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**To: Shah Dabirian, Air Quality Specialist, SCAQMD**

**RE: Assessing Abt's Evaluation of REMI's model for measuring impacts of QOL changes**

#### **SUMMARY OF UNDERSTANDING OF ATTACHMENTS**

##### **Abt's Position in Attachment A.**

Abt raises a major concern about the manner in which REMI has clients adjust for a change in quality of life (QOL) of an area. The concern is that clients can enter a QOL shock for a region as a change in *relative* total compensation (a so-called "compensating differential") that manifests in the model only through a change in net migration. They contend that the change in QOL should instead enter the model as a change in the value of the total amenity set within the area and not as a change in migration flows. In essence, Abt's concern focuses on what the model should use to normalize changes in QOL, i.e., the total value of local amenities rather as changes in migration. As Abt sees it, the amenity shock will indirectly increase the magnitude of the resulting in-migration flows in the case of a positive QOL change. They note that the magnitude of the capitalization of a QOL change (the compensating differential estimate that the REMI model requires as input) is nearly impossible to assess a priori as it could fall either way for a particular region. This is because positive wage effects depress the change in amenities and positive housing effects elevate that change, at least in the case of a net positive amenity change. The rest of Abt's assessment is devoted to how REMI might go about solving for the implicit prices of the various regional amenities using something other than a reduced-form approach, which is known to provide biased results. The idea would then to multiply the implicit prices by the regional quantities of the amenities to obtain a value for the amenity set for the area of concern.

##### **REMI's Response in Attachment B.**

In their response to Abt, REMI states that their equations work as suggested by Plantinga et al. (2013), which is cited by Abt. [As we shall see, this is not the case since Plantinga et al. (p. 297) note that "Individuals are assumed to choose locations conditional on expected wages and housing costs."] The response then lays out the key equations in REMI's model that focus on how a change in amenities is used to alter migration flows. Unfortunately, not all variables used in the equations are defined (e.g.,  $EO_{i,t}^l$ ,  $EOA_{i,t}^l$ ). Neither were two key equations.<sup>1</sup> Still, the implementation is fairly clear. In essence, a change in QOL is valued (this is an important part and not documented, herein) and added, as REMI instructs, to a migration equation to change the relative size of  $\lambda$  (the *permanent* fixed effect in part of their net migration equation). In turn,  $\lambda$  alters the

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<sup>1</sup> Elaine Shen sent the missing equations on August 11, 2015, via email. They were apparently supplied to her by Jerry Hayes of REMI Inc. on August 27, 2014 via email.

period's migration streams. Positive changes in the migration stream, depress wages rates (due a short-run increase in labor supply) and cause house prices to rise (due to short-run constraints in housing supply). These two results dampen migration in the following period to some degree. Of course, the new wage rates and home prices could still be above equilibrium values after this initial wave of migration, so subsequent migration flows could still be greater than those that existed prior to the positive QOL shock for a number of years. But they should diminish substantially in each succeeding year.

### **Abt's follow-up: Attachment C**

Abt remains concerned about REMI's short-cut approach to measuring the impacts of a QOL shock. They view it as a "rough" way to get at estimates usually obtained by the structural equations approach (using both hedonic wage and hedonic housing price equations) extolled by both Rosen (1979) and Roback (1992). In essence, it is perplexing to Abt that the value of any amenity shock must be valued outside of the REMI model and that value is then what is entered into the REMI model to affect migration. Abt insists that REMI's "ad hoc adjustment to the intercept" (the fixed effect based on  $\lambda$  for SCAQMD's region) is inappropriate. Instead, they contend that air quality should have a coefficient in both the hedonic wage and fixed-quantity hedonic housing price equations. These coefficients should have countervailing effects (improved air quality should lower wages offered but raise home values). In essence, net migration change, which is based in part on  $\lambda$ ) should be a function of changes of relative home prices and wages after an amenity shock.

### **REMI's Rebuttal: Attachment D**

REMI points out that Abt and REMI seem to have come an agreeable position on the viability of BenMAP to estimate the societal economic value of health improvements and on the basic equivalence of the BenMAP's term "willingness to pay (WTP)" and REMI's use of "compensating differential." In response to continued Abt criticism of the manner in which they instruct clients to effect changes in migration from the BenMAP estimates, REMI cites Greenwood et al. (1991), which articulates REMI's approach and which was published in a leading journal in the economics discipline. REMI insists that this paper improves the Rosen-Roback approach to account for both "equilibrium and partial equilibrium aspects" using panel data and instrumental-variables fixed-effects estimates. REMI therefore essentially asserts that their approach has been vetted and the "connection" to the Rosen-Roback approach "is clear."

### **CONCLUSIONS FROM THE ATTACHMENTS.**

Abt hits at serious points, and REMI seems not to be listening. Abt is not criticizing REMI's general modeling approach or even the migration aspect per se. Rather, Abt is saying "only" that the way REMI tells clients to effect a change in the economy due to a change in amenity level is incorrect if they wish to say their model is related to that of Roback's, Rosen's, and Plantinga's.

In Attachment A, Abt wonders why area nominal wage and salary disbursements are used to identify the *relative* effects of specific amenity changes rather than to the total value of the specific amenity within the area. By Attachment C, this general point no longer seems

to be an issue for Abt, even though REMI's reply in Attachment B does not appear to address the issue.

By Attachment C Abt's initial concern has become redirected somewhat. Still, they hammer away at the same core point and a bit more clearly. They note that REMI has amenities altering migration directly rather than through real wages or housing prices as extolled by Rosen and Roback. They say this makes no sense. They are implying that the changes to wage rates and housing prices that REMI's model measures are merely *indirect effects* due to migration. New perceptions of wage rate and house price offers, instead, should be what entices potential migrants to a region. This is certainly the proper viewpoint according to the Rosen-Roback framework.

In summary, it is Abt's viewpoint that if the model is to have a Roback-Rosen-Plantinga perspective, it must first value the amenities from the perspective of wages and from the perspective of home prices. That is, due to improved amenity levels most (if not all) workers in the region would be willing to accept lower wages and all homes in the region latently gain more value. Thus, Abt's point is that an equilibrium adjustment is required when quantities of amenities change. Moreover, householders do not notice that a region's amenity bundle has changed and migrate as a result of that. Rather, as in the Rosen-Roback-Plantinga model, changes in the quantities of amenities in a region cause changes in equilibrium wage rates and home prices in that region. This, in turn, affects net migration. That is, migration does not cause wage and price changes, rather changes in wages and home prices cause migration. But this then begs an explanation of how amenities cause wages and home prices to change. I explain below.

In essence, when they are offered an opportunity to move (lose/get job, retire, etc.), householders investigate the prospective economic landscapes of alternative viable locations. From this investigation, they judge whether the net package of home prices and wages are more advantageous in targeted alternative regions compared to their home region, given the amenity levels in both. Before any observed change in amenity levels, all regions are assumed to be equally appealing. (They are in equilibrium with respect to home prices and wages.)

But would full adoption of the Rosen-Roback framework make a practical difference in the modeling effort? Abt hedges on this; they say the answer to that question is unclear. Still, they err on the side of caution and via an "informed guess" suggest the impacts would likely be lower if measured properly. They provide no rationale for their informed guess, however.

The problem is that, without knowing the elasticities of pollution rises on wage rates and housing prices, it is tough to know the degree to which REMI's model might mis-estimate the impacts of pollution change on Southern California's economy. This, of course, assumes the model estimates net migration well. (I say this in part because I do not know the vintage of REMI model parameters: I am only aware of the vintage of the data in their models.) I agree the effects of migration on wages and home prices are likely lower than the higher home prices and lower wages rates that would be enabled by amenity improvements that allow that net migration. The difference could be large or insignificant.

