On Indirect Sampling and Small Area Estimation

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Outline

Problem

- Provide estimates for small domains when sample is obtained through Indirect Sampling.
- Consider internet data sources for statistical purposes.
- Application of SAE in Real Estate Market analysis.

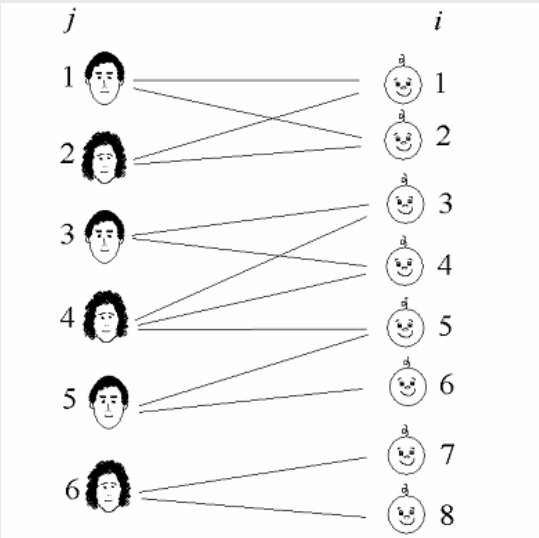
Indirect Sampling

Introduction

Indirect Sampling and Generalized Weight Share Method were proposed by Lavalleé (1995) in panel survey (SLID) for obtaining weights for individuals in households. For more detail information please see Deville, Lavalleé (2006), Lavalleé (2007). Indirect sampling is used when we do not have sampling frame for population B, but we have one for population A which corresponds with targeted population (B).

Indirect Sampling – simple example

Figure 1: Idea of Indirect Sampling



Source: Deville J-C., Lavalleé P. (2006), Indirect Sampling: The Foundations of the Generalized Weight Share Method, Survey Methodology, 32, 2, 165–176. A - Population of parents, B - Population of children.

Generalized Weight Share Method

Assumption

Generalized Weight Share Method has one main assumption: there is at least one link between units from population B and units from population A.

Weights

Denote U^A, U^B - populaton A, B; N^A - number of units in U^A; j - denoting unit from U^A; s^A - sample from U^A; n^A - size of sample s^A; π_j^A - first order inclusion probabilities of j unit from U^A (we assume $\forall_{j \in U^A} \pi_j^A > 0$); N^B - number of units in population B; k - denote unit from U^B; s^B - obtained sample from U^B;
For each k unit from U^B we have:

$$w_k = \frac{1}{L_k^B} \sum_{j=1}^{N^A} I_{j,k} \frac{t_j}{\pi_j^A}, \tag{1}$$

where: $t_j = 1$ if $j \in s^A$ 0 otherwise, $I_{j,k} = 1$ if there is link between j (U^A) and k(U^B) units, otherwise $I_{j,k} = 0$, $L_k^B = \sum_{j=1}^{N^A} I_{j,k}$. See Deville, Lavalleé (2006) for complex overview of GWSM.

Generalized Weight Share Method

Estimator of total

Unbiased estimator of total ($\hat{Y}^B$):

$$\hat{Y}^B = \sum_{j=1}^{N^B} \frac{t_j}{\pi_j^A} \sum_{k=1}^{N^B} I_{j,k} \frac{y_k}{L_k^B} = \sum_{j=1}^{N^A} \frac{t_j}{\pi_j^A} Z_j . \tag{2}$$

Variance

Unbiased estimator of variance

$$\hat{V}_p(\hat{Y}^B) = \sum_{j=1}^{N^A} \sum_{j'=1}^{N^A} \frac{(\pi_{jj'}^A - \pi_j^A \pi_{j'}^A)}{\pi_{jj'}^A \pi_j^A \pi_{j'}^A} t_j Z_j t_{j'} Z_{j'} . \tag{3}$$

In fact (2) is the Horvitz–Thompson estimator.

