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Conventional versus Innovative Technologies in the Transportation Sector: External Costs and Benefits

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Framing the Issue

- According to the IEA, global crude oil consumption increased at an annual average rate of 1.3% from 1971-2000, with oil consumption in developing countries increasing at an average annual rate of 4.6%.
- Growth in developing Asian countries has been exceedingly high.
  - For example: China (6.0%), India (5.5%), Indonesia (6.6%), South Korea (8.2%)
- The IEA projects global crude oil demand growth to reach 1.7% per annum between now and 2030. This growth is expected to be highest in developing countries (at 2.8% per annum).
- Largest projected source of growth in crude oil demand… transportation.
  - Global: 2.1% per annum to 2030
  - Developing countries: 3.6% per annum to 2030

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Framing the Issue (continued)

- 1 million tons of crude oil consumption in the transportation sector results in roughly 2.75 metric tons of CO_2 emissions.
- In 2000, global crude oil consumption in the transportation sector accounted for 4,666 million tons of CO_2. This is approximately 51% of global emissions from crude oil consumption, and 20% of **total** global CO_2 emissions from fossil fuel consumption.

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The *derived* demand for motor fuel

- Motor fuel is demanded to facilitate transportation services. As such, the decision to consume motor fuel is the result of a simultaneous set of decisions about
  - Motor vehicle ownership
  - Motor vehicle utilization
  - Motor vehicle fuel efficiency

- We can relate these variables to the demand for motor fuel by the following identity

$$\text{gallons} \equiv \frac{(\text{miles per vehicle})}{(\text{miles per gallon})} \cdot \text{vehicles}$$

- … or more compactly

$$e \equiv \frac{d}{\varepsilon} \cdot v$$

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The *derived* demand for motor fuel (continued)

- Medlock and Soligo (2002) develop a model that shows the demand for motor vehicle stocks can be written as

$$v^* = v(\mu_v, W)$$

  - where W = consumer wealth and μ_v = the user cost of motor vehicles

$$\mu_v = p_e \frac{d^*}{\varepsilon} + p_a - p_{a,+1} \frac{(1-\delta)}{(1+r)}$$

- ...and the demand for motor vehicle services can be written as

$$d^* = d(\mu_v, W)$$

- By substitution into the above identity, we then have

$$e^* = e(\mu_v, \varepsilon, W)$$

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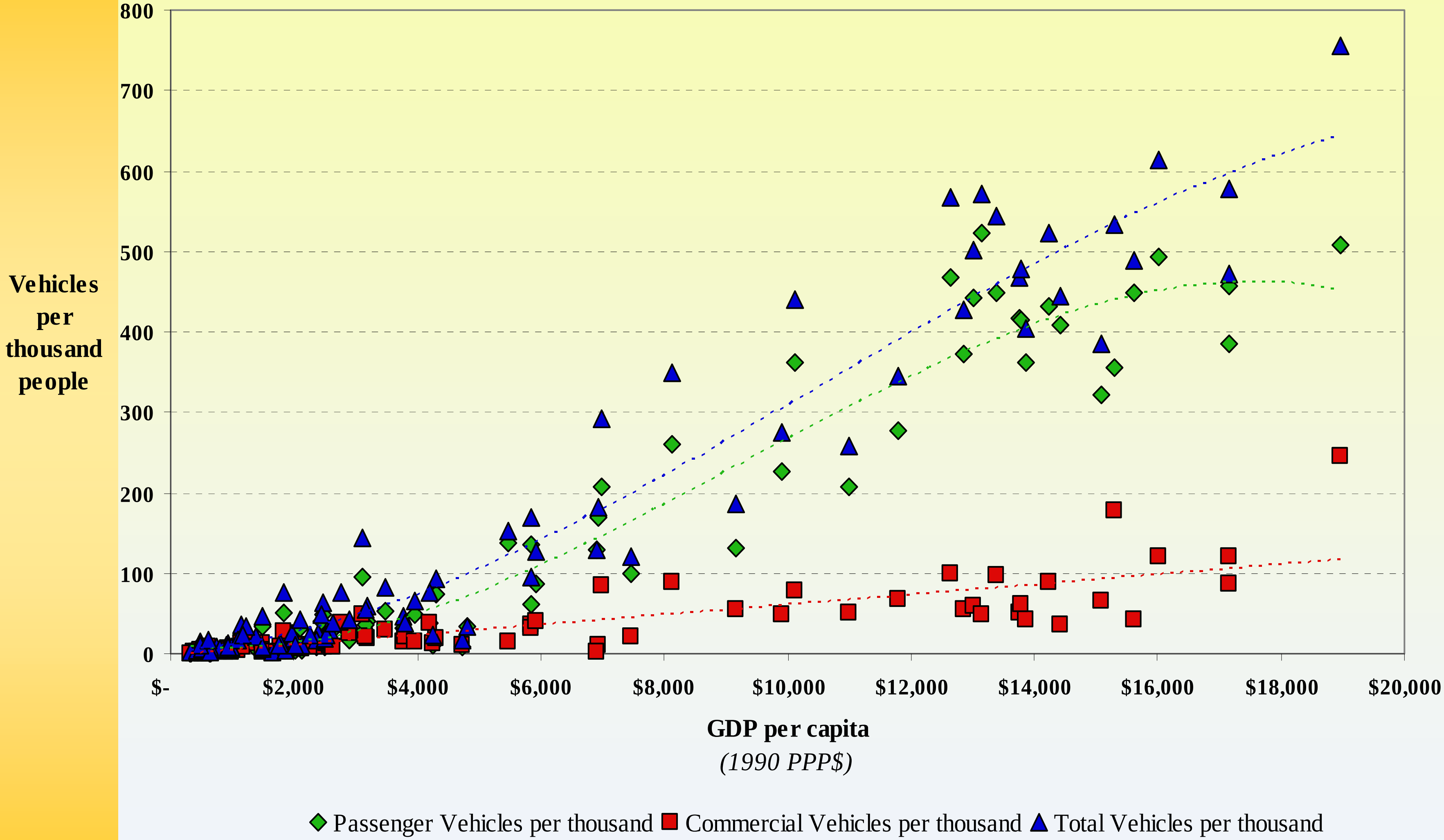
Motor Vehicle Stocks and Per Capita Income