## EMPIRICAL VERIFICATION

From an earlier report:

In an effort to gather more information on how REMI's model works, I used their online sample model, which is available free of charge (for some unknown Region X). I injected the model with \$500 million in amenities annually from 2014 to 2060.<sup>2</sup> Some basic results are available in the attached set of MS Excel tables. Population and labor force projections are at magnitudes that look more or less as one might expect them: Population rises by about 2,700 people per year, the labor force by 1,200 and employment by 500 jobs. Moreover, indices for home prices rise and for wage rates fall as REMI promises and the Rosen-Roback approach expects. But several strange set of results stand out: the average personal income per new worker is \$92,170 in 2014 and rises to \$1.19 million in 2060—all dollars in current year terms. The change in constant GDP per change in the count of workers also rises consistently, although at values about half that of personal income. Combined, the two pose puzzles. How can personal income rises be greater than rises in GDP? How can either rise as wage rates decline?

One answer is that in-migrants are elect to live in Region X but are commuting to their old work places outside of Region X. Except in some densely populated areas of the United States, this is an implausible rationale. Still it could be possible. But compensation per residential worker (which is by place of work rather than by residence) rises too, albeit more modestly. This last is certainly implausible in the face of declining wage rates, unless workers start to work more hours. The upshot is that something is wrong with the way the model is reacting to a rise in amenity levels. It seems that somehow some not insignificant share of the amenity boost is being transformed into personal income. But by definition, amenities are a nonmarket good. Their benefits are necessarily nonpecuniary. So how can it be that residents in the area are made immediately better off monetarily as wages lower and home prices rise? In summary, the only possible way that benefits should be able to rise is through the new migrants. The added income of these migrants should be the sole direct benefit.

This then begs the question of what we should be expecting as results from the REMI model. For one, we should expect some marginal productivity improvements in businesses that employ the added workers as many ate likely in-migrants. Note that net migration is the ***difference*** between in- and out-migration, so more labor is likely involved in affecting productivity improvement than just that reported as residence-adjusted employment in the REMI results. All homeowners will be getting

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<sup>2</sup> This implies that pollution levels improve and remain improved at near constant levels through 2060, given the of amenity value ratio to aggregate wages and salaries is quite close to constant as well, even though aggregate wages and salaries undoubtedly rise.

value added to in their homes as a result of the amenity improvement. The value of existing homes, however, is revealed only upon sale of the homes or as rents are raised by landlords. Theory suggests that both are likely to be a bit sticky. That is, it is unlikely that the value of residences are likely to be realized immediately, i.e., within a year or two of when the environmental improvements are experienced. Whenever a home is sold the beneficiaries are not only the homeowners but also real estate agents, lawyers, inspectors, and possibly governments for transaction fees. Contractors who build houses may also benefit secondarily as well. This latter is distinctly articulated in the REMI model via the variable *Regional Residential Actual Capital Stock*. The rest are unfortunately not so readily detected from the general set of REMI results.

Since I reported the above, REMI has assured me that Region X is a very small Midwestern metropolitan economy, so the annual shock I applied was far beyond norms. They insist that under such conditions odd findings can result from their model. They further say they tested SCAQMD's model with the same shock and that any of the "strangeness" that I uncovered was not present. I have no way of confirming this. They also said apparently have said they could not replicate my results, although I provided a complete listing of the changes I made to the Region X model. They did not contact me directly to pursue this matter further. I cannot conceive of a constructive response to this; the fact that the model region is irrelevant to the size of impacts I entered seems sufficient in any case, as long as such large changes can work on SCAQMD's model. I could possibly test smaller shocks on this region, but as I do not know the economic size of the region or the region's economic composition such sensitivity testing could again prove irrelevant to REMI. That is, such testing can no longer possibly be objective, as REMI could always object on grounds that the region was the wrong type of region for the test being conducted: and they might or might not be correct in their defense. I can only recommend that SCAQMD do such sensitivity testing using their version of the model.

## **Overall Conclusions**

From a theoretical/conceptual perspective, the approach REMI staff suggests that their clients use for entering valuated amenities should underestimate the effects of amenity change in home prices and wage rates. This is because it bypasses the articulation of the initial housing price and wage rates that would likely inhibit some in-migration. This does not mean that the net migration estimate is wrong. Indeed, there is no reason to believe there is anything incorrect about that particular equation. Rather, in bypassing the relationship of the various amenities' effects on home prices and wage rates and, instead, entering the value of the amenities on net migration directly the REMI model estimates only the secondary effects of net migration on home prices and wages. The extent of the impact of this missing initial price effect is unclear, other than it is clear the REMI model yields biased estimates of the home price rises and wage rate declines that arise from amenity improvements. In a nutshell, REMI's approach to modeling the effect of a change in amenities is likely sufficiently accurate for most uses. The concern then rests on how well REMI estimates the change in net migration, and equation that is based on household tastes, which change rather quickly—even more quickly as income rises, at

least compared to other foundations of economic change like technology, knowledge, and taxation.

Clearly a linchpin in the modeling exercise is assuring that what is entered into the REMI model is a reasonable estimate what the REMI model expects will be entered. In SCAQMD's case, it is my understanding that BenMAP and a survey of literature are used to produce the estimates entered into the model. The values used are those from residents' stated preferences for BenMAP estimates of health benefits in general. As they are based on published literature, these data are necessarily out of date and not necessarily pertaining to Southern California, both of which can be problematic factors. Further the study participants were asked only to state their willingness to pay for a *small* mortality/morbidity risk change and not those generated via air pollution only. That is other concerns, like superfund sites and water pollution could have been on their minds as they answered. Further, there are naturally other sensory benefits from pollution reductions beyond those that can be attributed strictly to *known* health benefits to pollution reductions, e.g., those limited strictly to visibility and smell. In this light, the estimates derived are likely conservative, unless those sorts of benefits are also understood by surveyed residents to be included in their assessments. Nonetheless, the conservatism of the BenMap starting point on the value of direct health benefits is mitigated to some degree by the heavy positive bias associated with contingent valuation techniques (Hausman, 2012). Regardless of all these potential issues, the approach used is the conventional practice in the field. Only a major undertaking by SCAQMD and related institutions on factors that affect *revealed* preferences of health outcomes in Southern California, with various levels of air pollutants evaluated as some of the potential causes, would be better.

More substantive issues may arise in the REMI model's outcome reports. These issues may or may not be related to the manner in which the valuated amenities are entered into the model. I was unable to identify the mechanisms by which they manage to unfold.<sup>3</sup> Still, it seems that the REMI model could be reporting some nonpecuniary impacts of the amenities as worker compensation. This issue is exaggerated even further when reported as residential personal income. Of course, such odd results may only occur when the equations used by the REMI are applied to data points that are beyond statistically viable measure. That is, while I obtained very strange results. I also may well have unknowingly entered data into the REMI model that reflected nigh-onto-impossible conditions.

As a result of the above assessment, I have a few recommendations. First, I suggest that SCAQMD evaluate the degree of match between the information that they enter into the REMI model and the number that *should* be entered into the REMI model as the estimate of compensating differential from the QOL change that calculates changes in migration flows. Second, assuming the value entered into the model is the "right stuff," SCAQMD should be sure to recognize that the REMI model is founded on statistical modeling and understand that  $\lambda$  is a stochastic variable. Thus, SCAQMD should investigate the sensitivity of model findings across the confidence interval of  $\lambda$ . And, third, I also suggest that SCAQMD perform sensitivity tests to determine the limits of their REMI

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<sup>3</sup> This is because I used a generic version of the REMI model (the actual region was not known) and apparently entered an overly large value of amenity change for the size of the economy.

model to assure that even pie-eyed estimates of changes in amenity-induced compensating differentials do not yield strange-looking outcomes.

## REFERENCES

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**Attachment A**  
**(Excerpts from the Final Report of “Review of the SCAQMD Socioeconomic Assessments”  
Related to Abt’s Concerns about Treatment of Non-Market Benefits in the REMI Model)**

**Executive Summary**

Pages x to xi:

We also identified some issues associated with the application of REMI. The REMI model allows users to specify changes to the coefficients in the migration equation as levels or as the equivalent of a proportionate change in real relative compensation. We believe the magnitude of these adjustments must be properly normalized to link the change in air quality to both the baseline level of air quality and the baseline levels of all the other amenities and dis-amenities that contribute to the estimates for the relative attractiveness of one area compared to others. This modification would not require a change in REMI’s structure but would require detailed analysis of the input information developed for REMI. There is recent literature that emphasizes the importance of considering a wide array of amenities in understanding the changes in relative real wages, housing costs, and the migration decisions that are being represented in REMI. Plantinga et al. (2013) and Kuminoff et al. (2013) are notable examples.