Internet Data Sources

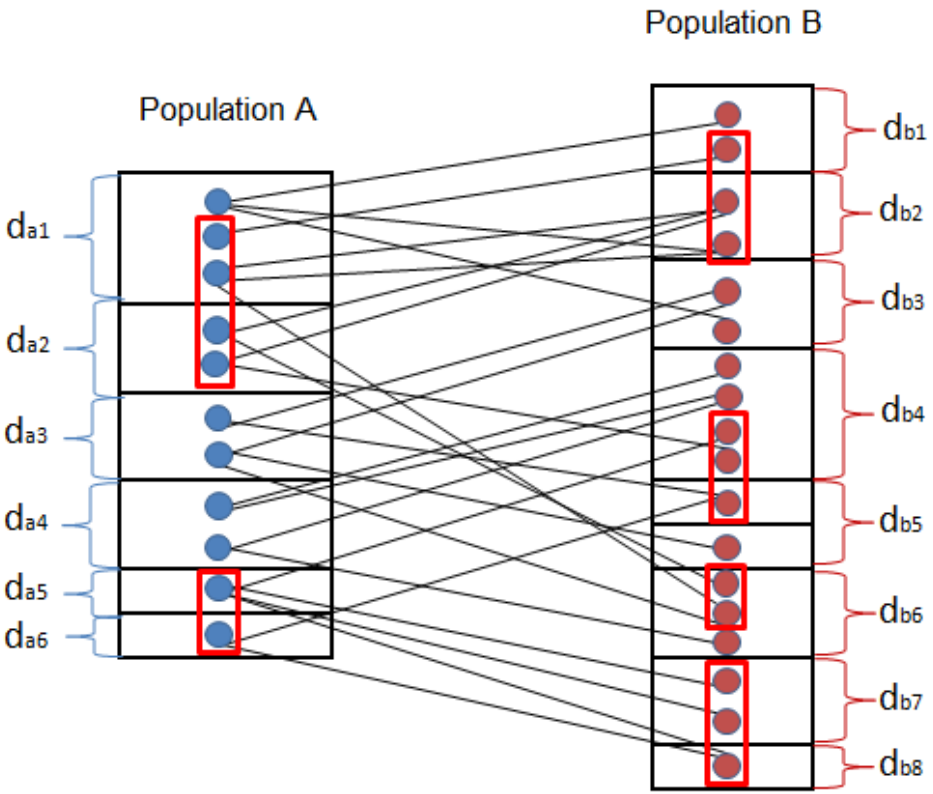
Internet Data Sources

- Data sources from the Internet are becoming more important (deep web data bases).
- Eurostat - NTTS 2013 Conference (`http://www.cros-portal.eu/content/ntts-2013`) and upcoming special issue of Journal of Official Statistics.
- Piet Daas from CBS Statistics Netherlands (`http://www.pietdaas.nl/beta/pubs/index.html`).
- Some of economical or sociological processes can be observed only (or mainly) on the Internet (eg. airline tickets, car rental).
- Internet Data Sources can be treated as sampling frame.
- There are similarities between administrative data and internet data sources.
- Open Linked Data.

What am I interested in?

- Websites which concerns economical data - eBay, booking, etc. Main issue - Secondary Real Estate Market in Poland.
- Behind the website are data bases which are interesting source of information.
- How to sample this data? How is it representative? What techniques of interference could applied?

Figure 2: Domains in Indirect Sampling



Source: Own elaboration.

Auxiliary variables – applicability of SAE methods

Consider 3 cases:

- (i) No auxiliary information from census or administrative registers is available for population or domains (eg. population size is unknown). Auxiliary variables are available only on the sample level.
  - Integration of different data sources could improve efficiency;
  - Borrow strength (or weakness) from other surveys;
  - Consider multiple data frames (web sites);
  - Data could be aggregated to area / domain level.
- (ii) Auxiliary variables are available on area/domain level (eg. population size or means are known on domain level).
  - Indirect estimation could be considered,
  - Fay–Harriot model could be applied (we cannot link unit level data).
- (iii) Auxiliary variables are available on unit level.
  - If it is possible, unit level data could be integrated with census or register bases.

First case is the most common and it is possible to have information from domain level if other data sources (other surveys) exist.

Model–assisted, algorithmic–assisted estimation

Model–assisted Särndal (2005)) or algorithmic–assisted (Dass (2012)) estimation could be applied, if we do not know the target population or auxiliary information comes only from the sample? Predictive, Bayesian approach?

