Davis and Hopkins 2011). While most of the work on inequality aversion does not control for average income, a number of researchers include a close empirical correlate. For example, Grosfeld and Senik (2010) control for the inflation and unemployment rates in their baseline specification, and Alesina et al. (2004) control for changes in the macroeconomic environment using the unemployment rate, the inflation rate, or both. While the literature on status effects is much larger, it has not as a rule attempted to account for potential correlations between peer income levels and income inequality. Indeed, much of the work proceeds at the industry level and omits macroeconomic considerations altogether.

Fourth, the model suggests that in the presence of tunnel effects, inequality shocks affect the happiness of the rich and poor differently. To the best of my knowledge, Alesina et al. (2004) is the only paper to propose an asymmetry in the effect of inequality shocks on rich and poor individuals and to design their empirical testing with this distinction in mind.[8] Accounting for this asymmetry requires dividing the sample between rich and poor, as in Alesina et al. (2004), or interacting inequality with a measure of relative wealth.

In addition to providing guidance on appropriate empirical specification, the model may also be useful in generating testable parameter restrictions and in relating empirical findings to various theoretical coefficients of interest. For example, regarding parameter restrictions, the model implies that $\theta_I^O = 0$, $\theta_I^{RY} + \theta_I^{PY} = 0$, and that $\theta_\pi^{RY} = \theta_\pi^{PY}$. The key parameters of interest may also be recovered from empirical coefficient estimates. For example, the taste for social status is estimated $\psi = \frac{\theta^O}{\ln y}$, an approach used by Davis and Wu (2014) to separate tunnel and status effects. In addition, the difference in the effects of income shocks on happiness for the young and the old may be used to identify the weight on prospective utility: $\beta = \frac{\frac{\theta^Y}{\ln y} + \frac{\theta^O}{\ln y}}{1 - \frac{\theta^O}{\ln y}}$. And the level of expected social mobility is given by $\gamma = \frac{2 - \theta_I^{YA}}{2\beta}$. Thus, the relative importance of prospective utility and the extent of inter-sectoral diffusion are recoverable, at least in principle, from empirical analysis.

A final issue regards the model's implications for understanding the degree to which tunnel effects differ across societies. Alesina et al. (2004) and Senik (2008) investigate differences in tunnel effects across countries, while Grosfeld and Senik (2010) consider the evolution of tunnel effects in a transition economy. However, none of these papers attempt to relate the strength of tunnel effects to the structural factors that Hirschman and Rothschild argue underlie beliefs about social mobility, e.g. the division of the economy along

[8] Ravallion and Lokshin (2000) find differential tunnel effects for the rich and poor in transition Russia. Their analysis differs from most of the work cited here in that they are concerned with support for redistribution rather than with happiness.

ethnic, linguistic and religious lines, the role of foreigner labor and capital in the economy, recent revolutions, etc. In addition, as noted in the discussion of (13), the ability of tunnel effects to offset status concerns among the poor depends not just on social mobility but also on the structure of preferences and, in particular, on the importance of prospective utility in current utility and the degree to which individuals are concerned with relative income or social status. International differences in these dimensions of preferences may be usefully empirically proxied by cultural and linguistic variable, e.g. Hofstede (2001) and Chen (2013).

5 Conclusion

This paper presents a model that analyzes the relationships between tunnel effects, economic growth and income inequality. The model highlights the importance of distinguishing between the young and old and the rich and poor when analyzing tunnel effects. It also distinguishes between the role of income and inequality shocks in generating tunnel effects. While tunnel effects increase happiness in the presence of a growth shock, the tunnel effects generated by an inequality shock may increase or decrease happiness. The model also indicates that current income shocks may reduce prospective utility through their effect on expected future social status. To the best of my knowledge, this effect has not been previously identified.

These findings largely support the interpretation of tunnel effects in the literature on social status, which holds that tunnel effects may offset concerns over the lost of status from rising income levels, e.g. economic growth, among one's peers. In contrast, the model suggests that tunnel effects should not be interpreting as automatically offsetting the disutility associated with rising income inequality. They also support the central proposition of Hirschman and Rothschild's original paper concerning uneven development: When growth is accompanied by rising inequality, tunnel effects may offset the loss of social status increasing utility among the poor.

The model has several implications regarding the empirical investigation of tunnel effects. The most important of these is that the prospective utility from expected future income responds differently to income and inequality shocks across the old and young and across the rich and the poor. In response, researchers should adopt flexible specifications that allow for parameter heterogeneity. The differential response to income and inequality shocks across these groups may be used to estimate key model parameters. Finally, the model suggests that the strength of tunnel effects may differ systematically across societies both due to structure impediments to social mobility and to differences in preferences related to future-orientation and the taste for social status. This prediction has not been noted previously or empirically exploited in the literature on tunnel effects.

In closing, I note that the happiness literature has proceeded without much reliance on formal theory and that the primary contributions of this literature have clearly been empirical in nature. As this literature advances and comes to address increasingly refined questions, formal modeling exercises may have a greater role to play in ensuring the internal consistency of arguments, generating testable hypotheses, and motivating empirical specifications, much as it does in other areas of economics.

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