Page xii:

[...] we suggest that the District improve the adjustment made to the location-specific fixed-effects coefficients of the migration equation in REMI model. The magnitude of these adjustments should be properly normalized to reflect the baseline levels of all amenities and dis-amenities that contribute to the estimates for the relative attractiveness of one area compared to others. [...]

**Section 3. Review of Socioeconomic Assessments of the SCAQMD**

**3.3 Review of Economic Impact Assessments**

**3.3.1 Tools and Methods**

**Analytic approach and application of tools**

Pages 3-13 to 3-14:

In general, the analyses of economic impacts in the SCAQMD’s socioeconomic assessments are straightforward in their approach and use a well-established and peer reviewed tool for conducting regional economic impact analysis—the REMI Policy Insight model—which has been customized for the four-county District.

However, the brief descriptions of the REMI modeling in the analyses omit the details necessary to judge the assumptions and implementation of the model for specific analyses. It would be desirable to include information or data that describe decisions and assumptions made by the REMI analyst. Lack of transparency about modeling inputs are, in part, the reason that some stakeholders view models like REMI as a “black box” which regulators use to achieve results that provide further justification for new regulations. For example, there are many steps needed in order to translate compliance costs or changes in revenue into inputs that can be accommodated within REMI, and many of these steps require expert judgment. In order to confirm that the approach and REMI modeling process is robust, the analyses should provide greater transparency about specific



steps in the process, including the data and assumptions used. These details can be placed into an Appendix if the discussion of modeling details is not accessible to the primary audience for the assessments, but they should be provided nonetheless.

Our evaluation of REMI and its application was aided by REMI's technical staff and the District economists, who provided additional documentation and assisted in clarifying the modifications to REMI to include the regulatory benefits associated with the air quality improvements. REMI's method for including non-market benefits uses one of two options in adapting the migration equation in REMI to reflect amenities: (1) changes to the coefficients in the migration equation that are fixed effects reflecting the relative attractiveness of each location or (2) changes based on the equivalent of a proportionate change in the real relative compensation that adjusts the same fixed effects. In this second case it is computed in relation to the real relative compensation in the location experiencing the air quality change. The basic logic of the adjustment for amenities was developed by one of the founders of REMI model. This logic assumes that the location-specific fixed effects in the migration equation can be modified to represent policy changes in the factors (e.g., air quality) that may contribute to the attractiveness of modeled areas. Once the change is specified, REMI treats the impacts on other variables that contribute to the regional adjustments in a format that is consistent with the logic of the model. There are two aspects of our concerns. In a formal sorting model we would expect adjustment in the coefficients of the other variables contributing to the migration equation as part of the equilibrium process. This is consistent with the logic of the Rosen-Roback framework and current research on sorting models (see Kuminoff, Smith and Timmins, 2003). For practical purposes it seems reasonable to assume for small changes the logic REMI uses would approximate the adjustments. However, the characterization of the size of the impact of the change in air quality is important. This leads to our second comment and the one that offers a change that can be implemented readily. This concern relates to the size of the adjustments to the fixed-effect coefficients. Based on our discussions with REMI and the economists of SCAQMD, we believe the magnitude of these adjustments must be properly normalized to reflect the baseline levels of all amenities and dis-amenities that contribute to the estimates for the relative attractiveness of one area compared to others. This modification would not require a change in REMI's structure but would require detailed analysis of the input information developed for REMI. Our concerns apply to both options that are in the model (i.e. adjustments using levels and those using proportionate changes in relative real compensation) for including the benefits of air quality improvements. It is difficult to conjecture about the effects of our proposed change. We believe it would require a reduction in the magnitude of the effects attributed to air quality benefits. However, at this stage this comment should be considered an informed "guess" that needs to be documented with a more specific assessment of REMI variables and the precise logic used to construct each type of modification to REMI.

REMI accounts for some interactions between wages, rents, and migration, but does so in terms of reduced form models that are not fully consistent with the logic used to estimate the economic benefits provided by air quality improvements. As discussed in Roback (1982), differences in the amenities between locations do not only affect relative wages, but also the prices for housing in places where amenities change due to regulation. Plantinga et al. (2013) estimate a migration equation based on amenities, relative wages, and housing costs and find that housing is a normal good and statistically significant. They rely on part of an equilibrium outcome that the Rosen-Roback logic describes. For local approximations with adjustment in the size of the estimated

effects attributed to air quality gains the inconsistencies in the two models may not be important to the estimated adjustments. Nonetheless this is a conjecture and should be an area for future research –assessing the difference between small local effects and larger effects where models like REMI may be especially vulnerable. To correctly incorporate measures of non-market benefits their analysis would need to begin from a consistent framework that describes how migration is an adjustment mechanism that contributes to the Rosen-Roback model’s equilibrium outcome. Plantinga et al. (2013) is an example of such logic. Kuminoff et al. (2013) discuss the logic of other local sorting models that are consistent.

## **Section 6. Recommendations**

### **6.1 Methodology**

#### **6.1.6 Economic Impact Analysis**

##### Pages 6-6 to 6-7:

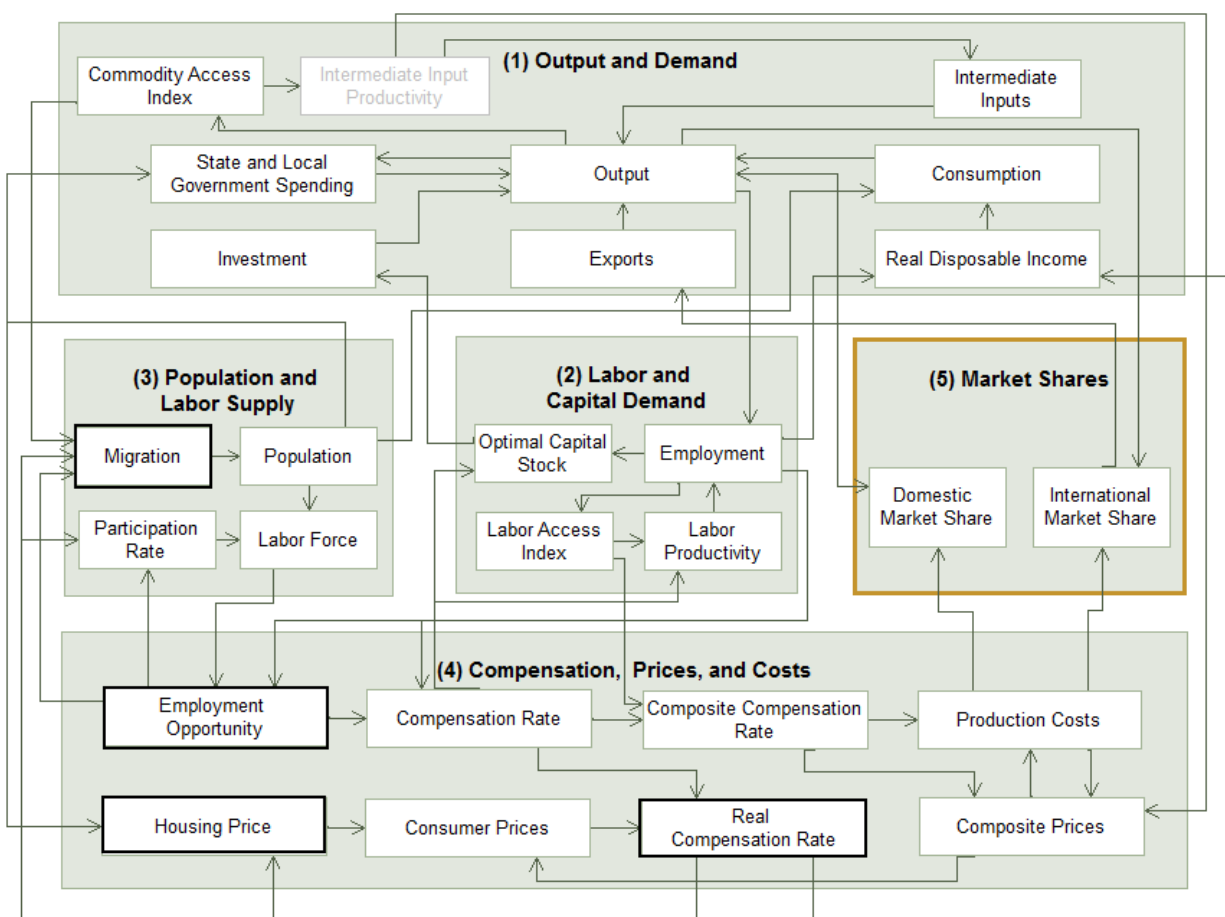
We recommend that the SCAQMD initiate a research task to consider the weighting of estimates of air quality benefits to reflect the relative importance of air quality changes compared to other area specific amenities. Since the adjustment is to a location-specific fixed effect in the migration equation, it reflects both positive and negative influences associated with each area in relationship to others. The issues associated with developing these weights need to consider what the set of important location specific factors should be, how the baseline conditions in relation to air quality should be defined, and the appropriate weighting for a migration equation. The nature of the adjustment would depend on whether the option to use levels or proportionate equivalent change in relative real compensation. Pending the development of this research SCAQMD could consider using weights based on the literature developing indexes for the quality of life in each area and include analyses based on alternative assumptions about the weighting of air quality benefits as additional scenarios along with an explanation of the reasons for providing a range of estimates. At this stage we do feel that current practices of giving the air quality benefits relative to an income measure a weight of one is appropriate. The challenge is in developing a justifiable set of weights. We would expect these weights would be less than one. Pending the development of the research necessary to develop the weights a strategy that uses a set of different weights based on this literature would identify the issue and provide users a sense of its potential importance. Ideally, SCAQMD economists would plan activities that would evaluate the proper scaling of estimated of air quality benefits to be consistent with REMI and with the literature on the relative contributions of environmental and other amenities to the relative attractiveness of different areas.