Simulation study

Details – Data

- Pseudopopulation – Real Estate Agencies (REA, 217 units) and sale offers (5219 units) taken from OtoDom.pl (website with offers of dwellings).
- Assumption: auxiliary variables and domains counts are known.
- Distribution of occurrence:

Occurrence	1	2	3	4	5	6	7	9	10
Count	4076	384	55	20	8	6	5	1	1

- Number of Real Estate Agencies that offer dwellings (offers that occur at least 2 times (479))

Number	Count
1	358
2	105
3	13
4	3
5	1

Simulation

1. Indirect sample REA with simple (number of sale offers for REA is unknown) and Poisson sampling (number of sale offers for REA is known). Sample size was fixed at 20%.
2. Compute weight for each sale offer.
3. Estimate mean price for square meter for all 31 domains (precints of Poznań) using: direct, GREG, synthetic and EBLUP estimators (calculation were made in SAS with macros from EURAREA project).

Simulation study - used estimators I

Direct

$$\hat{\bar{Y}}_d^{DIRECT} = \frac{1}{N_d} \sum_{i \in u_d} w_{id} y_{id} \tag{4}$$

where $\hat{N}_d = \sum_{i \in u_d} w_{id}$ and w_{id} is calculated by (2).

GREG

$$\hat{Y}_d^{GREG} = \frac{1}{\hat{N}_d} \sum_{i \in s_d} \frac{y_i}{\pi_i} + (\bar{\mathbf{X}}_d^T - \frac{1}{\hat{N}_d} \sum_{i \in s_d} \frac{\mathbf{x}_i}{\pi_i})^T \hat{\beta} \tag{5}$$

where $\hat{\beta} = (\sum_{i \in u_d} \mathbf{w}_{id} \mathbf{x}_{id} \mathbf{x}_{id}^T)^{-1} \sum_{i \in u_d} \mathbf{w}_{id} \mathbf{x}_{id} \mathbf{y}_{id}$, $\hat{N}_d = \sum_{i \in s_d} \frac{1}{\pi_i}$, $y_{id} = \mathbf{x}_{id} \beta_{id} + \epsilon_{id}$ and $e_{id} \sim N(0, \sigma_s^2)$.