- Motor vehicle ownership in 100 countries (1995).
- *Source: World Development Indicators; World Motor Vehicle Data Book*

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Motor Vehicle Stocks… an "average" country

- Medlock and Soligo (2002) estimated the demand for motor vehicles given a non-linear income-vehicle stock relationship, which captures the notion that vehicle stocks reach a point of saturation, such that growth matches population growth, i.e.-the marginal value (service) provided by an additional motor vehicle to each household diminishes as vehicle stocks rise.

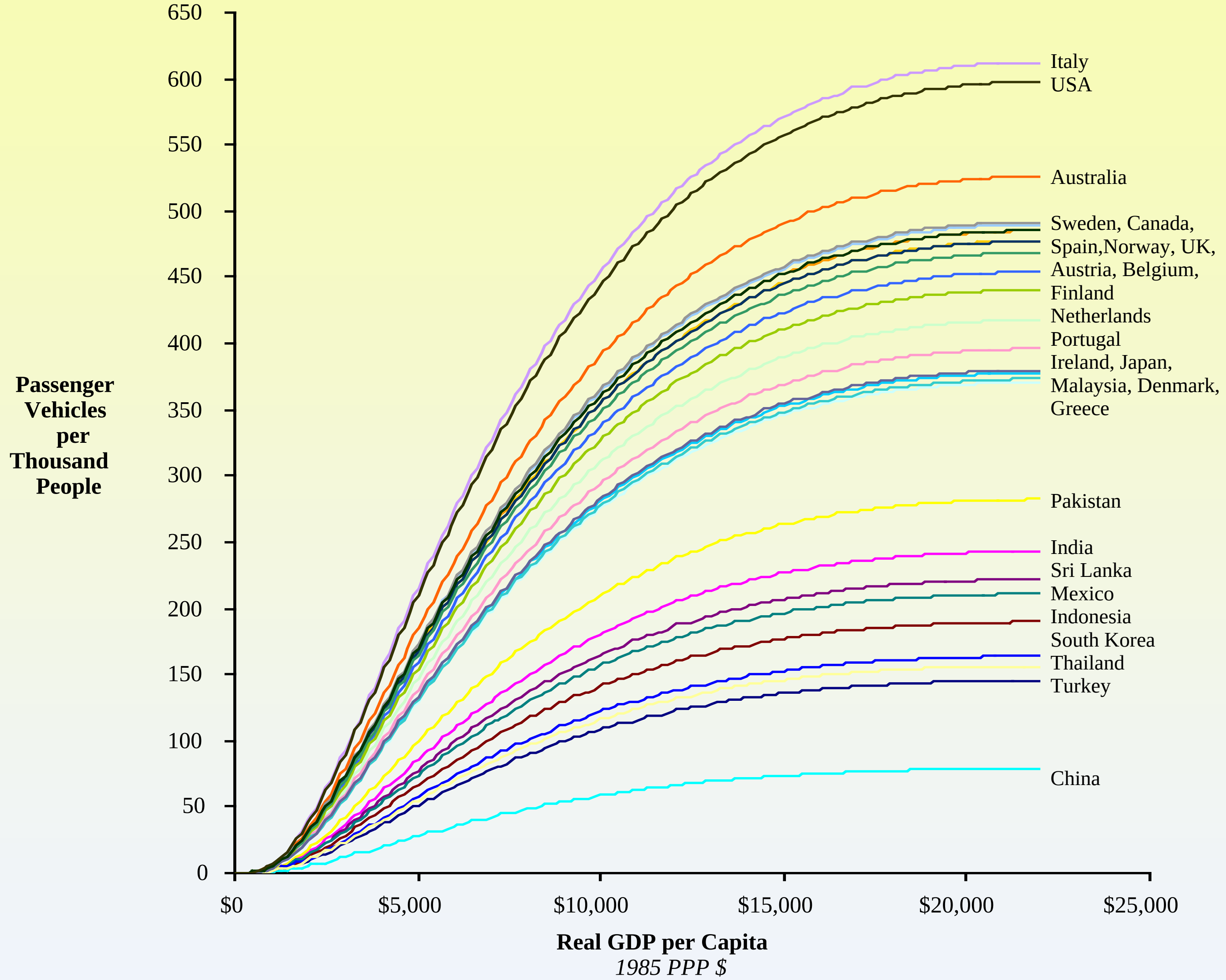
- The relation for *v*, for the Within-2SLS estimator, is specified as follows