Over the longer term the SCAQMD should consider evaluating REMI’s logic for incorporating amenities using the migration equation in relation to the more current logic that links migration to the equilibriums in labor and housing markets. We also encourage the SCAQMD to keep abreast of the USEPA’s development of methods for applying benefits in economy-wide models.

## Attachment B (REMI's First-Round Response to Abt's Concerns)

The Rosen-Roback model of amenities implies that increasing amenity in a region will increase housing prices and (usually) lower wages. Furthermore, Platinga et al. assert that an area with a lower housing price and higher wage, *cet par*, will be more attractive to migrants. REMI's equations for economic migration, price level, and compensation are consistent with the above frameworks. The text below outlines REMI's framework<sup>1</sup>.

The below model structure represents the underlying economic relationship of the equations that follow. The cascading effects following a direct change in the amenity start with migration (as represented in the migration equation). Migration changes population, and then population effects housing prices. A change in housing prices the real compensation rate which has an effect on migration. As such a positive effect on amenities, all else equal, would increase housing prices, which would have an offsetting effect on migration.



REMI's equation for economic migration is as follows.

<sup>1</sup> All equation numbers correspond to those in REMI's equation book that can be found here: [http://www.remi.com/download/documentation/pi+/pi+\\_version\\_1.6/PI+\\_v1.6\\_Model\\_Equations.pdf](http://www.remi.com/download/documentation/pi+/pi+_version_1.6/PI+_v1.6_Model_Equations.pdf).

$$ECMIG_t^l = \left[ \lambda^l + \beta_1 \ln(REO_t^l) + \beta_2 \ln(RWR_t^l) + \beta_1 \ln(MIGPROD_t^l) \right] * LF_{t-1}^l \quad (3-5)$$

Where;

$ECMIG_t^l$  = Net economic migrants (all migrants less than 65 years of age) in area  $l$ .

$LF_{t-1}^l$  = The labor force last period in area  $l$ .

$$REO_t^l = \frac{RAE_t^l / LF_t^l}{RAE_t^u / LF_t^u} = \text{The relative employment opportunity in area } l \text{ in period } t.$$

$RAE_t^l$  = Residence-adjusted employment in area  $l$  in period  $t$ .

$MIGPROD_t^l$  = The consumption access index in area  $l$  in period  $t$ .

$$RWR_t^l = \left( \frac{CR_t^l}{CR_t^u} \right) * \left( \frac{RYD_t^l / YP_t^l}{RYD_t^u / YP_t^u} \right) = \text{The relative real compensation rate in area } l \text{ in period } t. \quad (3-8)$$

$$CR_t^l = \sum_{i=1}^n \frac{E_{i,t}^l}{TE_{i,t}^l} * C_{i,t}^l = \text{Local average compensation rate} \quad (3-9)$$

$$CR_t^u = \sum_{i=1}^n \frac{E_{i,t}^l}{TE_{i,t}^l} * C_{i,t}^u = (u) \text{ average industry compensation weighted by the employment industry shares in } l.$$

$\lambda^l$  = A fixed effect that captures the relative attractiveness of area  $l$ .

$\beta_1, \beta_2$  = Estimated coefficients.

From the term  $RWR$ , we can see that migration is positively related to the real compensation rate in the region. In other words, increasing (decreasing) nominal compensation and decreasing (increasing) the price level will increase (decrease) economic migration.

To further elaborate, a price index is used to convert nominal to real dollars. The consumer price index based on delivered prices is as follows.

$$CIFP_t^l = \left( \prod_{j=1}^r \left( \frac{CIFP_{j,t}^l}{CIFP_{j,t-1}^l} \right)^{WC_{j,t-1}^u} \right) * CIFP_{t-1}^l \quad (4-7)$$

Where;

$CIFP_t^l$  = The consumer price index in region  $l$ .

$WC_{j,t}^u$  = The proportion of commodity  $j$  in time  $t$  in the total union of regions consumption.

$CIFP_{j,t}^l$  = The CIF (delivered) consumer price of consumer commodity  $j$  in region  $l$ .

The above is further adjusted for potential in or out migrants as follows.

$CIFPH_t^l$  = Equation (4-7) with the housing cost replaced by relative price of purchasing a house.

$$CIFP_j^l = PH_t^l$$

Where;

$PH_t^l$  = Relative housing price at time  $t$  in area  $l$ .

$CIFP_t^l$  = The cost of living in area  $l$  when the relative price of buying a new house is used in the consumer price index for housing costs.

And where;

$$PH_t = \left\{ \left( \varepsilon_1 \left( \frac{RYD_t \div RYD_t^u}{RYD_{t-1} \div RYD_{t-1}^u} - 1 \right) + \varepsilon_2 * \left( \frac{N_t \div N_t^u}{N_{t-1} \div N_{t-1}^u} - 1 \right) \right) + 1 \right\} * PH_{t-1} \quad (4-8)$$

$PH$  = Relative housing price.

$RYD$  = Real disposable income.

$\varepsilon_1$  = the estimated (or user-entered) elasticity of response to a change in real disposable income.

$\varepsilon_2$  = the estimated (or user-entered) elasticity of response to a change in population.

$N$  = Population.

$N^u$  = Population in  $u$ .

The housing price equation shows that as population in a region increases, housing prices will also increase.

Nominal compensation is also an endogenous variable in the model which is specified as follows.

$$CR_{i,t}^l = \left[ (1 + \Delta CRD_{i,t}^l) (1 + k_t^u) \right] * CR_{i,t-1}^l \quad (4-9)$$

Where;

$CR_{i,t}^l$  = Compensation rate in industry  $i$  in time  $t$ .