Synthetic

$$\hat{\bar{Y}}_d^{SYN-a} = \bar{X}_{.d}^T \hat{\beta} \tag{6}$$

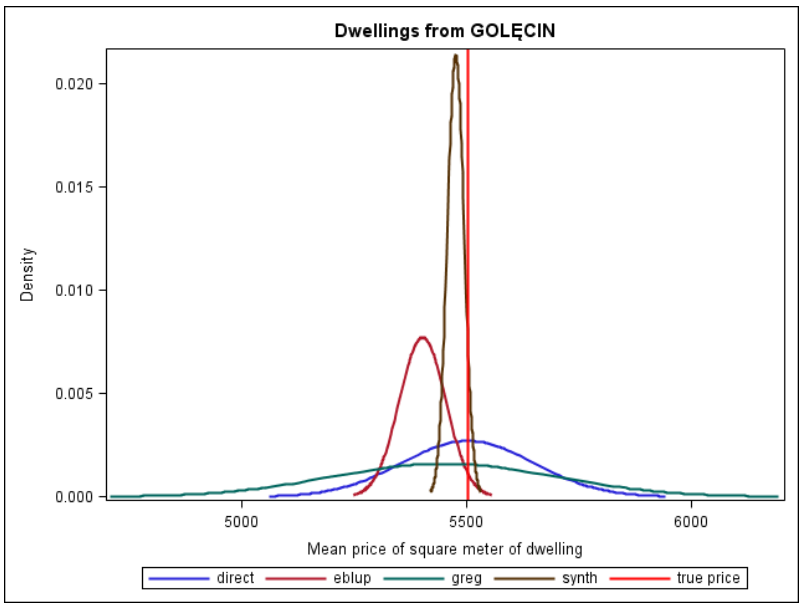
Simulation study - used estimators II

EBLUP

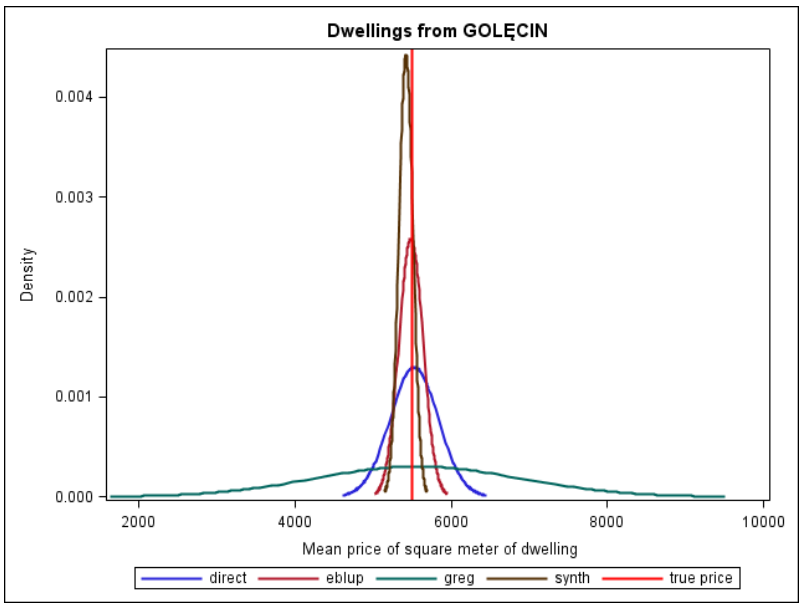
$$\hat{\bar{Y}}_d^{EBLUP-a} = \gamma_d \hat{\bar{Y}}_d^{DIRECT} + (1-\gamma_d)\bar{X}_{.d}^T \hat{\beta} \tag{7}$$

where $\gamma_d = \frac{\hat{\sigma}_u^2}{\hat{\sigma}_u^2 + \hat{\sigma}_e^2}$, $u_d \overset{i.i.d}{\sim} N(0, \sigma_u^2)$, $e_d \overset{i.i.d}{\sim} N(0, \sigma_u^2)$, $\hat{\beta} = (x^T D^{-1} x)^{-1} x^T D^{-1} y$.