$$\ln v_j = \beta_{0,j} + \beta_1 \ln p_j + \beta_2 \ln y_j + \beta_3 (\ln y_j)^2 + \beta_4 \ln v_{j,-1}$$

- Using the parameter estimates for $\beta_{1,} \beta_{2,} \beta_{3,} \beta_4$, we can simulate motor vehicle stocks for the "average" country by calculating the intercept term ($\beta_{0,i}$) in the above equation to match the "average" country.
  - Averages:
    - GDP per capita (2000 PPP $) - $19,686
    - Vehicle stock per thousand people – 398
    - Motor fuel price ($/gallon) – US$4.10 (or about US$1.08/liter)

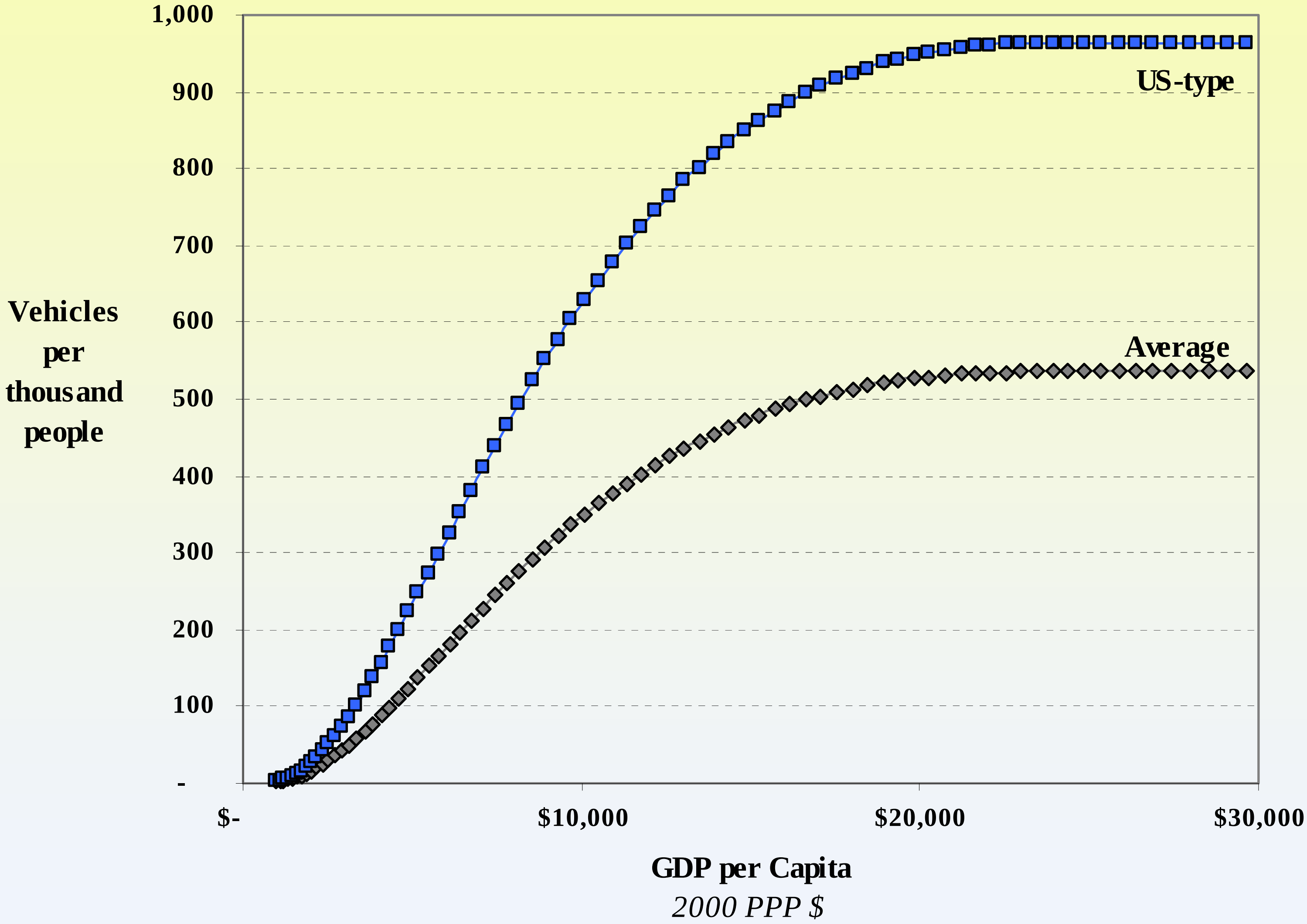
- Individual countries can be simulated directly by using the estimated country-specific effect ($\beta_{0,i}$) .