$\Delta CRD_{i,t}^l$  = The predicted change in the compensation rate in industry  $i$  due to changes in demand and supply conditions in the labor market in area  $l$ .

$k_t^u$  = The change in the national compensation rate that cannot be explained by changes in the national ( $u$ ) average compensation rate for all industries, which is due to change in demand and supply conditions and to industry mix changes in the nation.

$$\Delta CRD_{i,t}^l = \alpha_1 \left[ \left( \frac{E_t^l}{LF_t^l} \div \frac{EA_t^l}{LFA_t^l} \right) - 1 \right] + \alpha_2 \left[ \left( \frac{EO_{i,t}^l}{EOA_{i,t}^l} \right) - 1 \right] \quad (4-10)$$

$LF_t^l$  = The labor force.

$LFA_t^l$  = A geometrically declining weighted average of the labor force.

$\alpha_1$  = Estimated parameter using pooled time series data.

$\alpha_2$  = Estimated parameter using pooled time series data.

The above equations show that the compensation rate depends on the supply and demand of labor in the region. To simplify, the number of jobs and the number of people in the labor force combine to help determine the compensation rate.

To summarize, taken together, the Rosen-Roback and Platinga et al. frameworks imply

- On the first order, migration in a region is positively associated with wages and negatively associated with housing price.
  - Equation 3-5 shows that in the REMI model migration is positively associated with the real compensation rate which means it is positively associated with compensation and negatively associated with the price level.
  - Equations 4-7 and 4-8 show that the price level used by migrants is positively associated with the housing price.
  - Taken together, the REMI model framework is consistent with Platinga et al. framework where migration in a region is positively associated with wages and negatively associated with housing price.
- On the second order, an increase (decrease) in amenity will normally increase (decrease) housing prices and decrease (increase) wages.
  - Equation 3-5 shows that economic migration is positively associated with amenity. Increasing economic migration then increases population and labor force.
  - Equation 4-8 shows housing price is positively associated with population.
  - Equations 4-9 and 4-10 show that the compensation rate is negatively associated with the labor force.
  - Taken together, the REMI model framework is consistent with the Rosen-Roback framework where a change in amenity will normally increase housing prices and reduce wages.
- On the third order, an increase (decrease) in housing price and a decrease (increase) in wages will decrease (increase) further economic migration.
  - This interaction occurs as a result of the linkages described in the above two bullets.

**Attachment C**  
**(Abt's Follow-up Clarifications of its Concerns)**

Clarification of Abt Comments on REMI's Migration Modeling  
Abt Associates  
December 11, 2014

Based on all the materials the SCAQMD and REMI provided (e.g., "amenity.xlsx", "2012 AQMP Health.xlsx", "Description of REMI Models Amenity and Migration Framework.docx", "monetize amenity.pdf"), here is our understanding of what REMI does: it adapts the intercept in the net migration –using an estimate of the economic value for air quality improvements (that user transforms into a formulation consistent with the analytical logic developed in the "monetize amenity.pdf") and the coefficient on real wages ( $\beta_2$  in Equation 3.5 in the "Description of REMI Models Amenity and Migration Framework.docx"). This process is explained as converting them to equivalent adjustments in the intercept which is interpreted as the relative attractiveness index for each area; the "amenity.xlsx" provides an example of the front end calculations but not what REMI does. We relied on an early paper by George Trez and co-authors and REMI's notes for the discussion of what REMI does with the adapted migration equation. The following comments are based on our understanding described above.

Our basic point is that the theoretic logic REMI uses attempts to join two modeling frameworks. The first is their econometric model based on the Trez and others logic that has a "rough" correspondence to structural equations along with some equations that are best viewed as reduced form relationships describing adjustment. The second is the Rosen Roback logic derived from an equilibrium structural model that treats hedonic housing price and hedonic wage equations as equilibrium relationship. Given their assumptions these equations can be related under specific conditions to measures of the marginal willingness to pay for changes in site specific amenities. More specifically this logic implies that improving desirable amenities in equilibrium reduces wages (compensation needs to be less to live in the place) and raises housing prices (locations with better amenities are more desirable places to live and this is capitalized in housing prices). The marginal WTP in the Rosen Roback framework reflects the net effect at the margin of the wage and housing price effects. These are assumed to be determined as part of in and out migration across metropolitan areas in response to any exogenous change in site specific amenities. The two models are distinctive. Putting them together is not simply a matter of making an adjustment to the intercept in migration equation. It cannot be treated as an exogenous input to model. The economic values contributing to WTP are determined in part by adjustment to the air quality change. The logic that BenMAP uses to measure the benefits of air quality improvement stems the health effects associated with air pollution. For the most part benefit measures are transferred into the computations with the VSL the most important factor in most applications. It relies on changes being a small part of the economy so adjustment in employment or other resource allocations can be assumed small enough to ignore. Otherwise some of the benefit measures would themselves change. When REMI switches to a quasi-Rosen Roback logic is assuming that there is equilibrium adjustment. This would imply that more than the intercept would change in the model. Thus, the issue is not simply the estimation of the migration equation; but the issue is that wages and housing costs are jointly determined in response to an exogenous change in the amenities in any one or more of the all regions. This is the logic of the Rosen Roback model. From another perspective

REMI envisions an adjustment but represents it differently and this ad hoc adjustment to the intercept does not reconcile things. It may well be quite seriously flawed –but this would take added research to determine.

There are two issues:

1. Adaptation to migration is inconsistent with theory –we don't know if it is an adequate approximation for small changes
2. Key point –we believe it does GROSSLY mis-estimate the employment effects

Even with all the materials provided to us, we are not 100% sure what exactly REMI does because many calculations/components are black box. But to get the logic correct, the only way REMI can consistently estimate effects of air quality changes is to have site specific difference in air quality (and other site specific amenities) given specific roles in the model; ad hoc adjustments to intercepts using other parameters and monetized benefits from air quality improvements –treats the adjustment in wages and housing costs as conditional to the air quality benefits –when the benefits are jointly determined with those wages and housing costs because the tradeoffs emerge from the equilibrium. As a result the employment effects emerge in REMI due to what we believe is the logic in the model should be questioned. Basically the migration increases labor force (due to exogenous amenity improvement) –that the increase in labor force in turn reduces wages and these lower wages increase demand for labor. It would seem based on what was explained to us as the REMI logic that this is what the model implies as it describes labor market equilibrium.



**Attachment D**  
**(REMI's Second-Round Response to Abt's Concerns**  
**As Communicated to the SCAQMD Staff)**

REMI staff believed that both REMI and Abt have agreed that there are two aspects of the SCAQMD approach: first, the calculation of the willingness to pay (compensating differential) in the migration equation; second, the use of air quality benefits from BenMAP to measure the willingness to pay/compensating differential.

First, REMI staff explained that the REMI calculation of the compensating differential is based on the methodology in the seminal *American Economic Review* publication by Michael J. Greenwood, Gary L. Hunt, Dan S. Rickman and George I. Treyz (Greenwood et al., "Migration, Regional Equilibrium, and the Estimation of Compensating Differentials," *The American Economic Review*, Vol. 81, No. 5, 1991, pp. 1382-1390). This publication in the leading economic journal is regarded as seminal contribution and is the most widely cited paper on compensating differential estimations (cited in 281 subsequent academic articles).<sup>2</sup> In the article, the authors note the widespread literature on regional "compensating differentials" (Roback, 1982, 88; Hoehn et al., 1987; Blomquist et al., 1988). Compensating differentials measure the willingness to pay for quality-of-life differentials across regions. The willingness to pay for regional amenities is measured by differences in wages and housing costs, and can be measured in real wage differentials (combining nominal wages and housing costs). In the *American Economic Review* paper, the authors extend the literature with an improved methodology to account for both equilibrium and disequilibrium aspects, using panel data and instrumental-variables fixed effects estimates. Therefore, REMI staff believed that the methodology regarding the migration equation to capture willingness-to-pay is well-established: Abt raised concerns on the correspondence of the migration equation to the structural equations in the REMI model; however, the literature shows that the connection is clear. Otherwise, REMI staff understood that Abt agreed with the *American Economic Review*/REMI calculation of the compensating differential.