Simulation study - results I



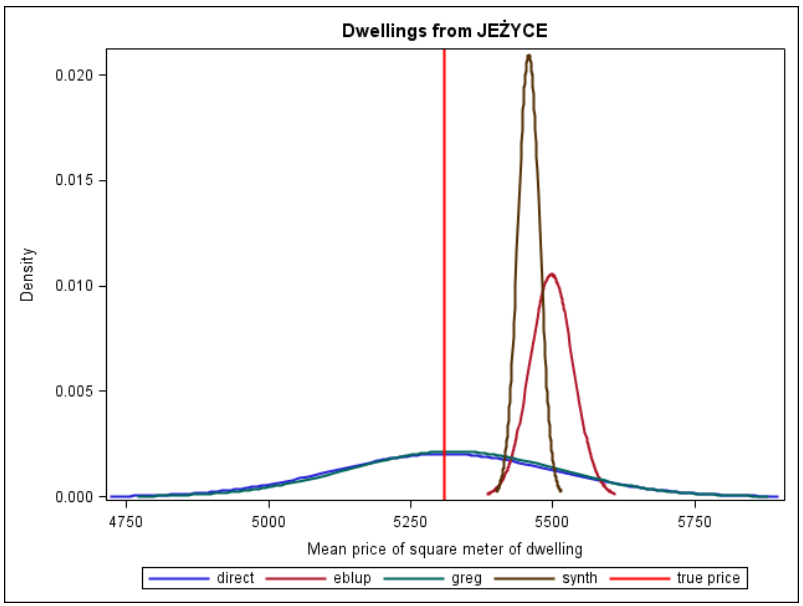
(a) Poisson sampling



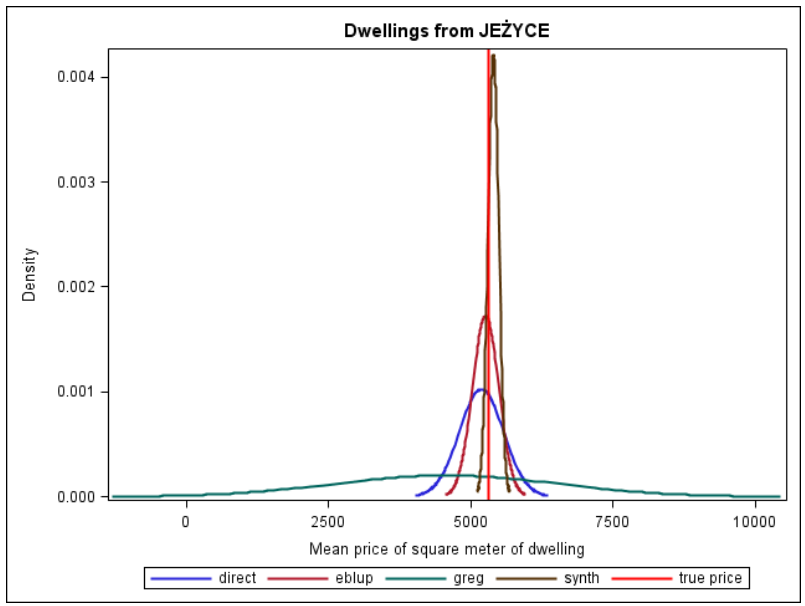
(b) Simple sampling

Source: Results for GOLĘCIN precinct using Indirect Sampling

Simulation study - results II



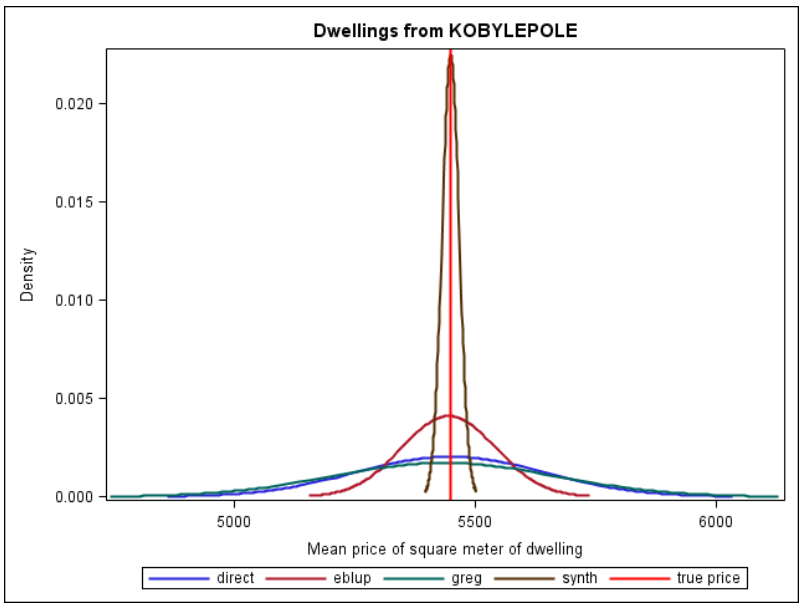
(a) Poisson sampling



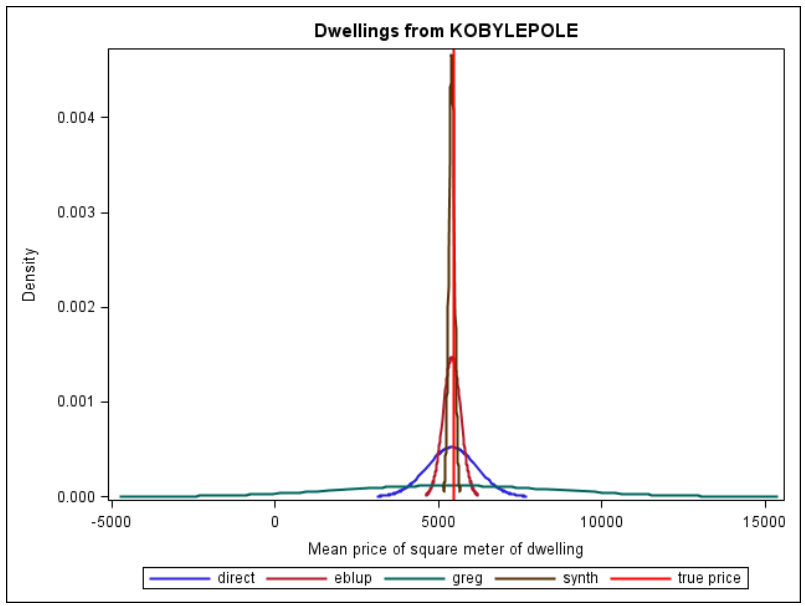
(b) Simple sampling

Source: Results for JEŻYCE precinct using Indirect Sampling

Simulation study - results III



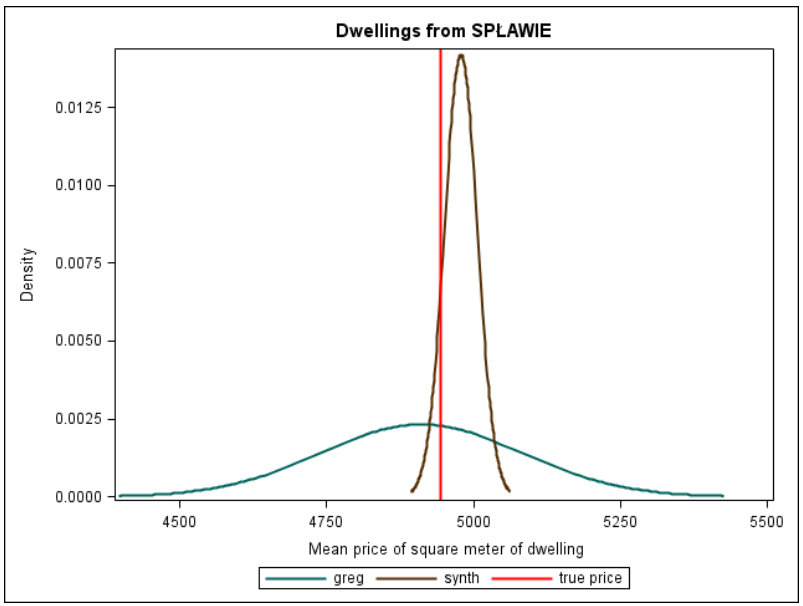
(a) Poisson sampling



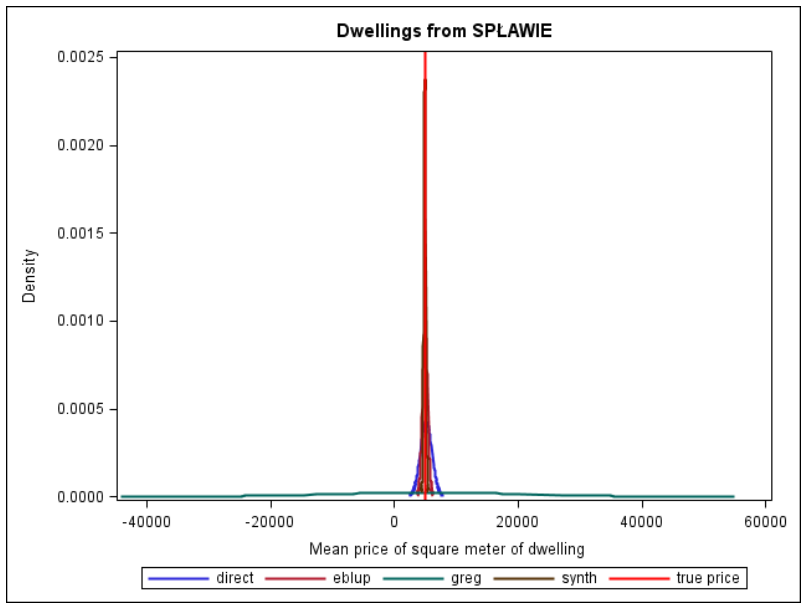
(b) Simple sampling

Source: Results for KOBYLEPOLE precinct using Indirect Sampling

Simulation study - results IV



(a) Poisson sampling



(b) Simple sampling

Source: Results for SPŁAWIE precinct using Indirect Sampling

Conclusion

1. We could apply SAE in situation when sample is obtained using Indirect Sampling.
2. Direct sampling and GREG have unacceptably large variance.
3. EBLUP and Synthetic estimators have the smallest variance but are biased.
4. Simulation study suggests that if we have auxiliary information concerning domains we could apply SAE methodology to obtain results for dwelling prices.

Discussion

1. We could consider Indirect Sampling in the context of multiple frames and then apply SAE.
2. Representativity of the Web data sources (undercoverage).
3. Assessment of quality of the Web data sources is crucial.
4. Situation may be difficult if we do not have information form census, administrative registers or other surveys.
5. Possibility of integrating internet data sources with administrative registers.

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Thank You for the attention!

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