Motor Vehicle Stocks and Per Capita Income



- Simulated data for 28 countries assuming constant price and using the country-specific effect (see Medlock and Soligo (2002)).

Motor Vehicle Stocks Simulated…
An "average" country and a "US-type" country



Motor Vehicle Utilization

- According to Medlock and Soligo (2002), at the household level, motor vehicle utilization is a function of income and user cost

$$d = d\left(\mu_v, W\right)$$

- Johansson and Schipper (1997)
  - Panel data for 12 countries to estimate each component of the identity $Q \equiv S \cdot I \cdot D$ where Q=demand for car fuel per capita, S=car stock per capita, I=fuel intensity, and D=driving distance per car.
  - Use a recursive approach… estimate S and I separately, then D as a function of S, I and other variables.
  - Then, plug results into identity to get estimates of long run elasticity of motor fuel demand with respect to income, price and other variables.
  - The relation for D, for the Within-2SLS estimator is specified as follows

$$\ln D_i = \gamma_{0,i} + \gamma_1 \ln D_{i,-1} + \gamma_2 \ln P_i + \gamma_3 \ln Y_i + \gamma_4 \ln S_i$$

- Using the parameter estimates for $\gamma_1, \gamma_2, \gamma_3, \gamma_4$, we simulate motor vehicle utilization by calculating the intercept term ($\gamma_{0,i}$) to match 2000 published data for various countries. We also simulate the "average" country described above.

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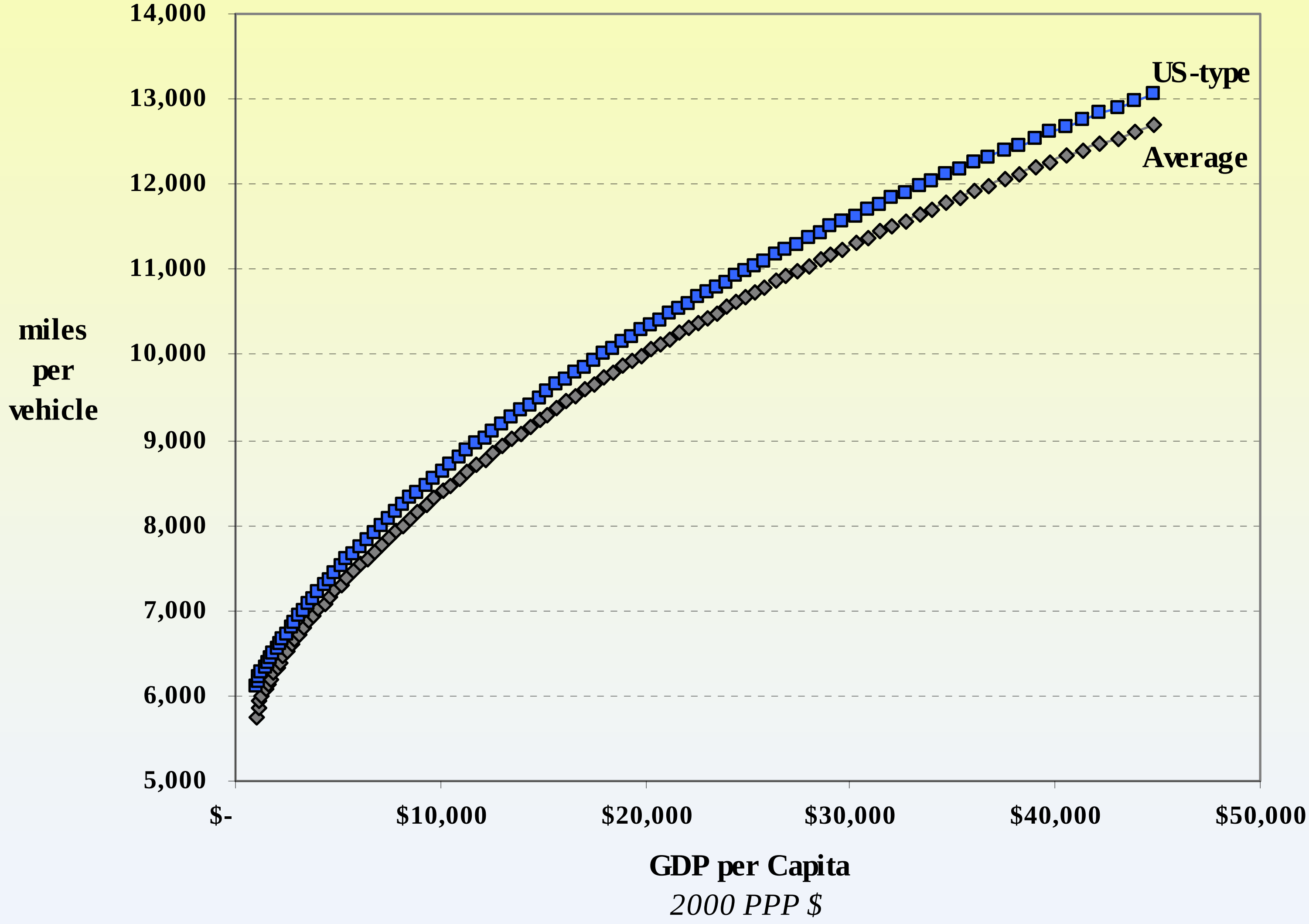
Motor Vehicle Utilization Simulated…
An "average" country and a "US-type" country