Second, Abt addressed the use of air quality benefits from BenMAP to measure willing-to-pay for benefits of health care improvements. REMI staff's understanding was that Abt agreed with the validity of these BenMAP estimates. Then, Abt discussed the use of BenMAP willingness-to-pay in the REMI compensating differential equation. REMI staff understood that the use of the term "willingness-to-pay" in BenMAP is equivalent to the REMI term "compensating differential." Both measure the dollar value of quality-of-life differentials. The use of BenMAP dollar values in REMI allows the calculation of macroeconomic effects of air quality improvement. As Abt noted, "REMI... is assuming that there is an equilibrium adjustment. This would imply that more than the intercept would change in the model." REMI agreed: In a model simulation, the REMI model calculates a new equilibrium, with adjustments in housing prices, employment, output, and literally thousands of variables. This is typical of a computerized macroeconomic equilibrium model such as REMI.

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<sup>2</sup> The findings in this article were used to evaluate the 1991 AQMP, which was published in a peer-reviewed journal (Lieu, S, and Treyz, G.I., "Estimating the Economic and Demographic Effects of an Air Quality Management Plan: The Case of Southern California," *Environment and Planning*, Vol 24, 1992, pp. 1799-1811).

REMI staff also agreed with Abt that “the issue is not simply the estimation of the migration equation; but the issue is that wages and housing costs are jointly determined in response to an exogenous change in the amenities in any one or more of the all regions.” BenMAP calculates the willingness to pay, which is entered in the REMI model as the “compensating differential” policy variable. Then, the analyst runs the REMI model to generate a macroeconomic analysis, in which wages, housing costs and other variables are calculated as a result of the change in the compensating differential. The procedure for running a macroeconomic model is standard for all computerized economic models such as REMI. The user changes a policy variable(s), and then runs the model to generate a new equilibrium result. In structural models, such as REMI, the impacts of a small change can be calculated.

In response to the two issues noted in Abt’s “Clarification of Abt Comments on REMI’s Migration Modeling,”

“1. Adaptation to migration is inconsistent with theory –we don’t know if it is an adequate approximation for small changes”

REMI staff would refer to the literature regarding the theory of compensating differentials (see above). Regarding small changes: in a structural model, a policy variable can be small or large. Whether small or large, the model can still calculate the economic result.

“2. Key point –we believe it does GROSSLY mis-estimate the employment effects”

REMI staff believed that they have provided sufficient clarifications to address Abt’s concerns about the logic of incorporating non-market amenity benefits into the REMI model. Any remaining concerns expressed by Abt were due to Abt reviewers’ misunderstanding, or incomplete understanding, of the basic operation of a computerized macroeconomic model, such as REMI.

## RESPONSE TO REVIEW PREPARED BY REMI

The reviewer and Abt express concern with how REMI incorporates amenity, the attractiveness of a region, into the model where it affects migration directly rather than affecting housing price and wage rate initially. They are also concerned with REMI's use of BenMAP estimates in the migration equation instead of having a specific variable for quality of life (QOL) aspects, such as air quality. Because BenMAP estimates provide an accurate measure of the amenity for a given region, and the Rosen-Roback and Platinga et al. method of amenity having a direct effect on migration first is widely cited, the reviewer's concerns of the REMI model may be misstated.

Abt is concerned that REMI changes wage rate and housing price indirectly, and therefore underestimates them, since the amenity for a region affects migration first in the REMI model instead of first affecting wage rate and housing price (see equation (3-5) from Attachment II).

REMI's equation for economic migration is as follows (see Attachment II for more details):

$$ECMIG_t^l = [\lambda^l + \beta_1 \ln(REO_t^l) + \beta_2 \ln(RWR_t^l) + \beta_1 \ln(MIGPROD_t^l)] * LF_{t-1}^l \quad (3-5)$$

The reviewer states that the REMI model only estimates the "secondary effects of net migration on home prices and wages", and that "New perceptions of wage rate and house price offers, instead, should be what entices potential migrants to a region". REMI agrees that wage rate and housing price are determinants of migrants to a region because the new perception of higher wage rate and lower housing price draws migrants into a region. Specifically, when amenity increases, it makes a region more attractive, so for a given housing price and wage rate, people perceive more value in a house in the region and more compensation for a job in the region. The Rosen-Roback and Platinga et al. frameworks imply that migration in a region is positively associated with wages and negatively associated with housing price, suggesting that people are drawn into a region with higher wages and a lower housing price. They also imply that an increase in amenity will increase housing prices and decrease wages, but it is the migration (not the amenity itself) into the region that causes the labor and housing markets to tighten, causing wage rate to decrease and housing price to increase.

Although these frameworks state that increasing amenity in a region will increase housing prices and lower wages, it does not imply that amenity will directly increase wages; amenity must increase wages through migration. The reviewer tends to assume that migration is only indirectly affected by amenity. The reason why amenity causes an increase in housing price and a decrease in wage rate is because of a change in migration, not from amenity itself. The population in a particular area must change in order to tighten or loosen housing and labor markets, leading to a higher or lower housing price and wage rate. Saying that amenity should affect housing price and wage rate directly is equivalent to claiming that housing price changes instantaneously as QOL components change, before such components affect migration factors, such as the number of people bidding for houses in a given region.

The reviewer also brings up the point that homeowners will get value added to their homes with the amenity increase, but notes that this will not be realized until homeowners sell their houses. REMI agrees; the whole Rosen-Roback framework assumes that the increase in amenity will not be realized until houses are sold because migration must occur (and therefore

the buying and selling of houses) before the amenity increase ultimately has an effect on housing price and wage rate.

The reviewer suggests that amenity affects housing price directly rather than as an indirect effect through migration, which assumes that amenity can increase housing price without a change in population. Although we are not aware of literature that supports such a scenario, our model has the capability of simulating a change in amenity if the assumption is that it affects housing price directly in addition to through migration. The policy variable “Housing and Land Prices (share)” can be used to adjust perceived changes to housing price.

Abt expresses concern for REMI not having transparency with modeling inputs, but the modeling process regarding amenity is quite straightforward: amenity directly affects  $\lambda$ , which changes migration, and migration in turn lowers wages and increases housing prices. The concerns from Abt and the reviewer appear to be speculative. Abt claims, “It is difficult to conjecture about the effects of our proposed change... at this stage this comment should be considered an informed ‘guess’”, suggesting that their concern with REMI is only speculative and not based on empirical data. In addition, Abt states, “We believe the magnitude of these adjustments must be properly normalized to reflect the baseline levels of all amenities and dis-amenities... This modification would not require a change in REMI’s structure but would require detailed analysis of the input information developed for REMI”.

The mechanism by which amenity affects migration and then wage rate and housing price is widely cited: the *American Economic Review* publication demonstrates that the migration equation is an accurate method of calculating amenity via compensating differential. BenMAP estimates, used for the compensating differential, account for the direct effect of amenity on a region using the migration equation, and are represented in the migration equation as change in perception via the fixed effect  $\lambda$ . For example, if  $\lambda$  is 0.9, perceived wage rates relative to the U.S. are 90% of the U.S. wage; if  $\lambda$  is 1.10, perceived wage rates are 10% higher than the regional real wage relative to the U.S. real wage. As a result, workers perceive equivalent real wages to be higher in high-amenity locations. A new perception of wage rate and housing price offers is what entices potential migrants to a region. As new migrants enter a region, housing demand and labor supply increase, leading to reduced wage rate and higher housing price.