Motor Fuel Demand…putting it all together

- The demand for motor fuel is a *derived* demand.

- As noted before, we can identify the demand for motor fuel as

$$e \equiv \frac{d}{\varepsilon} \cdot v$$

- Thus, we can substitute the simulation results for motor vehicle stocks (*v*) and motor vehicle utilization (*d*), and assume some motor vehicle efficiency to obtain motor fuel consumption.

- Note, we can determine the growth rate of motor fuel demand as follows

$$\%\Delta e = \%\Delta d + \%\Delta v - \%\Delta \varepsilon$$

  - Thus, we would expect motor fuel demand to rise more rapidly in developing countries than in developed countries... growth in motor vehicle stocks is diminishing due to saturation effects, i.e.- $\%\Delta v \rightarrow 0$.

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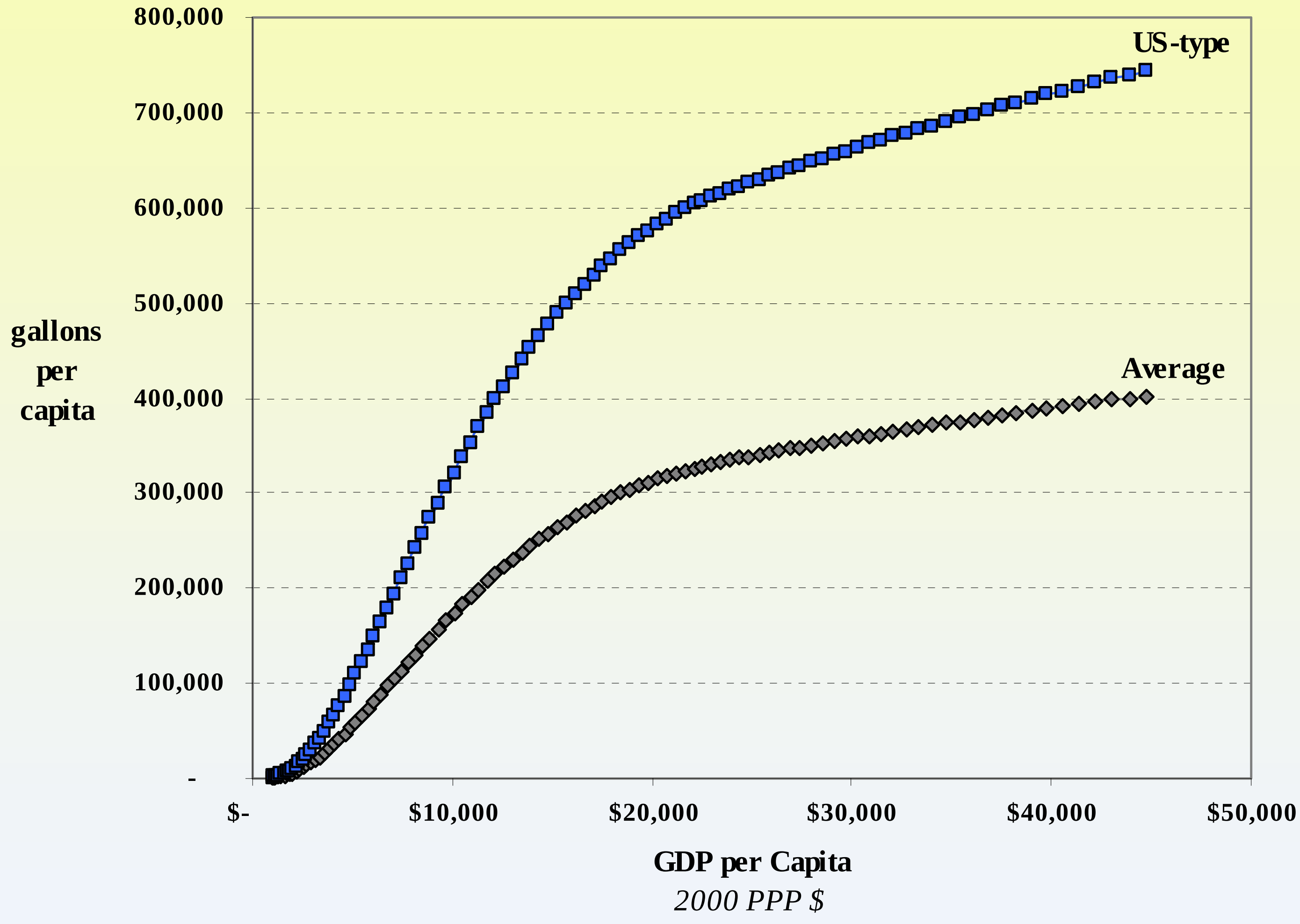
Motor Fuel Demand Simulated…
An "average" country and a "US-type" country