If additional variables were added to account for air QOL measures, such as a location-specific fixed-effects coefficients of the migration equation, as Abt suggests, it would be double counting. The BenMAP estimates already account for the additional willingness to pay amount associates with an amenity increase, and is measured in real wage differentials, calculated by combining nominal wages and housing costs. BenMAP estimates are supported by literature as an accepted method of incorporating amenity into the migration equation, so for a given amenity level, the migration equation can estimate wage rate and housing price accurately; therefore, the elasticity of pollution rises on wage rate and housing price is not needed for the analysis, as the reviewer suggests. Abt claims that BenMAP estimates are not sufficient for large amenity changes, as an equilibrium adjustment would be required; however, this appears to be a misinterpretation of the model functionality, because REMI calculates a new equilibrium, in addition to adjustments in many other variables, when amenity changes in the model. Abt states, “It may well be quite seriously flawed—but this would take added research to determine... we believe it does grossly mis-estimate the employment effects”. Abt argues that REMI does not calculate the economic impact of amenity changes correctly, but does not provide supporting data or an empirical estimate that would show to what extent the results are inaccurate.

The reviewer claims that the REMI model only estimates secondary effects of migration on housing price and wages, stating “the extent of the impact of this missing initial price effect is unclear”. Abt and the reviewer suggest that impacts of amenity on the economy are lower when amenity affects migration first than housing price and wage rate directly, yet provide no evidence to show what the difference might be. We have not found any literature that suggests that amenity affects housing price and wages directly. If such literature were available, then the economic impact could be compared of amenity affecting housing price and wage rate directly versus amenity affecting migration directly. It is clear, however, how amenity affects migration directly and then housing price and wages, through the Rosen-Roback and Platinga et al. frameworks.

The reviewer states that from entering \$500 million each year in the model, the average personal income per worker is \$92,170 in 2014 and \$1.19 million in 2060, and GDP per worker is half of that. However, after entering in the same values in LA County from 2014 to 2060, a much different picture is seen: average compensation is only \$48,370 in 2014 and goes to \$96,347 in 2060 (see Figure 1 below).

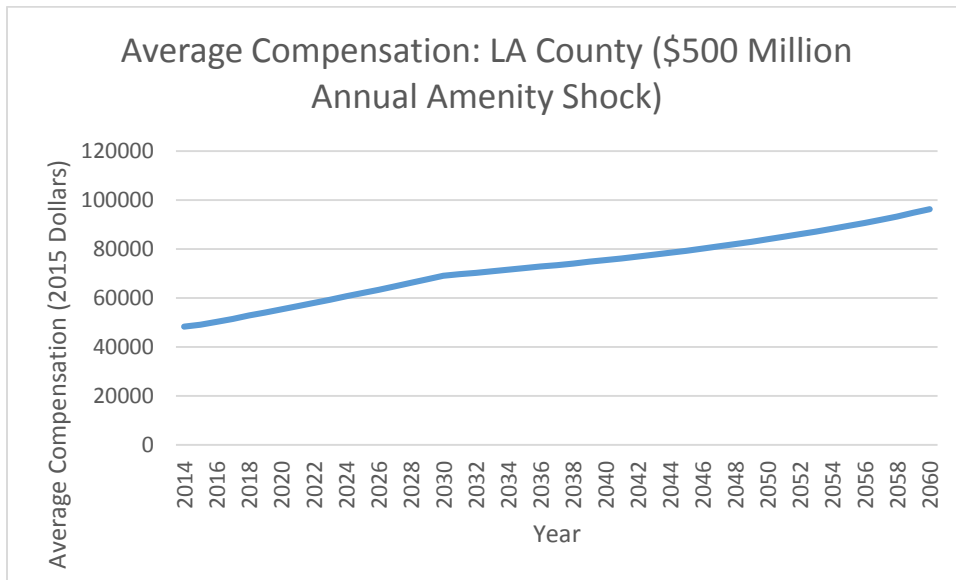


Figure 1: Average compensation in LA County with a \$500 million annual amenity increase

This represents just a 0.008% increase in compensation in 2014. Furthermore, GDP is not half, but more than twice average compensation. Additionally, the same calculations were done in the demo model, but the consultant’s results were unable to be replicated. From the simulation, the highest average compensation values were seen in the “Urban Counties” region, at \$51,334 in 2014 and \$238,631 in 2060 (see Figure 2 below). Figures 3 and 4 show average compensation for the “Suburban Counties” and “Rural Counties” regions, respectively.

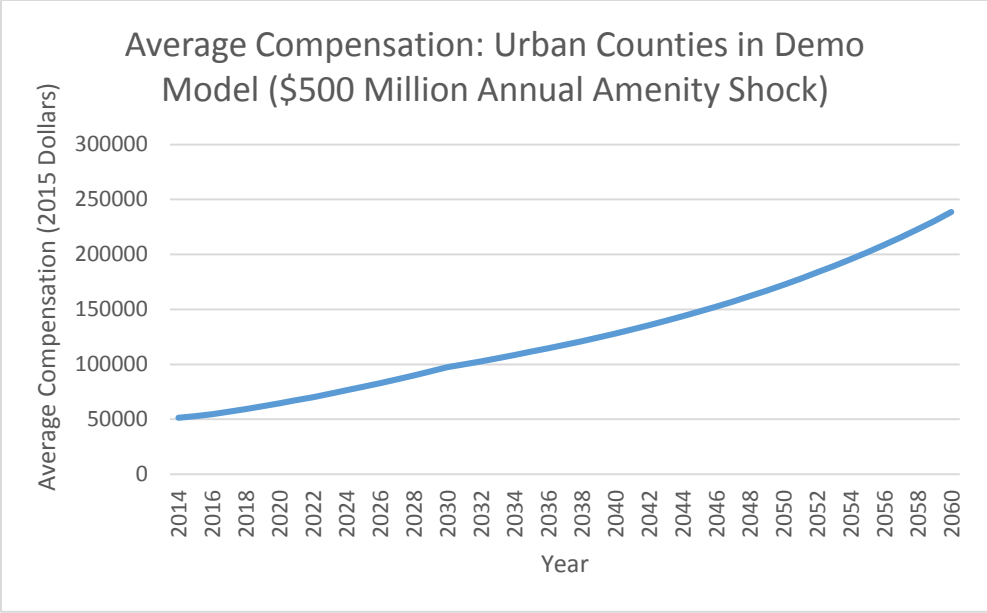


Figure 2: Average compensation in the Urban County with a \$500 million annual amenity increase

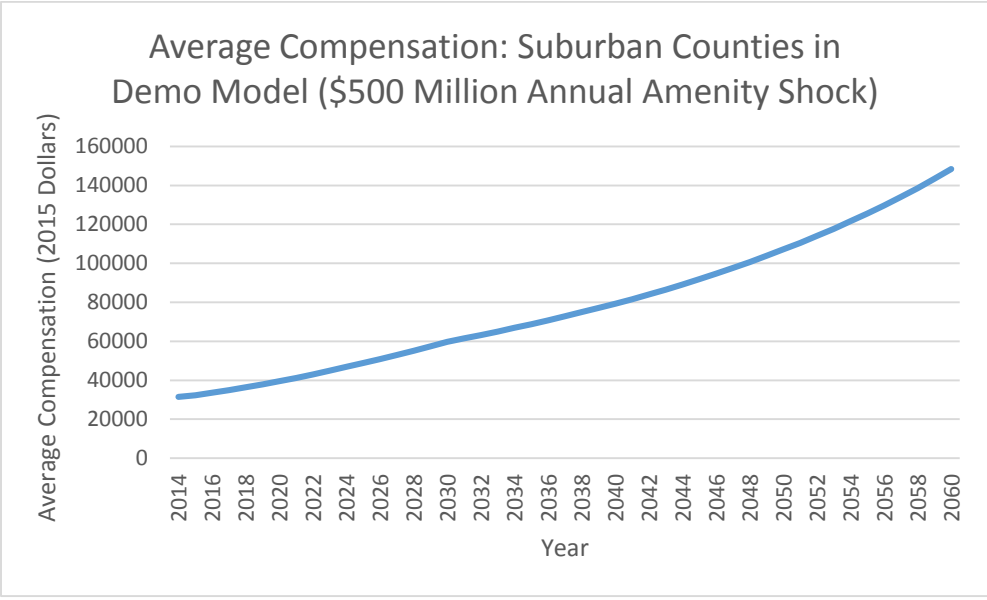


Figure 3: Average compensation in the Suburban County with a \$500 million annual amenity increase