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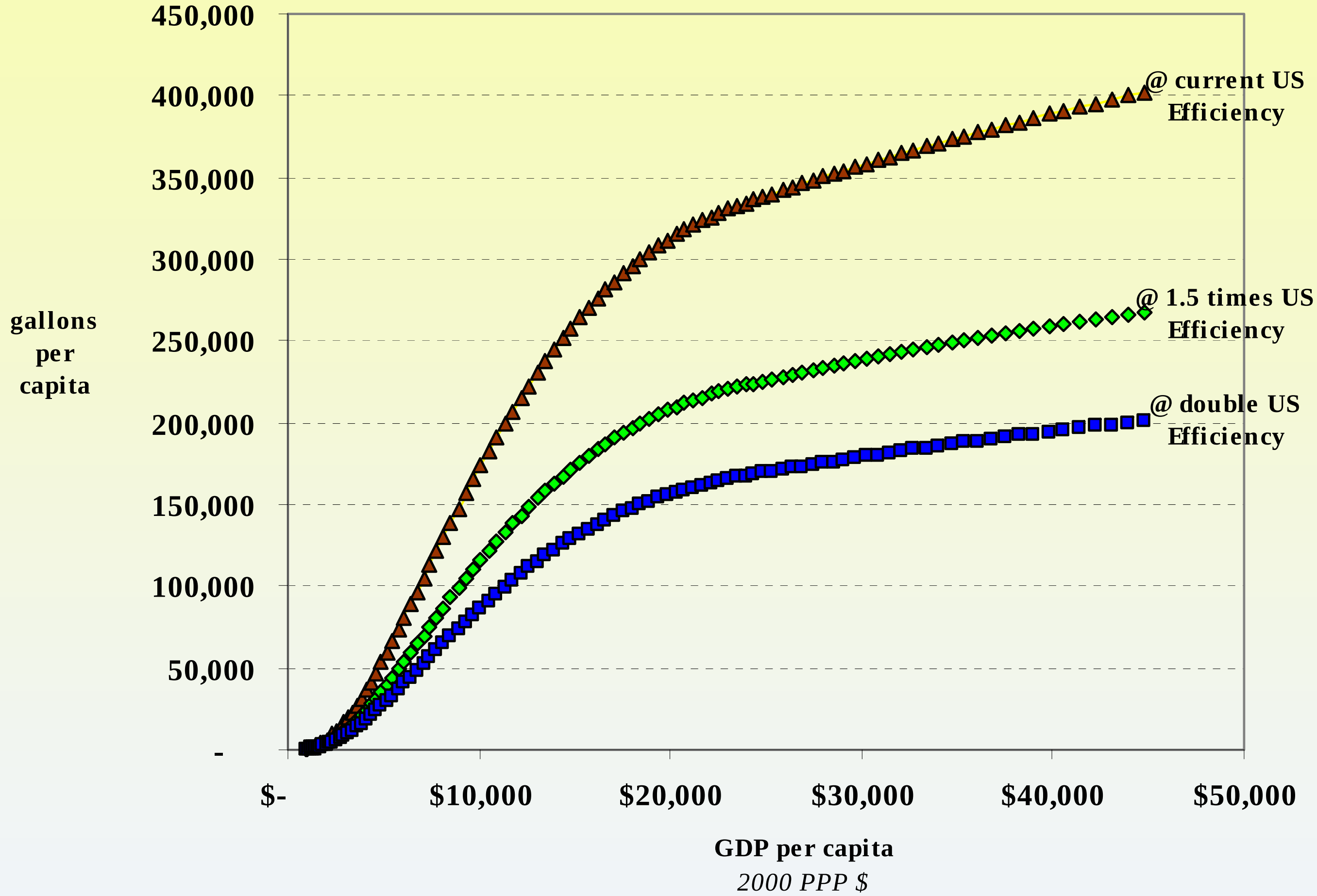
Motor Fuel Demand Simulated… an "average" country at different efficiencies



- Current US motor vehicle efficiency is reported by the US EIA to be 16.9 mpg. Thus, at 1.5 times current we have 25.4 mpg, and at 2 times current we have 33.8 mpg.

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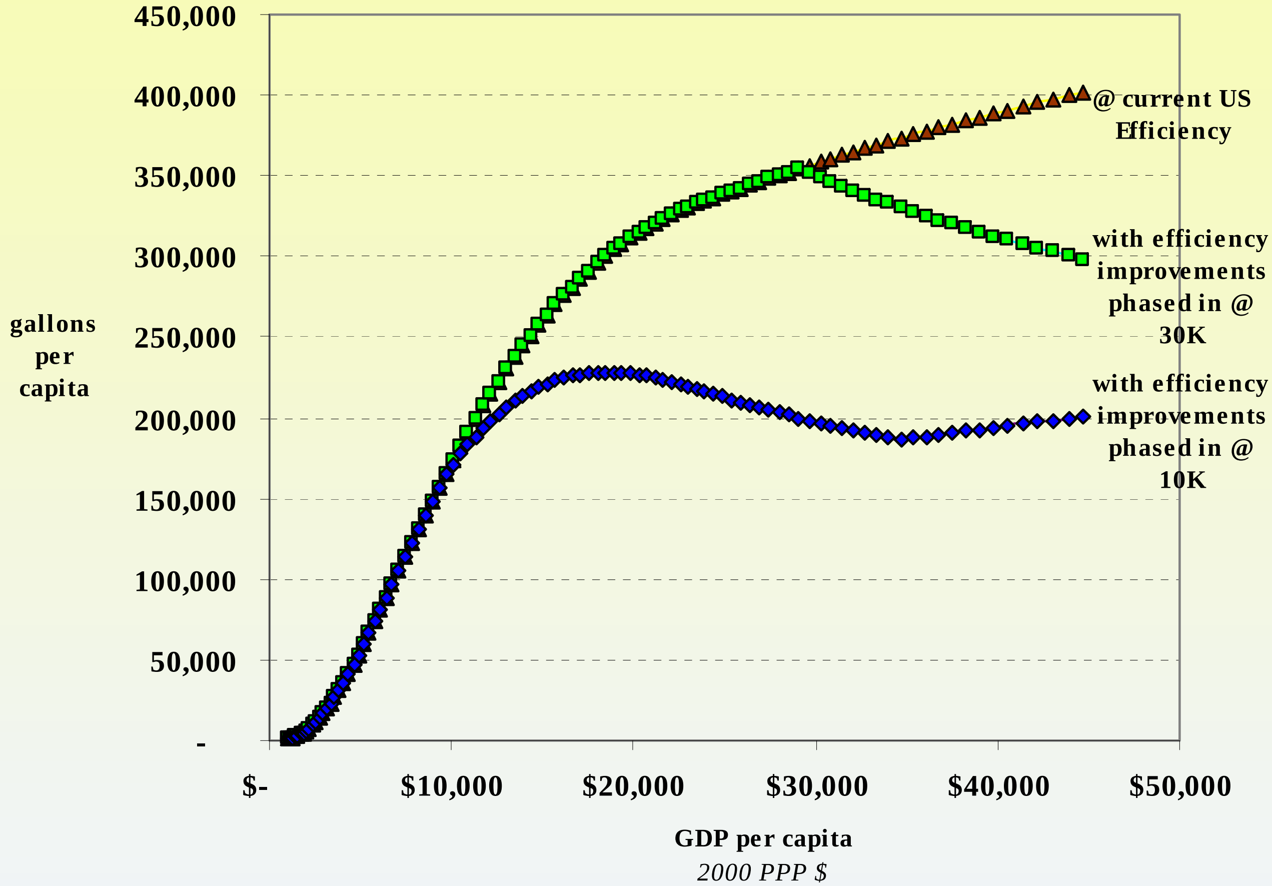
Motor Fuel Demand Simulated…
an "average" country with efficiency phased in



- Efficiency improvements are assumed to be phased in at different points of the development process to illustrate the potential impacts across a range of incomes.
- Assumptions:
  - Life of a vehicle = 7 years.
  - Percent of new vehicles sold with efficiency (x2) improvements = 10%.
  - Results in complete turnover in 50 years.

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An Important Caveat

- Care must be taken in reviewing the simulation results. Efficiency improvements will lower motor vehicle user cost. This will increase both motor vehicle stocks and motor vehicle utilization for a given level of income. This serves to offset, to some degree, the effect of the increase in efficiency on total motor fuel consumption.