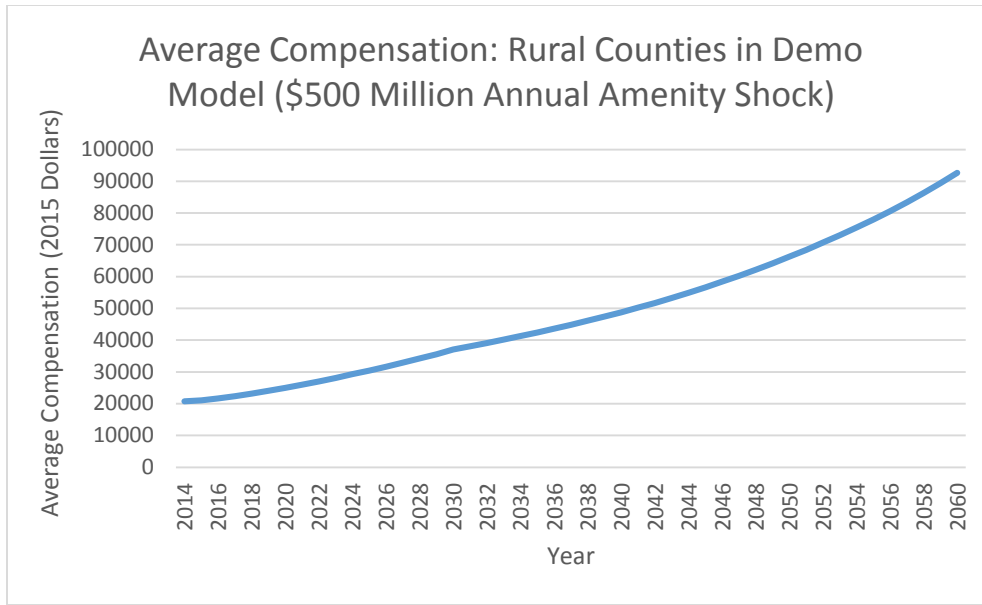


Figure 4: Average compensation in the Rural County with a \$500 million annual amenity increase

Perhaps the reviewer divided the differences in compensation by the differences in employment, and therefore produced unrealistic values. The percent change in average compensation from the baseline to adjust forecast with the amenity change is negative, so the average compensation should be even lower the baseline; wage rate decreasing is characteristic of an increase in amenity (see Figure 5 below).

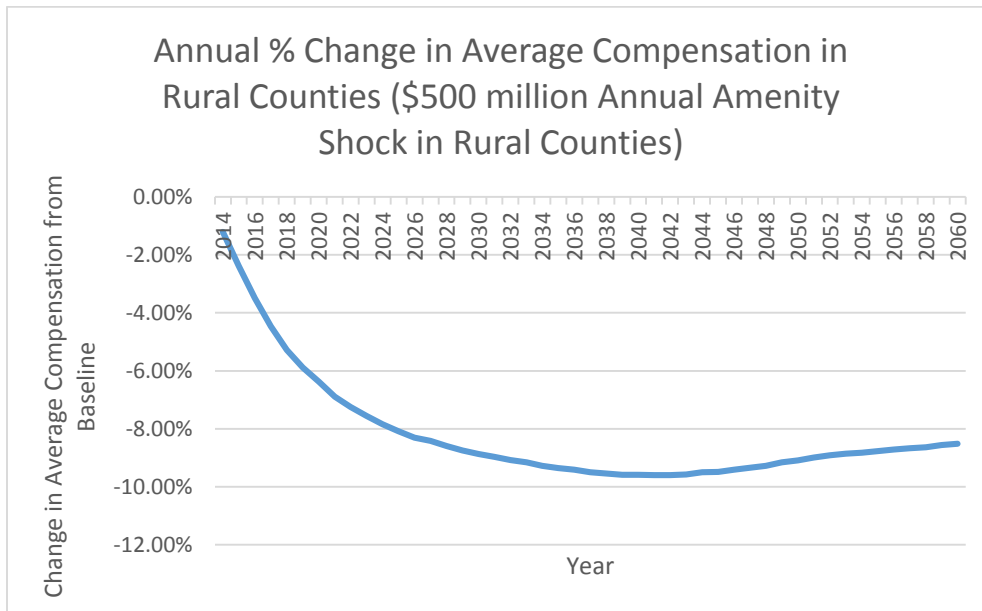


Figure 5: The annual percentage change in average compensation in relation to the baseline average compensation forecast

Although employment and compensation both increase, average compensation decreases when compared to the baseline because of the increasing size of the labor market. It is important to note, however, that such a large change in average compensation is expected after making such a large amenity change in a region with such a small GDP. It is important to factor GDP size into the analysis when using amenity or any policy variable. Perhaps if the reviewer entered an

amenity as a small percentage change, reasonable results would be calculated. The reviewer did not specify which region in the demo model he applied the amenity shock, but the regions in the demo model are much smaller than the LA County region. The GDP of LA County was \$542 billion in 2014, whereas the largest GDP in the demo region (the urban county) was only \$101 billion in 2014. The other two counties had GDP of \$45 billion and \$1.7 billion. As shown in Figure 5, the change in average compensation from the baseline is dramatic when a relatively large amenity change is applied to a relatively small area: \$500 million annually in a region with a GDP of \$1.7 billion. It is therefore not surprising how the reviewer found unusual results in the simulation. If the reviewer did the same analysis but in LA County instead, which is significantly larger than Urban County in the demo model (see Figure 6 below for a comparison), he would notice a normal set of results, as demonstrated in the LA County simulation (as shown in Figure 1).

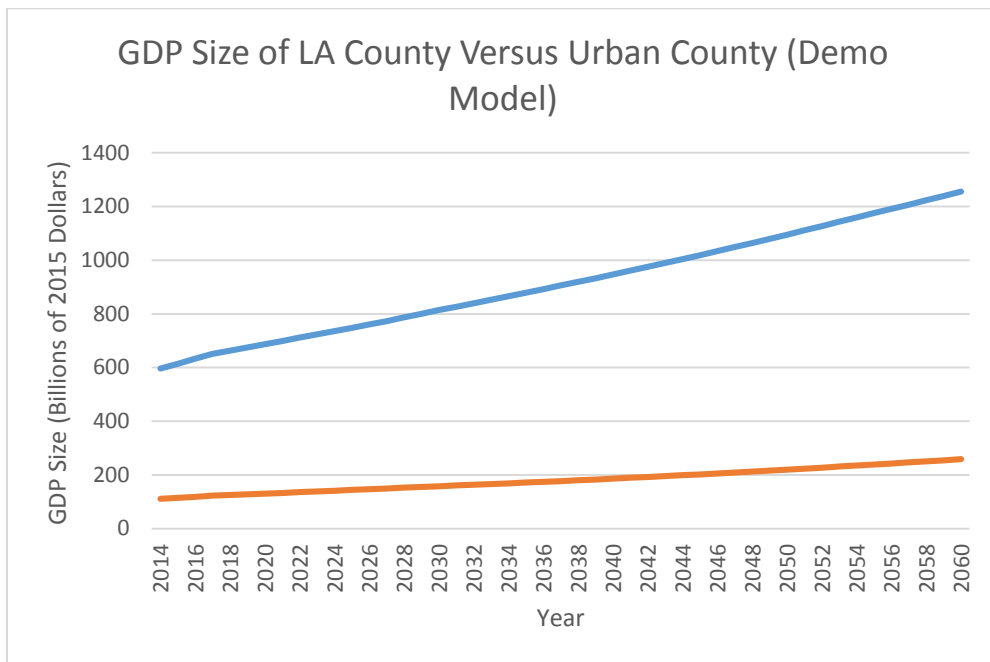


Figure 6: GDP Comparison of LA County versus Urban County

*This response was written by Billy Leung and Jeffrey Dykes of REMI, and edited by Brian Boyd.*