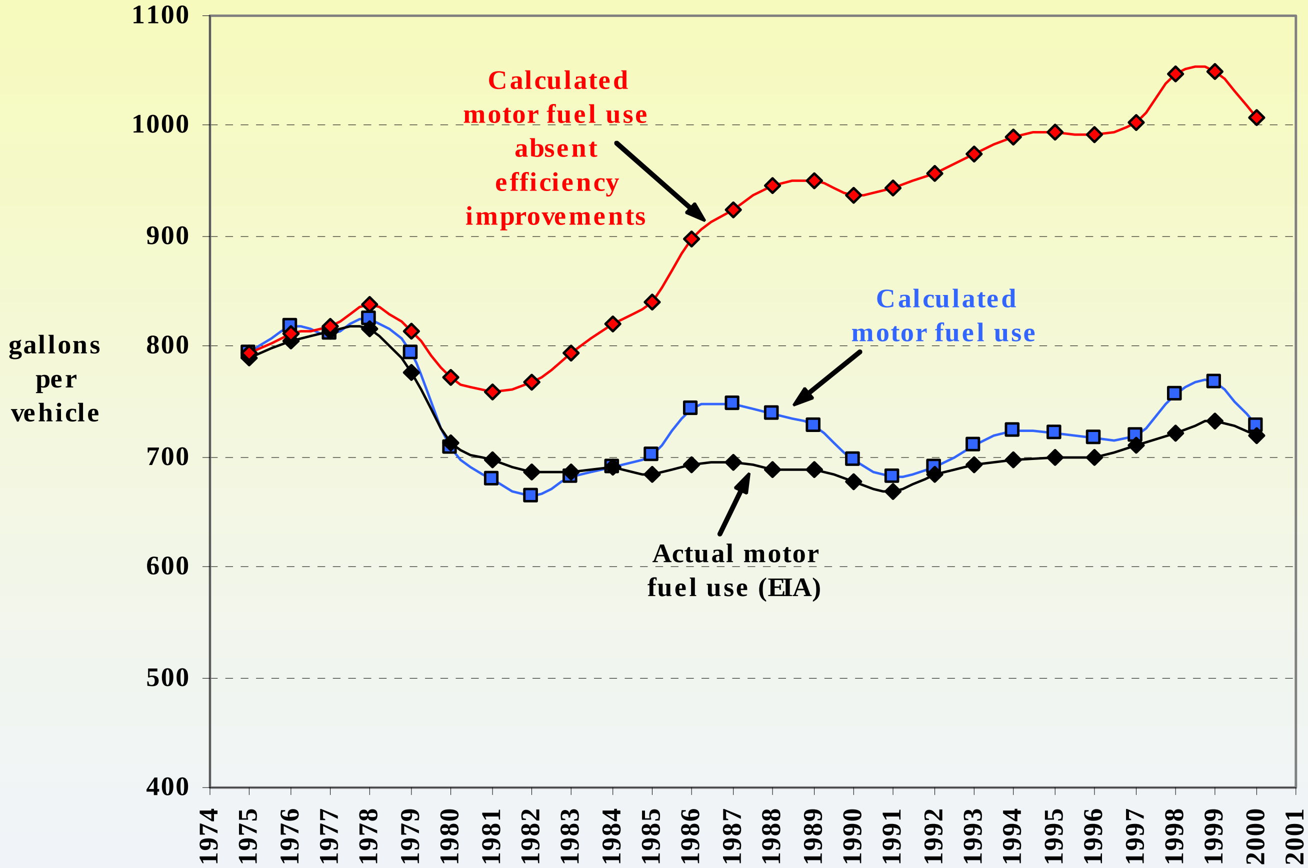
- Recall,

$$\mu_v = p_e \frac{d^*}{\varepsilon} + p_a - p_{a,+1} \frac{(1-\delta)}{(1+r)}$$

$$d^* = d(\mu_v, W)$$

$$v^* = v(\mu_v, W)$$

How important is efficiency improvement? Evidence: US Motor Fuel Consumption – History and What Could Have Been



- “Calculated” indicates the methods outlined above were used along with historical data to simulate the referenced curve.

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A Measurable Benefit

- Energy cost and energy security benefits:
  - Efficiency improvements in the US have resulted in a cumulative savings of almost 225 trillion barrels from 1975 to 2000, or about 2.46 million barrels per day per year. At a $20/barrel, this comes to $49.2 million per day, or $18 billion per year.
  - In 2000, the savings totaled about 4.3 million barrels per day, or about 40% of current consumption.

- Environmental benefits:
  - On average globally, 1 million tons of crude oil consumption in the transportation sector accounts for approximately 2.75 million tons of CO_2 emissions.
  - Applied to the energy savings estimated above for the US, this translates to a cumulative savings of about 10,444 million tons of CO_2, which is almost double the total CO_2 emissions in the US in 2000.
  - The savings for 2000 amounted to about 729 million tons of CO_2, or 13% of total emissions in the US in 2000.

Future Benefits

- ?????
- Research to come…
  - Simulate a range of countries across multiple stages of development.
  - Assess the environmental and energy savings of efficiency improvements in multiple countries given various rates of diffusion of technological improvements.
  - Account for any potential positive “feedback” to motor vehicle stocks and motor vehicle utilization resulting from efficiency improvements.